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SKILL BIASED TECHNOLOGICAL CHANGE AND PROCESS INNOVATION IN QUEST III WITH R&D:

Policy Simulations for "Industria 4.0"

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Introduction

The awareness that the global productive system is facing a deep and irreversible transformation is a common evidence in all the modern industrialized economies. The perception that this transformation involves both the economic and the social system concentrates the interest on this issue, and make this theme a concrete topic in the discussion on economic policy.

Due to the pervasiveness and extensiveness of the forecasted changes, the term of industrial revolution is often evoked. As in the well-known historical precedents, the effects of the present industrial revolution, defined with the attribute of the fourth, will be deeply different from the previous ones.

The Fourth Industrial Revolution is characterized, hence, as a phenomenon with persistent effects, which influence many aspects of society and of the economic environment (Schwab, 2016) and the economic context itself should be enabled to react in effective and positive ways to the changes brought about. The basic characteristic of the Fourth Industrial Revolution is the so-called "Digital Manufacturing", seen as the present evolution of manufacture, (Möller, 2016).

It is exactly the reference to manufacture that allows the link with the structural change phenomena of the past. These phenomena, in a historical perspective, outline the phases in which "catastrophic" changes, caused by technological discoveries and inventions, impact on economy and society. The first phase of this process is given by the First Industrial Revolution. From the XVIII century, with the introduction of the steam engine, the structural change starts in different productive sectors, such as textile sector (cotton), metallurgic (iron) and extractive (fuel) until the Victorian age that will be for England, and then for other countries, the period of development and peak of their own economy, stronghold of the industrialized capitalistic system. The second phase, the so-called Second Industrial Revolution, took place in the XX century with the introduction of electricity and of the assembly chain in the production processes. Together with the standardization of products it brought to a significant fall of costs and production times and gave the start to the era of the mass production. Finally the so called Third Industrial Revolution, which took place from the eighties [of 1900] brought to technological discoveries related to informatics and telecommunications (ICT sector). This revolution encouraged globalization, in the sense that it eliminated distances between individuals which through computers and internet were enabled to communicate at long distances and share a massive amount of information.

The Fourth Industrial Revolution, even if linked to the previous ones and characterized by invention and use of more specialized and advanced technologies, presents itself somehow different from the others. The technologies introduced, or improved, are slowly cancelling the borders among physical, digital and biological world. New technologies facilitate a always stricter interaction between high skills – architects, engineers and scientist – and machineries and infrastructures, when endowed of specific devices. In addition, the speed of processes, in this phase, is high, in each sector and sphere of economy and has deep impacts in the productive and institutional systems of the whole society. The Fourth Industrial Revolution, as the previous ones, has or should have the aim of increasing income of individuals and improve the life conditions of the entire society. However one of the high risks that threatens the society, due to the effect of the changes produced by the Fourth Industrial Revolution, is the emergence of inequalities particularly in the labour market (Brynjolfsson, and McAfee, 2016).

The higher value produced by faster connections and shared information, indeed, does not change immediately into growth of the income flow, rather into growth of capital stocks value. This value increases because of the growth of the intellectual content of physical capital and human capital. More wealth is then created using less labour, which leaves room for the appearance of the so-called *skill premium*. The *medium skilled* workers will be the most disadvantaged. The higher specialization requirements, in fact, will cause a rise in the wages of the high skilled workers and a decrease in demand of *medium/low skilled* workers.

The perspective of future growth remains confined to the possibility that the economy could create, at aggregate level, a rate of employment, that is higher than that of unemployment created by automation, even if only confined to typologies of high skilled labour, in substitution of non-qualified workforce, and that the non-qualified worker will be easily enabled to acquire new skills and abilities. Furthermore, it is necessary to empower skills to face changes, favor the formation of start-ups, encourage and develop research projects, discourage rents situations, through taxation and subsidies.

Automation and digitalization will substitute manual work and that will bring a wide economic inequality, which will be reflected into a higher political inequality. That mechanism, called sometimes the "*winner takes it all"*, rewards skilled workers and disadvantages unskilled workers. Beyond highly skilled workers, a second class of beneficiaries of the Fourth Industrial Revolution is that of investors and providers of physical capital. According to Schwab (Schwab, 2016), the future will shape a talent-based labour market which will see two main categories of workers "*low skilled/low/pay"* and "*high skilled/high pay",* with high unemployment in the medium class.

Facing these situations, partly favorable but partly critical, which reveal wide technology driven progresses, but also signs of possible instabilities, various countries have begun to design measures for encouraging a gradual and progressive technological change. The country that first took the initiative of studying actions aimed to favor the transition from the third industrial revolution (ICT/Human to machine) to the Fourth Industrial Revolution (Machine to machine) was Germany. The action plan supported at a federal level, that involves the biggest technological and industrial operators is known as *Industrie 4.0*. The results realized in Germany have also other European countries to engage themselves on analogous initiatives: England with *Catapult – High Value Manufacturing*, France with *l'Industrie du Futur*; the Netherlands with *Smart Industry* (2014); analogously in Denmark the plan *Made* (2012), Belgium (2013) with the program *Made Different, Industria Connectada 4.0* in Spain (2014). In Italy (2016) the National Plan "Industria 4.0" highlights the strategies aimed at involving firms on sustainability and relevance of the industrial development through the specification of key direction for the period 2017-2020 along two applied policy lines: i) Innovative Investments and ii) Skills Achievement.

The evolution of the economic and technological context, that we have shortly described, has caused a progressive evolution in the theoretical and applied quantitative tools used in the applied economic analysis. Such an evolution is traced in the 4 Paragraphs of Part I. In particular in these paragraphs, we intend to sketch some issues, that will be referred to in the following parts of this thesis. In particular, the first chapter in the first part traces the introduction of knowledge and learning as inputs of production process, in the wider context of process and product innovation. The second Chapter delineates the interactions between research (R&D) and innovation with reference to the spillover effects, with the aim of introducing them in the simulation model. The aim is that of considering the productivity growth of capital due to the spread of new ideas for evaluating its expansive effects in the simulation phase. The third Chapter illustrates the evolution in the growth theory, that was led to the Romer model from which the semi endogenous growth model QUEST III derives. In the fourth Chapter the skill biased technical change (SBTC) and the wage premium is introduced.

Part II is devoted to the characteristics of QUEST III Italia and numerical simulations of the policy measures considered in the National Plan Industria 4.0. In particular in Chapter II.1 the measures put into action by various countries for supporting innovation in the Fourth Industrial Revolution are described, while the characteristics and the behaviors of agents in the digital era are traced in Chapter II.2 on Digital Manufacturing. To the policy measures implemented by the Italian government under the name of Industria 4.0 is devoted Chapter II.3. Specifically, measures for innovative investment, in Paragraph II.3.1 and measures for skill acquisition in Paragraph II.3.2.

Chapter II.4.describes the structural features of QUEST III Italia of the Italian Treasury, in the two Paragraphs II.4.1. and II.4.2 and shows the parameters of calibration and its performance in simulation, Paragraph II.4.3. Simulation results are shown in the two Paragraphs of chapter II.5: Innovative investment in Paragraph II.5.1, and the creation of skills, in Paragraph II.5.2.

In Part III, the attempt is made of inserting in the model the *skill biased technological change* and the *innovation of process.* In Chapter III.1 SBTC and the process innovation in the model are introduced, with the generation of a variant of QUEST III Italy, that we called QUEST III Mod. The determination of the parameters linked to the equations introduced or modified is shown in Chapter III.2., the simulation results and the comparison with the results obtained in the simulation with QUEST III Italy and QUEST III Mod are described in Chapter III.3.

PART I

INNOVATION, RESEARCH AND GROWTH

This introductory Section outlines the evolution, in applied quantitative tools of economic analysis, propedeutical to the path that links the study of the economic outcomes of the Digital Era both to the theory of growth and to the dynamic general equilibrium framework with its computable implications. The essential ingredients of the discussion we want to follow, are sketched in the four Chapters. Chapter I.1 introduces the discussion on how knowledge and learning can become functional to the production process in the same way as a factor of production. In the same terms of the previous Chapter, Chapter I.2 concentrates on innovation and research and their diffusion. Chapter I.3 stresses the evolution of the role of Total Factor Productivity. The new role of skills in recent applied discussion is highlighted in Chapter I.4.

I.1 Knowledge, Learning and Innovation in the economic process

The outcomes of the Third Industrial Revolution in terms of ICT, together with the generalized rise in the education levels make the perspective of economic growth more effectively linked to the diffusion of new ideas. The progressive systematic definition of the reciprocal roles of information, technology and learning in determining the performance of operators in the economic system brought to the recognition of knowledge as primary engine of productivity and growth, (Lowe, 2017). On the other hand, the emergence of concepts as "Knowledge Economics" in the double connotation of *knowledge economics* and *knowledge economy,* as that of *knowledge-based economy,* proves the relevance of the link between new technologies and knowledge in modern economies. (Dunning, 2002)

This link originates from the observation that, at the present time, workers, more and more often, need to acquire new competencies and continuously adapt them to processes, products and services, (Archibugi and Lundvall, 2002). It is, hence, always more apparent that the best strategy to encourage economic growth is that of widening the knowledge basis. However, the basic concept of knowledge makes various analytical questions emerge, not always easy to solve in a satisfying way.

The discussion on the contribution of the economic analysis to the understanding of the knowledge utilization within production process provides the definitions of the basic concepts for the treatment of knowledge and learning, and acknowledges the new economic trends and the formation of a new Learning Economics (OECD, 2013). Knowledge and learning, are, in fact, traditionally, two of the main mechanisms linked to innovation. Schumpeter (Schumpeter, 1936; Venturini, 2012) defines the innovation as "the set of new combinations of existing knowledge and organizational learning". Kogut and Zander (1996), include in the concept of innovation both the existing knowledge but also the acquired knowledge. The role of knowledge is linked with the key role of interactive learning aimed to reach a high performance by the firm. Learning process, indeed, permits the agents to acquire or improve competences providing higher results within the firm, and more in general, at level of whole nation. Knowledge is, hence, together with learning, the determining factor for innovation (Lundvall, 1994).

Knowledge includes the empirical evidence and the productive capabilities of the single individuals both aimed to produce and sell goods and services. Knowledge is, for the most part, economically useful in the measure in which knowledge is put into practice by individuals who embody it, those individuals constitute the human capital potentially useful for the economy. In general, Knowledge is codified, but it can be also "tacit", that is owned by individuals but not written, probably because it has been learnt through the modality "learning by doing." (Thopmson, 2010).

Knowledge in the economic process, and in its representations, essentially enters as production input. Opposite to employed materials in the production process that after their use disappear, embodied in the final output, knowledge, i.e. the ability of the individual, does not disappear, rather empowers and increases after each productive process. This peculiarity includes the production process of knowledge within the joint-production processes; indeed the main production process leads the production of innovation but besides it, a joint process develops which leads to the production of new knowledge (Lundvall, 2010).

Hence, the concept of knowledge, together with that of education, is considered and studied as an innovative service intended for the market and resulting in an asset. In this context, it has the role of an input – given by the set of abilities and skills that belong to an individual or to a group of individuals employed in the productive process - and of an output – granted by the new knowledge, that is by the innovation that originates from productive process. In this direction since long time OCSE has patronized research activities (OECD, 1996; Foray and Lundvall, 1996), and also at European level analogous initiatives have been taken since 2000 and developed under the patronage of the Council of Europe. The strategic lines for economic growth seem to develop in the direction of empowering the basis of knowledge and learning characterized by the features related to the dichotomies private/public, local/global, tacit/explicit, (Kline and Rosenberg, 1986).

The immediate, but also most restrictive, definition of innovation is that according which innovation consists in the development of new products of higher value with respect to the existing ones, based on the most recent technical advancements, emerging from the research activity, (Edler et al., 2017). This activity is, generally, performed by highly qualified workers in research centers often known at international level. In a wider sense, however, innovation is contained in practically all the productive activities, not only in terms of new products, but also in relationship to processes that characterize several activities, (Bell, Pavitt,1993). The term innovation, defines also ideas, processes or products that are considered new only if belonging to a determined context, also local, if they are known at a global level (Fagerberg et al. 2004), (Semieniuk, 2017). The innovation can, hence, take place both in sectors which represent a novelty for the firm itself and for the market, and in the traditional sectors which need an higher competitive relaunch.

Within the various sectors of the economy, the innovation process, linked to the process of production of new ideas, takes place. The dominating sectors from the supply side, such clothing, produce inside themselves little innovation, assigning this task to other linked firms. The sectors linked to food production or construction, concentrate their innovative efforts manly on the process innovation and hence try to improve their production technologies. In specialized sectors, engineering or software, the most relevant innovation is the product innovation, as in the case of the creation of a new software, and sectors such as chemicals or electronics in which innovation, which can be of both types, i.e. process and product innovation, is developed in collaboration with research centers or universities, (Malerba, 2004).

Innovation can be seen as a process articulated in many phases. Each phase is, however based on the presence of three fundamental elements. First of all, human capital needed for the actuation of the activities included in the specific phase, that can be more or less skilled and must own specific skills aimed to the achievement of the objectives characterizing the specific phase. The second element, which constitutes each phase, is knowledge, generally embodied in human capital and in the specific technology. Finally, the time needed to reach the forecasted objective by each of the phase. The output of each phase is given by a tangible good, in case of production of material good, or intangible, when concretizes in the production of a service. The R&D process emerges in a nearly exclusive way in the former phases of the innovative process, where individuals create first contributions of research, individually or within public organization, such as universities or research institutes (Foray, 2014).

In particular in the first phase, the phase of generation and mobilization of ideas new ideas are created, new inventions made by human genius and intellect. The inspiration for a new idea can be originated by an improvement of the existing idea, or by a completely new idea. The mobilization takes place when the idea concretizes and passes to another department and therefore to another phase of elaboration.

In the phase of discussion and monitoring, the true value of the idea and its potential utility, in terms of benefits and limits is evaluated. In a third phase, if in the discussion and from the debate has emerged a positive evaluation of the idea, its improvements and refinements will be considered. The experimentation phase, is a phase that basically accompanies all the phases, indeed there is experimentation when, during the monitoring, ideas are evaluated, but experimentation brings also new knowledge and new information that can suggest new ideas. In this phase, time is fundamental so that individuals can be enabled to do in a correct way all the operations and study the final results. Commercialization comes as the fourth phase in which the real innovation emerges for the first time that has to be commercialized. On the basis of its intrinsic value, a market value has to be associated to the innovation. The idea has to be publicized through practical demonstrations and clarifications about its utilization.

This very last phase is characterized by the diffusion of innovation to the market, and is linked to the acceptation of the innovation by the public. From this latest phase is important to receive feedbacks that can stimulate a new cycle of innovation, indeed the new idea can be improved generating an new innovation process. (Dubickis, and Gaile-Sarkane, 2017).

Technological innovation results then as an output of the innovative process, accompanied in all its phases by the process of knowledge, that is knowledge creation, knowledge production and technological knowledge (Antonelli, 1999); (Nonaka and Takeuchi, 1995), (Sharma and Harsh, 2017), (Puusa and Eerikäinen, 2010).

I.2 Research, Development and Spillovers

Innovation appeared, therefore, in the majority of cases, as consequence of progresses in fields of research and development, R&D. Particularly, it has concretized at the end of that process in which the phase of research is the initial step. It represents the phase where the innovative idea, produced by research, passes to the phase of product commercialization, in which the product is transformed following the innovative idea itself (Ogawa et al.,2016). Speaking about R&D means, in fact, referring to scientific research and technological development. The scientific research and technological development sector include all that activities done by scientists to discover and interpret behaviors, methodologies, empirical evidences and theories regarding every aspect of knowledge, using scientific method, aimed to innovation and long run growth.

The OECD studies on industrial development confirm that we are progressively passing from a knowledge based economy, to a learning based economy, grounded on R&D. In addition, growth appears as progressively more based on the amount of acquired knowledge, the employed work force in R&D sectors is becoming more and more qualified, as well as the skills of workers in the latest periods, (OECD, 1999), (OECD, 2017).

The R&D sector is made by all that activities, source of the innovation process, which consist in basic scientific knowledge production intended to develop new projects, processes or prototypes. These activities imply the work of many agents, included public scientific institutions, universities, singles scholars or single firms. From the financial point of view R&D activities are different from the other kind of activities, in the sense that in the development of these activities there is no expectation of immediate profit, on the contrary, investors in that activities do large investments but expecting a profitability only in the long run, (Hall, 2002).

In the R&D sector, the majority of advantages from the investment made by a firm easily extends to the competitors, at the national and often at the international level. This characteristic of R&D has a double and opposite impact. A positive impact given by the positive externality prospected by R&D, in the sense that benefits linked to R&D are higher than benefits strictly linked to the producer, that is the firm that finances innovative projects. On the other hand this so called *spillover effect*, discourages the firm to invest in R&D, because, only a negligible part of the gains deriving from innovation remains within the firm - i.e. the so called appropriable knowledge - letting the not- appropriable part - the share not protected by patents or copyrights - to spill over (Hall et al., 2017).

As knowledge spreads out, private benefits decrease and spillovers increase. The issue of spillovers acquired relevance in the economic literature from the nineteenth century. In that period, organized scientific research, within industries, was not wide.

Technological knowledge was transmitted through apprenticeship and learning by doing. (Gaynor et al., 2005). Marshall, (1920) realizes that spillovers are shaping a situation in which “secrecy of commerce in general diminishes and main improvements in method rarely remain secret in the long run after having passed the experimental step”. Steurs (1994) defines R&D spillovers as the involuntary dispersion by the innovation creating agents who are not able to appropriate of the rents of its new discoveries, towards the other firms which benefit freely and legally. The definition of spillover includes, however also the voluntary exchange of useful information related to invention or a determined technology, research object (Grossman and Helpman, 1992), (Tavassoli, et al.,2017).

We can identify three main classes of spillovers: i) market spillovers, ii) knowledge spillovers, iii) network spillovers. Market spillovers are strictly linked to the acquisition of goods, services and machineries; that kind of spillovers are also defined “monetary spillovers” (or rent spillovers) because they are originated from the difference between the price of intermediate goods owned by the firm, without innovation, and those evaluated including improvements for interventions of research and development. (Aldieri and Vinci, 2017).

Market spillovers originate when market negotiations for a new product or process cause some benefits to all the market actors (firms or consumers) except for the innovating firm. If the firms introduces in the market a new product, even if it is covered by patent, it will be sold at prices, which do not fully capture all the higher value of the new product with respect to that available before the introduction of the innovation. This fact brings a benefit to the whole society, which is not appropriated by the innovator. Innovation has effects in terms of higher quality/performance and lower prices, advantaging consumers even more.

Knowledge spillovers take place, particularly in the phase of basis research but we can see them also in the applied research and in the technological development. In this typology, knowledge created by a firm, can be used for free by another agent, or at a more lower price than the value of knowledge (Fujiwara, 2017). Knowledge spillovers can be voluntary or involuntary. The voluntary diffusion of knowledge by the firm takes place when the intention of the innovator agent is that of spread the new discover to the broadest public possible, (as it happens, partly, for the academic publications). Broadest knowledge spillovers are the involuntary ones, due to the development and use of the new knowledge. The sell of products which incorporate new knowledge brings with the facts that different aspects of new knowledge are revealed to other economic agents.

Finally, network spillovers take place when the economic and commercial value of a new technology is strongly linked with the development of a set of linked technologies, as in the set of firms which develop a software for the same operating system. Indeed, if the net of firms is built so that there exists a set of projects linked together, the firm creates a positive externality for the other firms of the group, assuming the major risk in the realization of the complete set of projects. The prevailing approach of measurement of market spillovers is that of the analysis of Input Output flows or flows of international commerce. (OECD, 1999; Debresson and Hu, 1999) (Goodridge et al., 2017).

Another classification of spillovers is linked to the proximity of firms. To this aim we can distinguish between MAR spillovers and Jacobian spillovers. (Romagnoli, 2014). MAR (Marshall –Arrow – Romer) spillovers occur within firms belonging to a common industry. The closeness of firms facilitate the diffusion of knowledge for innovation and growth. The MAR spillover assumes higher when firms are near, and lower values when they are far. Jacobian spillovers take place when the spread of knowledge arise between near firms belonging to different industries.

The study of the issue of spillovers highlighted how social benefits deriving from research, development and innovation, are widely higher than that those provided to the single innovator firm, which creates innovations. To encourage innovation, then, we can appeal to an incentive to the value of activity, prompted in general at the government level. For the discoveries of new technologies, in lots of scientific fields, primarily in the pharmaceutical, the use of innovation by the firm does not prevent its usage by other firms, but this, surely influences the market value of innovation for the innovating firm, lowering its profits. Once entered in the market, even if knowledge is intrinsically not rival, it can have a rival value. The public good "Research, Development and Innovation" can be also partially excludible, both using Innovation Property Rights and also using secrecy contracts stipulated within the firm itself. (Mrad, 2017), (Frischmann, 2017).

The R&D level which is most easily associable with externalities, generally positive, is the applied one. Once a given level of advancement and application is reached and a level of knowledge inserted within innovations, it is very difficult to hide and make the discovery inaccessible to the majority of other firms and to society in general.

I.3 Growth, Total Factor Productivity, R&D and Innovation

The evolution of the concept of innovation, stimulated by the present economic and technological context, shows how this topic has acquired a relevant position in the discussion on economic growth. This is the reason why, in this chapter, we give a brief account of the evolution of the concepts and instruments that treat the problem of economic growth. In search of the stages in which the explanation of economic growth progressively opens to the treatment of innovation both in methodological and applied terms (Kogan et al., 2017).

Even if restricted to a stylized representation of the economy, determined by a low number of macroeconomic variables, the original core of the study and quantification attempts of economic growth rate is provided by the vision of growth by Harrod and Domar, HD. In such perspective, to enable an economy to grow in equilibrium, the actual growth rate of GDP, $g_e = \Delta Y/Y$, that is the resulting of elements such expectations and decisions of consumers and entrepreneurs, must be equal to the warranted growth rate, $g_w = s/v$. The warranted growth rate is essentially governed by the ratio between saving propensity, s and the incremental ratio capital/product, v, and must, in turn, be equal to the natural rate of growth $g_n = g_l + g_{pr}$, which results defined essentially by the growth rate of workforce, g_l, corrected by labour productivity, g_{pr}.

However, the determination of that triple equality, $g_e = g_w = g_n$, is not guaranteed in general, since each of the three growth rates is determined by variables which are mutually independent and the economic explanation does not provide channels of interaction among the different levels. The growth path, if it exists, in addition, results dynamically instable, that is, each difference from the warranted growth path tends to be amplified (Harrod, 1939), (Domar, 1946). A first attempt to build interaction channels within the explanation of growth is given by the indigenization of the saving propensity by Kaldor. Assuming different saving propensities for the different income classes earners, a change in the income distribution, such as in the distributional share of profits q_π, generates an endogenous change in g_w equal to $g_w = s_\pi q_\pi / v$, (Kaldor,1957), (Pasinetti, 1961).

An attempt to enrich the interaction between different levels of explanation of economic growth, starting from the HD scheme, is given by the Solow explanation. In a neoclassical context, he shows how the growth of capital stock, g_K, the growth of workforce, g_N, and the technological progress, g_A, will lead to growth in aggregate production, g_e, of goods and services, $g_e = g_A + \alpha g_K + (1-\alpha) g_N$. Growth rates of the two factors, capital and labour, are weighted with the own production elasticity α and $(1-\alpha)$, which match consistently with the neo classical feature of the individual distributive share. It emerges, hence, a share, g_A, of the real growth rate, g_e, which is not due to growth in the factors' utilization and is known as the *Total Factor Productivity, TFP* or the Solow residual.

Solow highlights the crucial role of the mechanization as a mean for technological advancement in the first Industrial Revolution and asserts that differences in economic growth are based on differences in rates of capital accumulation. His model is based on standard neoclassical assumptions such as: i) perfect information and competition, with the direct consequence that in each instant employment is always at full employment; ii) exogeneity in technical progress and in the dynamic of population; iii) constant returns to scale technology which satisfies the Inada conditions: positive and decreasing marginal productivities; iv) perfect information; v) absence of externalities. The technology of production used in the Solow model, hence, presents decreasing marginal returns: further increases of capital, in presence of a fixed supply of labour, bring an always lower increase of GDP until they reach a point in which the growth stops.

In relation to the international process of convergence among developed and not developed countries, the Solow model suggests some important consequences. The only factor that in this context can explain the differences in the per capita growth among countries is the so called "transnational dynamics": since conditions in general differ, countries may grow at different rates in the process of reaching the long run equilibrium. This can happen if rich countries grow faster than poor countries, since in countries in which capital is scarce with respect to work, that is, when the ratio capital/labour is low, we can expect a higher rate of return of capital, hence a higher accumulation rate and a higher per capita growth. If capital is internationally mobile and shifts toward countries in which there are higher perspectives of profits, this tendency may be considerably enforced. Hence, differences in income levels among rich and poor countries should be filled and eventually disappear.

In Solow the need of increasing in time the quantity of capital per worker is highlighted, that is its intensity. In the long run the ratio capital/labour will stop augmenting, the economy then, will enter in a steady state condition in which the increase of the capital intensity itself stops; the real wage growth stops as well as capital returns and interest rates remain constant. In practice, however, this result does not seem to be true, particularly when we look to the relevant productivity increases registered in the XX century (Fuà,1993).

Technological progress is an exogenously determined phenomenon and demonstrates how the economic system converges toward a path, the steady state path, once reached, the per capita income increases at a rate equal to the growth rate of technical knowledge. Once the economic system has reached the steady state there cannot be further growth unless it is imposed exogenously: growth then tends to end. The process for which economy can continue to growth although decreasing returns is given by the creation of new technologies (technological progress) which enable to produce more with less resources.

Hence, empirical analysis underline that the GDP growth cannot be due exclusively to the increase of labour and capital, but it exists a non-explained part, called Solow residual, assumed to be caused by the technological progress deriving from innovation. Technological progress causes an increase of the marginal productivity: the same amount of labour and capital produces a higher quantity of GDP. Indeed, in addition to the consideration of the increase of the capital intensity, we have to consider of the technological progress which determines an increase of the product per worker and the subsequent increase of wages; not only, we have also to consider that innovation increases the capital productivity which compensate for the decrease of the profit rates, (Mc Combie, 2000). The Solow model is founded on the simplified hypothesis that only one type of capital exists given by equipment and machineries. Equally relevant is the public component, the infrastructures, and the human capital, that is provided by competences and knowledge that workers acquire through education and formation. Investment in human capital, if feeding the capacity of generating innovation and encouraging the propensity to assume calculated risks, can be used for preventing the obsolescence of labour skills. These forms of capital, as well as the physical capital, allow for accumulation and make workers more and more productive. However, they differ from physical capital, because human capital presents increasing returns and, hence, capital returns are, in total, intended as investment aimed to the increase of the stock of physical and human capital, constant. In that context economy never reaches the steady state. The growth process, and its increasing rate, depends indeed on the capital on which the country invests. The action of policy maker who wants to stimulate growth has to take into account what is the typology of capital more convenient for the country.

The appeal to the intervention of the policy maker reveals its opportunity in the observation that each country has a different level of productive efficiency with respect to the others. This difference is attributable to the diversity of the institutions and laws which rule the acting of individuals and determine the allocation of resources. In particular among the different institutions, the law system of the country has a predominant role. The quality of institutions is a fundamental determinant for the performance of the economic system. Where property rights are more adequately respected, individuals have a stronger incentive to achieve investments which favor economic growth.

For the neoclassic hypothesis all the countries have access to the same production function and so all of them should converge to the same growth rate and, saving propensities being equal, to the same level of income. Exogenous growth theory of Solow cannot explain international differences in income and their historical evolution, for it doesn't provide an explanation for the reason according to which different countries use the same technology in different ways. Furthermore it does not take into account how technologies are adopted. The adoption of a technology has not cost, is exogenous, and firms must not do nothing, between a period and another, to adopt a new technology and increase productivity.

All the differences in the income levels among countries are attributed to the different saving rate, which however do not seem to mute in an adequate way as income rises. The empirical observation related to non-convergence of growth rates and high productivities, observed in XX century make indispensable the introduction of the explicit explanation of technological progress and hence, of the endogenous explanation of the "Solow residual."

The empirical analysis of the different growth experiences, among that those of EU and USA, starting from year 1990, highlighted the critical issues of exogenous growth theories (Aghion and Howitt, 2006).

The endogenous view of growth tries to overcome that difficulties making up to the intrinsic gap in the exogenous growth models, trying to explain the growth rate of TFP. We want, therefore, to try to identify and determine the Solow residual $g_{A,}$ which neoclassical economists and, in particular, Solow model, considered exogenous. The context indicated the presence of maximizing rational agents who take intertemporal decisions of consumption or saving, in finite or infinite time horizons.

In the field of endogenous growth theory there are two big families that refer to the human capital concept and to that of R&D. In the first case knowledge is considered as a particular form of capital which, in order to be considered productive, must be incorporated in workers (Barro, 1990, Becker and Lucas, 1988, Mankiw, Romer and Weil 1992, Murphy and Tamura 1990). In the second case, reference is made to labour productivity and to its linkage with knowledge, skills and private investments in innovation (Aghion and Howitt ,1992; Romer, 1990).

Both the approaches admit hypothesis of constant or increasing returns to scale. For these assumptions productivity increases with the raise of the size of the production of positive externalities of the learning by doing type both in the working environment and in the R&D sector.

The presence of these positive externalities requires the public intervention to solve possible market inefficiencies. Both of them respond to the need of assigning to the economic policies an impact on the growth rate of the economy also in the long run. Measures that encourage R&D, education and formation, and, generally speaking that impact on innovation and on knowledge accumulation are aimed to support the growth rate, with non-transitory impact on economy.

The two families of endogenous growth models, share with exogenous models the optimizing behavior of agents but they differ because knowledge, and hence, technological progress, are endogenously determined. From what emerges from the previous chapter, the ways to acquire new knowledge can be classified in three categories: i) Learning in the workplace, ii) Education, iii) Research and Development.

The endogenous vision permits to widen the definition of capital, introducing the concepts of human capital and public capital. That extension implies the generalization of the productivity patterns to include also the observed cases of increasing marginal productivity and constant marginal productivity (Romer, 1987). During the capital accumulation process cases of constant marginal productivity can take place when there are decreasing returns of physical capital together with increasing returns of human capital, due to the higher skills acquired by operators, which permit them to discover new methods and processes aimed to the productivity increase.

In general, we should have higher benefits at the society level than those obtained at individual level, also in case of decreasing returns for the single firm. The model, that, can be considered the founding stone of the endogenous growth and human capital models as a mean of increase of knowledge, is that of Robert Lucas (Lucas,1998). It was the first model where the contribution of human capital to the economic growth was formalized and inserted, taking into account also of the positive externalities that human capital generates (Uzawa,1965; Arrow,1962).

The economy, in the Lucas model (Lucas, 1988), is characterized by two sectors. First sector produces the final good (Y) with a Cobb-Douglas production function with decreasing returns to scale to each single factor and constant private scale returns, using physical capital and human capital; in that production function the role of the human capital of the positive externality is highlighted, in the production $h_a(t)^{\beta}$

$$Y(t) = AK(t)^{\alpha} [u(t)h(t)L(t)]^{1-\alpha} h_a(t)^{\beta} \quad (1)$$

Y is the level of final product, A is a parameter higher than zero, which represents technology, K and L represent respectively productive factors capital and labour, u symbolizes time spent in the productive activity, h is the medium level of human capital, from this is derives that $h(t)L(t)$ represents the labour efficiency.

As highlighted above $h_a(t)^\beta$ is the term which includes positive externality brought by human capital, where $h_a(t)$ represents the medium level of human capital and $\beta \geq 0$ represents its intensity.

In the second sector production concerns the human capital formation. This is determined by the still existing human capital at period t (*h(t)*), and by the time employed in the education (*1-u(t)*). The resulting function of human capital accumulation will be:

$$\Delta h(t) = h(t)\delta\,(1 - u(t)) \tag{2}$$

where *u(t)* represents the time devoted to work and (*1-u(t)*) represents the time devoted to study and learning.

In the case in which [*u(t)* = 1] all the resources are spent for the labour activity and nothing in the human capital formation. The human capital accumulation will be, equal to zero. In the hypothesis in which [*u(t)* = 0] the human capital accumulation process is maximum i.e. *h(t)* grows at maximum rate δ. In the intermediate phases returns for the stock *h(t)* are constant independently from the level of *h(t).*

Economic growth is reached by the learning by doing process because the human capital accumulation $\Delta h(t)$ is linear in human capital $h(t)\delta$, (Helpmann, 2004). If there is no substitutability among goods, economy converges to a long run equilibrium in which human capital growth rate is equal in each sector. In case of high substitutability among goods, the dominant sector of economy will be that with the highest learning rate.

The second family is centered on R&D models. In this typology of models we take into account new ideas introduced with externalities, in general positive since by nature non-rival goods. In principle, a new discover of scientific nature, a new idea will have in general positive consequences for the whole economy. This may brig also increasing returns to scale for the production function of ideas, in the sector where they are produced, that is, as we will see, the R&D sector.

The endogenous growth model to which reference is usually made in the treatment of this theme, is the endogenous growth model of Romer (1990). Following innovation, scientific discoveries have a key role in the economic growth. We endogenize technological progress assuming that in developed economies growth is driven by the R&D sector. In addition the model adopts the neoclassical production function $Y=K^{\alpha}(AL_Y)^{1-\alpha}$ and takes from the neoclassical theory also the capital accumulation and the population accumulation function. The innovative element introduced in the Romer model consists in the equation of accumulation of knowledge:

$$\Delta A=\delta A^{\varphi}L_A^{\lambda} \quad (3)$$

in which ΔA represents the number of new ideas introduced in any period A, is the stock of all the existing knowledge in the society. L_A represents human capital in terms of the number of scientists and engineers employed in research and then in the discovery of new ideas. δ is the rate at which individuals discover new ideas, it can be constant or increasing when δ e φ are supposed constant.

$$\underline{\delta} = \delta A^{\varphi}$$

if φ >0 (with δ constant) the rate of productivity increases with the increase of the stock of existent ideas, in this case there are *knowledge spillovers*, on the contrary, if φ <0, the productivity of research decreases when existent ideas increase. This happens due to the fact that more obvious and urgent ideas are the first to be discovered and as time passes by ideas are always more difficult to be discovered. If φ = 0 the productivity rate of research is independent from the stock of existent ideas. λ is a parameter so that $0 < \lambda < 1$, a condition assumed on the basis of the assumption that ideas increase with increase of human capital employed in R&D.

From eq. (1) and assuming that ϕ=1 and λ=1 that is constant returns in R&D resources and human capital in R&D we obtain:

$$\Delta A = \delta L_A A \quad (4)$$

Dividing the knowledge production function for knowledge A we obtain:

$$\Delta A / A = \delta L_A$$

This growth model, as other growth models of first generation have the peculiarity of strong scale effects and so if the returns of R&D are constant, doubling resources in R&D will double growth rate.

From the empirical point of view, however, this theorization has not had much success, since we have assisted to long periods with no growth in front of large expenses for R&D and increases in hiring of workforce in R&D. On the contrary, there have been periods in which US experimented high growth while investments in ICT and R&D had remained constant or rather decreased. However an increase in financing and in the participation in R&D that should bring, according the theory, higher economic growth rates is not likely to happen in practice (Jones, 2005).

The structure of endogenous growth models seemed valid as technological progress was never an element which independent from agents, but rouse as result of a voluntary work by rational agents who maximizes profit. The issue was that of slightly modify the structure of these models to best adapt them to the empirical evidence ad solve this problem characterized by the existence of strong scale effects. The changes suggested by Jones were that of assuming $\phi < 1$, which introduces the generation of semi endogenous growth (Minniti and Venturini, 2017).

Jones considers eq. (3) imposing the condition that $\phi < 1$, assuming that returns of accumulable inputs are decreasing.

$$\Delta A = \delta L_A A^{\varphi}$$

Dividing both sides by A:

$$\Delta A/A = \delta L_A A^{\varphi} / A$$

In the balanced growth path we will have the following condition, after the logarithmic differentiation:

$$0 = \lambda (\Delta L_A/A) - (1-\phi) (\Delta A/A)$$

The variable that, eventually limits the growth of employment in R&D sector is the growth rate of population, and the growth rate of scientist cannot overcome the growth rate of population and that means that:

$$g_A = \lambda n / (1-\phi)$$

If $\varphi = 1$, a growth path does not exist. But in the case in which $\varphi < 1$, the growth rate of population is a determining element of the per capita growth.

The elements of fundamental relevance introduced by this model of semi endogenous R&D growth. First of all it is coherent with empirical evidences, the growth rate of economy, strictly linked with the growth rate of productivity which derives from the work of rational agents in R&D, is exogenous and invariant to policy decisions. Individuals have a fundamental relevance which exclusively depends from the population growth rate. R&D subsidies and capital accumulation don't have a run effect in the model but only in the transition period from the old to the new steady state.

Growth is, then, semi endogenous because, although the process which generates growth is endogenous to the model, it takes place through the production function of knowledge, the growth rate of knowledge is completely exogenous, it depends on exogenous parameters and the population growth rate, exogenous variable. In that way growth rate of ideas does not depends from policies which encourage R&D.

Introducing this hypothesis, ($\phi < 1$) Jones preserves the structure of the endogenous growth model theorized by Romer. Growth originates, indeed through labour of rational optimizing agents who under take R&D projects, the model is, however, protected by policy interventions, making them effective only in the short run, imposing an exogenous growth rate which depend nearly exclusively by the population growth rate.

From this tradition and from the Romer growth model originates a class of semi endogenous growth models in which QUEST III with R&D is included. This model belongs to the DGE model class and has acquired some typical New Keynesian elements (imperfect competition, price stickiness and nominal rigidities) integrating them into a general equilibrium environment. The choice of DGE frameworks to model macroeconomics aspects receives lots of critiques from relevant scholars for the bidirectional character of the operability of variables, not only from the specific to the general but also from the general to specific, from the macro to the micro. (King, 2014; Duarte, 2015). There are different preferences and it is difficult to substitute them with the representative agent. (Romagnoli, 2017). Despite the critique this choice is consistent with the fact that the use of representative agent allows us to model our economy and to implement our policy reforms, (Bruch and Atwell, 2013).

The Italian version of this model of the European Commission for Italy, to which we refer as QUEST III Italia, will be the simulation tool used in this work, in order to evaluate the effects on growth stimulated by the policy measures of the Italian government known as “Industria 4.0”. In addition, on that model some modifications will be performed in the aim of introducing the spillover effects and indigenizing employment shares for increasing levels of the labour skills. Then substitutability between workers with different skills and the substitutability among low skilled workers and physical capital will be, in this way, introduced.

I.4 Beyond the neutrality of technological change

As we point out in the former paragraphs, the productive process can be split into several phases: the installation of equipment, the maintenance, and the assembly phase where the productive process ends with the final output. The first two phases have to be undertaken by the skilled workforce, and by technology acting as a complementary good, while the assembly phase is a concern of the unskilled workers.

In the first part of this work the changing role attributed to technical progress in the process of economic growth has been outlined. In the early stages of the discussion, its exogenous character was stressed, as in the metaphor "*Manna from heaven"* (Solow, 1957). This feature discloses the "residual" role to which technological change is confined. In this framework the impact of technical change on growth is whatever effect on growth other than the impact of the primary factors. In that growth context, technical change is presented as "factor neutral". In fact, technological progress is such that an increase of the total factor productivity, TFP, influences exclusively the marginal productivity of both factors in the same proportion, while keeping constant the marginal rate of technical substitution. For a long time it was assumed, according the idea of Hicks neutrality, that technological advancement would have been the only responsible of the increase of the per capita income, (Wilkinson, 1968).

Empirical evidences of the latest thirty years seem to contradict this established belief, as they show a considerable rise of the skilled labour compensation with respect to that of unskilled labour. that takes place despite a corresponding increase in the supply of skilled labour. That ratio is, indeed, augmented from 1.45 in 1965 to 1.7 in 1995 with a labour supply that is tripled in the same temporal span (Violante, 2008). Such an increasing trend is confirmed, also in the recent years, in connection with the diffusion of digitalization. This is the reason for the introduction of the idea of technological skill bias. Technological bias refers to the shift towards or away from the use of a factor caused by technical change. Obviously the precise meaning of bias depends also on the definition of neutrality used. The skill bias, in particular, refers to the observed shift in the use of labour with higher skills, (Bekman et al., 1998).

It seems, therefore, appropriate to abandon the restriction of this rather limiting hypothesis of factor neutrality according, for considering the emerging cases of factor biased technological change where all primary factors do not play the same role in growth, rather some of them have greater influence on growth and receive comparative higher compensation. In this sense technological change advantages some productive factors, limiting in direct or indirect manner the payment of the others. This bias of technological progress has implications in the wage distribution to the different typologies of workers and so acting as driving force that encourages the groups of workers to adopt the new technologies, (Card and Di Nardo, 2002).

The debate on the founding aspects of the factor biased technological change has its roots from the pioneering book by Hicks, “The Wage Theory” (1963). Here the hypothesis of induced innovation is introduced, a hypothesis under which a change in the relative prices of the productive factors encourages the invention and, in particular, the innovation directed to economize on the factor that is becoming more expensive. Progresses in the subject of induced innovation and its consequences at macroeconomic level, in particular the relationship between technological progress and factor prices, have progressively developed (Binswanger and Ruttan, 1978), (Perera, 2017).

These progresses have refined the concept of factor biased technological change, in particular the *skill biased* technological change which determines the so called ***skill premium***, whose size can be quantified and detected (Moore and Ranjan, 2005). Skill premium is defined the ratio between the wage of skilled workers and the wage of unskilled workers, assuming that the skilled workers would have a higher wage than the unskilled workers (Roser and Nagdy, 2016). That value can also be considered as a reward given to the workers who decide to reach high levels of education, (Sill, 2002). It has been observed that the historical trend of this ratio shows that the skill premium, both in developed countries and in undeveloped countries, has strongly increased in the last decades.

In the largest time horizon, the most significant changes in its values took place in relation with historical events of great importance such as the Black Death, the Industrial Revolutions, and in more recent years, the ICT revolution. In particular nowadays in the era of digitalization, the most relevant historical event which emerges in the economic and technological context is the digitalization (Van Zanden, 2009). The decrease of the skill premium in the First Industrial Revolution seems to be attributed, on the contrary, to the so called *un-skilled biased technological change*. That phenomenon, which prevailed in that context, is linked to the fact that the work of many skilled workers was substituted by machines that have divided and de-qualified the work and gave it to unskilled workers with simple tasks to be performed by the machines. In the recent years, the before known as *un-skilled biased technological change* has evolved in the direction of the *skilled biased technological change* (Goldin and Katz,1998; Kim, Kim and Lee, 2017).

The movements of the skill premium are due to the economic progress. Development encourages and bring with them the introduction of new technologies that vary the composition of the demand of labour, between skilled and unskilled labour. In the supply side cost and returns from education influence the investment in human capital of the individual. As already highlighted in the latest part, the mechanization and the digitalization go together with the unemployment, as the technologies and the machineries eventually substitute the unskilled labour force. From the demand side the digitalization brings also an increase of the real wages because with the rise of the quantities, prices will go down, (Burstein, and Vogel, 2010).

In the United States of America between the years 1970 and 1990 there was a rise of the number of graduate students almost twofold and still now they represent the majority of the inhabitants,(NCES, 1993). On the contrary of what is normally to think, the rise of the supply of skilled labour has not been accompanied with a decrease of the real wage. Therefore, a rise of the education level that brings the increase of the supply of skilled labour, has corresponded and increase in the demand of skilled labour.

New technologies, with the Fourth Industrial Revolution especially substitute unskilled jobs and favour skilled jobs, to which is required the tasks to program and manage the machineries that, in turn can autonomously perform the majority of less qualified tasks. The rate of technological progress seems to determine, indeed, the speed of growth, while its factor direction or bias specifies which inputs have been used most intensively in the production: work, capital, energy or other intermediate input, (Klump et al., 2007).

The empirical evidences on *skill biased technological* change and labour market suggest that the technological change has been labour saving in the developed countries from the mid of twentieth century. (Acemoglu and Autor, 2012) In particular, progresses in computing and other technologies of information and communication (ICT) have been complementary to the high skilled work. These skills are linked to non-routinized and cognitive tasks and substitute the routinized tasks of medium skilled workers, with the result that some of these are gone in low skilled services, at least for that manual works not easily automatable. The subsequent crowding out of the distribution of employment through the several skill levels imply that the level of employment medium skilled decrease. (Autor and Dorn, 2013; Goos et al., 2009).

For the future, the technological change seems to be vulnerable to suffer deeper labour bias, *labour biased technological change*, as the progresses in knowledge of machineries and robotics linked to big data will able the machines to substitute workers also in the non- routinized tasks, both manuals and cognitive (Frey and Osborne, 2013) and (Brynjolfsson and McAfee, 2014).

Although all levels of skill will be influenced, the most dramatic impact is likely to hit the low – medium skilled labour while the high skilled competencies, requiring tasks like perception, manipulation and social creative intelligence, seem to be less passible to automatization. (Frey and Osborne, 2013). Analogously with the introduction of the new technologies, the demand of skilled labour force capable of installing, managing and maintaining the new tools has increased. On the other hand the routinized and less skilled functions are intended to be performed by technologies themselves, it seems likely to think that the big increase of the skill premium would be due to *skill biased technical change,* SBTC (Mc Adam and Willman, 2015).

The forecast that the majority of gains from the technological progress may enrich exclusively most creative and talented workers opens the debate linked to the possible increasing economic inequality (Piketty, 2013).

PART II
Policies for Growth and QUEST III

In this part we want to study the design and effectiveness of policies for growth through the use of the QUEST model. In the two preliminary chapters II.1 and II.2 problem of low growth and zero growth is put forward, II.1, and as the challenge posed by digitalization and the fourth industrial revolution. This challenge puts European countries in the need to design consistent policy replies based on the support of the innovative effort, II.2. Each European country, with different timings, has designed a set of governmental measures to face the new situation; chapter II.3 shows the policies designed by the Italian government to cope with the incoming digital era. In particular, the national plan *Industria 4.0* in its two articulations: *Innovative Investments and Skills Achievement* is sketched in a way consistent with the possibility of scenario simulations with QUEST III-Italy. The feature of the latter model are specified in chapter II.4 with special reference to those involved in our policy analysis. Finally simulation experiments with QUEST III-Italy are performed and showed in chapter II.5.

II.1 Innovation Policies and Zero Growth

Although the production of new goods and services and the indispensable diffusion of innovation define the evolution of the economic process of our days, research on innovation has evolved fragmenting itself into a number of economic disciplines, from macroeconomics to public finance and economic development, (Stanko and Calantone, 2011). The innovative activity has always represented the key factor for the improvement of the life standards, for the economic competitiveness of the country and the national progress, (Kogan et al.,2017). In recent years it reveals itself as the main device to face the leading challenges emerging at world level, such as the climatic change and the sustainable development, (UN, 2014).

The innovative activity can be successfully put in operation, and then become a productive economic activity able to fulfil its role, only if the technological advancements are accompanied with a wise entrepreneurial activity, with a market structure capable to recognize the innovation itself and with a normative scheme, which permits its diffusion.

Intellectual activities, connected with innovation, include themes related with human capital and knowledge, R&D sector and with the evaluations of the patents and trademarks achieved. They generate productivity growths and their value is determined by the actual evaluation of the market, being them source of increases of value for products and processes in which they are included.

To this purpose, there exists evidence that the investment in R&D is associated with high rates of returns. In particular, investments in software, which constitute R&D, have contributed in a substantial manner to the business performance and to economic growth. Indeed, for more than a decade, since 1995, more than one third of the total contribution of ICT, Information and Communication Technology, to GDP is due to investment in software in economic realities such as Denmark, France, The Netherlands, Sweden and United States (OECD, 2007).

The globalization has furthermore highlighted the importance of innovation, in the ICT field, for example, it brought the access in new markets for creation and transport of innovative services. The globalization has also provided an incentive to prevent the stop of the innovative process in both OECD and not OECD countries, to the point that the latter ones are becoming able to compete on equal terms in R&D matters.

Nowadays in developing countries, that are progressively globalizing, we can observe as immediate consequence, that scientific or research collaborations for innovation, particularly in the academic context or in industry, are the main engine of economic growth. Emerging countries, BRIC, also offer to OECD countries, new markets, innovative products and an incoming flow of highly skilled human capital, (Distefano et al., 2016). In addition to the aims of the global economic growth, the not developed countries are pushed to collaborate with the developed countries, stimulated by the emerging global challenges and the economic requests emerging from the society (Cassiolato and Lastres, 2011).

In the new global context, innovation becomes a key element in the collaboration between inhabitants of different countries, aimed to develop skills, to solve problems at different levels: individual, social, regional and global (Poetz and Schreier, 2012) because this new era seems to push toward the individual assumption of the risks connected to the transformation of their own ideas in value.

However, in the latest years, we observe a gradual slowdown of the economic growth in Europe compared to United States of America, Asia and to several developing economies in relation to research, development and innovation (R&D&I).

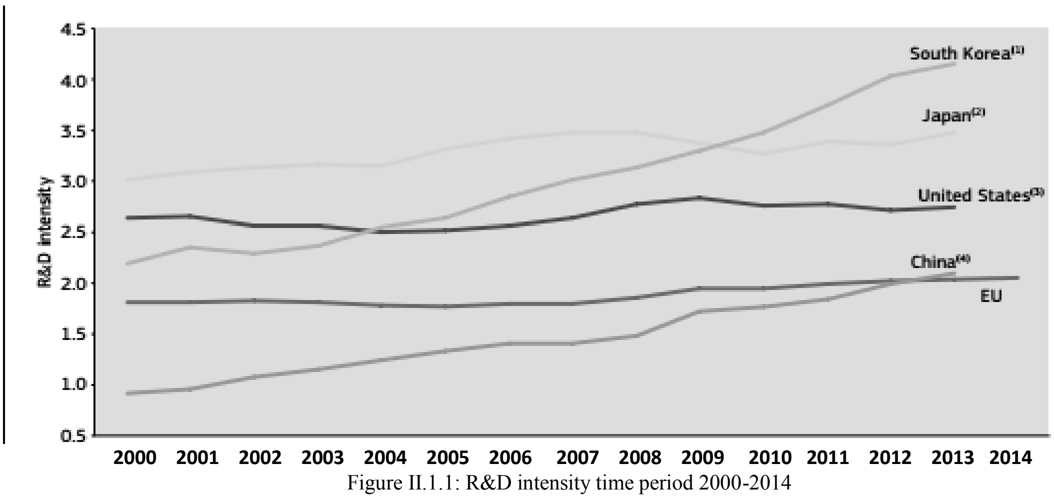

Figure II.1.1: R&D intensity time period 2000-2014
(Source: EC, 2016)

As shown in Figure II.1.1, the EU appears out of track for reaching the target of 3% in intensity of R&D by 2020. The Figure also shows that China reached EU in terms of total R&D intensity already in 2013. Moreover, the extension of the 2007-2014 trend seems to direct the EU to miss its 2020 3% R&D intensity target. “The world is becoming more R&D-intensive and the relative weight of the EU in this new global R&D landscape is decreasing, mainly due to the rapid rise of China" (EC, 2016).

Even if there are positive signs in some areas[1], in general, investments in innovation remain rather inadequate. The most dynamic sectors, as ICT, account for, at least, half of the growth of productivity in EU, but, at the same time, that fact constitutes the main reason of the growth gap between EU and US. The rise of the ICT sector for each European country becomes also more crucial with the introduction of the Digital Agenda for Europe that aims to help citizens and European firms to obtain the maximum from digital technologies, predicting a contribution of 550 billions of euros, 4% of GDP of the EU economy (EC, 2014).

Nowadays, nothing is more important than open the innovative potential of EU through innovation to the aim of relaunching the EU Project. The European Union has given priority to research for growth based on innovation and has allocated resources in R&D promotion, but the performance of innovation remains weak, and the lack of results brings with it exhaustion that frustrates the interest and increases critiques to policy.

The R&D on the European total GDP ratio (public and private) remains at 2%, in 2015 (Eurostat, 2016) still far from the objective of 3% and much lower than US, Japan, South Corea and Singapore. In addition, we can observe few signs of positive development, particularly when compared with China, which is recovering at very fast rhythms, and is already at EU level with respect to that indicator. To be effective, the innovative policy should be, on one hand, addressed to those able to implement growth based on it; on the other, it should be systematic. Innovation policies should, in fact, include a set of instruments that cover the whole innovative process eliminating weaknesses and reducing bottlenecks.

The fundamental justification for the public support to research in the typical topic of market failure: markets do not provide sufficient incentives for private investments in research for the non-excludable and non-rival characters of knowledge as public good.

[1] "*The new scoreboard reveals that EU innovation performance continues to increase, especially due to improvements in human resources, the innovation-friendly environment, own-resource investments, and attractive research systems. Sweden remains the EU innovation leader, followed by Denmark, Finland, the Netherlands, the UK, and Germany. Lithuania, Malta, the UK, the Netherlands, and Austria are the fastest growing innovators.*" European Innovation Scoreboard 2017

With special reference to basic research, the new knowledge created becomes only partially non-excludable: others can learn and use the ideas, without necessarily paying for them.

These spillovers cause the rates of return of the entire economy to be higher than private ones, and so the levels of private investments will be under the socially optimum investment levels. That difference between social rate of returns and private ones pushes the state intervention to encourage the investment in private R&D so that it can increase until it reaches the socially optimum level.

In addition to the case of spillovers, a second market failure derives from the high risk and from the uncertain nature of the R&D incomes. That uncertainty, together with the asymmetric information between the capital markets and R&D investors, causes imperfections in the financial market, preventing the access to financing for risky innovative projects. Moreover public research is necessary to meet specific needs of public interest, included common goods that market does not offer on its own, such as defence, public health and a clean environment.

Hence, the public support to research therefore finds its main motivation in the market failure in case of R&D investment for growth, considered the constant difference between private and social returns. Its objective remains, in any case the attention to the convergence between the private innovative efforts and the socially useful level. Naturally, the public intervention is valued also comparatively with the opportunity costs of intervention, that an increase in taxation can produce, as increase of debt and restrictions in the public expenditure on other sectors of the economy. In addition, we have to evaluate also the real success of the public policy in generating that increase in private investment for R&D able to push investments to the socially optimum level.

Innovation appears, always more, a phenomenon that delineates clusters of nations able to actuate policies that endow individuals, also out of their borders, with different abilities to solve problems, as already said, at the different levels, individual, collective, regional and global. In recent years, clusters of countries have been identified through the use of a multidimensional statistic indicator the so called Global Innovation Index, GII[2] (WIFO, 2017).

Since 2007, world economies have been classified following that indicator, built with the aim of representing and evaluating the polyhedral phenomenon of innovation and skills and results in this context, obtained in the various countries. The picture that emerges of the phenomenon of innovation is that it is always a global phenomenon, even if there persist a gap between different countries. The GII 2017 reveals, indeed, a multipolar world with respect to the phenomena of research and innovation, where the majority of innovation is still concentrate in high income economies and some selected of medium income.

Looking to the ranking of the Global Innovation Index for 2017, we see some little differences with respect to those of years 2015 and 2016.

In 2017, Switzerland remains at first place for the seventh consecutive year and the same for Sweden that maintains the second position and USA that defends its fourth place. The Netherlands grows from the ninth position to third position and the same for Denmark (from seventh place in 2016 to fifth place in 2017) and Germany (from tenth position to ninth position). The worst part has been made by UK which cannot maintain its third position and decreases to fifth position, Finland (from fifth to eightieth position) and Irland, from seventh to tenth position.

Luxemburg, ranked at ninth place in 2015, has fallen at the 12th place, since last year. For the first time, a middle-income country (China, 22nd place) takes part of the 25 most innovative countries. The progress of China reflects the registered improvement in the qualities of its innovative infrastructures and of the relevant level of investments in research and human capital. Although the growth of China and the growth and consciousness between the policymakers of the key role of the innovation in the economic growth, there is a significant difference between the middle–high income economies and high income economies,(Broda et al., 2017). Many middle –income countries still depend from high income economies for what regards the technological transfers aimed to provide solutions to problems of internal nature, that is, in fields like

[2] The Global Innovation Index (GII) since 2007 is a classification index of world economies according their abilities and results in the field of innovation that utilizes 80 indicators that include measures of the development of human capital and research, growth funding, university performances, comparative size of the patent demands. GII has shown in the years that the innovation ability in each country is measured not only on what is achieved within the individual country, but also on the impact it has on the entire planet.

healthcare, (Lewis et al., 2012) and energy, (WEF, 2017). For what concerns low income countries, close to the innovation divide, that separate them from the middle income economies, many countries ranked out of the first 25, are doing better than the countries of their income group.

COUNTRY/ECONOMY	SCORE (0-100)	RANK	INCOME	RANK	REGION	RANK	EFFICIENCY RATIO	RANK
SWITZERLAND	67.69	1	HI	1	EUR	1	0.95	2
SWEDEN	63.82	2	HI	2	EUR	2	0.83	12
NETHERLANDS	63.36	3	HI	3	EUR	3	0.93	4
USA	61.40	4	HI	4	NAC	1	0.78	21
UNITED KINGDOM	60.89	5	HI	5	EUR	4	0.78	20
DENMARK	58.70	6	HI	6	EUR	5	0.71	34
SINGAPORE	58.69	7	HI	7	SEAO	1	0.62	63
FINLAND	58.49	8	HI	8	EUR	6	0.70	37
GERMANY	58.39	9	HI	9	EUR	7	0.84	7
IRELAND	58.13	10	HI	10	EUR	8	0.85	6
REP.KOREA	57.70	11	HI	11	SEAO	2	0.82	14
LUXEMBOURG	56.40	12	HI	12	EUR	9	0.97	1
ICELAND	55.76	13	HI	13	EUR	10	0.86	5
JAPAN	54.72	14	HI	14	SEAO	3	0.67	49
FRANCE	54.18	15	HI	15	EUR	11	0.71	35
HONG KONG (China)	53.88	16	HI	16	SEAO	4	0.61	73
ISRAEL	53.88	17	HI	17	NAWA	1	0.77	23
CANADA	53.65	18	HI	18	NAC	2	0.64	59
NORWAY	53.14	19	HI	19	EUR	12	0.66	51
AUSTRIA	53.10	20	HI	20	EUR	13	0.69	41
NEW ZEALAND	52.87	21	HI	21	SEAO	5	0.65	56
CHINA	52.54	22	UM	1	SEAO	6	0.94	3
AUSTRALIA	51.83	23	HI	22	SEAO	7	0.60	76
CZECH REPUBLIC	50.98	24	HI	23	EUR	14	0.83	13
ESTONIA	50.93	25	HI	24	EUR	15	0.79	19
MALTA	50.60	26	HI	25	EUR	16	0.84	8
BELGIUM	49.85	27	HI	26	EUR	17	0.67	47
SPAIN	48.81	28	HI	27	EUR	18	0.70	36
ITALY	46.96	29	HI	28	EUR	19	0.73	31
CYPRUS	46.84	30	HI	29	NAWA	2	0.74	28

Table II.1.1:Global Innovation Index 2017 Rankings
Source: (Dutta, Lanvin, and Wunsch-Vincent,2017)

These *innovation recipients* include many economies in Africa, such as Kenya, Madagascar, Malawi, Rwanda and Uganda, and economies in other regions such as Armenia, India, Tajikistan and Vietnam.

In relation to the European countries, 15 of them are included in the group of the first 25 countries in the GII 2016, the first three are Switzerland, Sweden and the Netherlands. Europe benefits of strong comparative institutions and developed infrastructure, and it is successful in environmental issues, ICT access, school and life expectation. However, margins of possible improvement still exist with respect to aspects such as businesses, knowledge and technological outputs.

Innovation in growth theory has been often treated with *ad hoc* methods, showing some difficulties to allocate itself in a whole macroeconomic vision and to obtain results immediately comparable with the aggregates of macroeconomic accounts. The Italian economy, characterized by a high public debt to GDP ratio and a low percentage TFP growth and low competitiveness is experiencing a very low economic growth. The traditional positive economic trend, that characterized the industrialized economies of the past, has disappeared and the recent economic results register pattern characterized by fluctuations of almost negligible entity, around a steady state centered on zero.

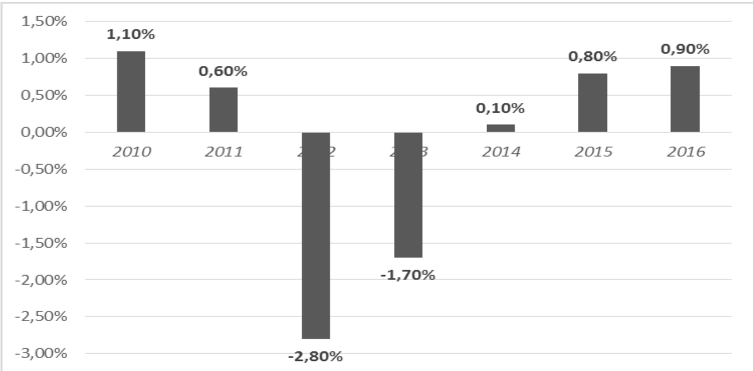

Figure II.1.2: GDP growth for Italy in time period 2010-2016
(Source:Istat, 2017)

The phenomenon worries also because in the international context, traditional developed economies show difficulties in achieving satisfactory growth rates, in the alarming perspective that zero growth can become the stable steady state especially for Italy. A way out for facing this internal and international situation can be postulated in terms of technological progress. This path, however, could imply transformations that, for complexity, size and scope, could manifest as extraordinary and unique where the answer provided by the private and public operators should be conscious and integrated. It has been theorized, indeed, that the Fourth Industrial Revolution (Schwab, K., 2016), based on new technologies, will succeed in achieving the transfer from the third *human to machine*, to the fourth industrial revolution, *machine to machine*. While the first industrial revolution was grounded on water and steam engine to attain the mechanization of production, the Second Revolution relied on the electric energy to create the mass production, the Third Revolution, i.e. the information and communication technology, ICT, era, reached the automation of production through informatics, electronic and nanotechnologies.

The country that has first taken the initiative of foreseeing and studying the actions in both the public and private context, aimed to favor the transfer from the third, *Human to Machine*, to the fourth industrial revolution, *Machine to Machine*, was Germany. A working group[3] at the Hannover fair in 2011 presented to the federal government a series of recommendations for the design of an industrial plan that considered investments to renovate the German productive system and bring back German manufacture to the past levels of excellence. The action plan supported at a federal level, which involves the biggest industrial and technological operators, is known as *Industrie 4.0*. Suggested investments involve energetic systems, research centers, infrastructures, schools and firms, (EC, 2017a).

Results realized by Germany have led also other European countries to design and realize analogous initiatives. Great Britain with Catapult-High Value Manufacturing, (TSB, 2012), considered an action plan, promoted by the government and the institute for manufacturing of the Cambridge University, for the support of firms and applied research. France with the *Industrie du Futur (*La Fabrique de L'Industrie, 2014) designed a centralized plan of the government for the investment in technologies 4.0 and reindustrialization initiatives. The Netherlands, with Smart Industry in 2014, (EC, 2017b), undertook the creation of a network approach through which combine the traditional industrial system with the new opportunities offered by the applied sciences; analogously in Denmark the plan Made 2012, (EC, 2017c), Belgium in 2013 with the program Made Different, (EC, 2017d), and Industria Connectada in Spain in 2014, (MINETUR, 2014).

In Italy (2016) the National Plan called Industria 4.0(MISE, 2016) highlights the strategies aimed to involve firms in the sustainability and the relevance of the industrial development through the specification of key directive for the period 2017-2020 in two aspects: i) Innovative Investments and ii) Skill Achievemement, (MEF, 2017). The first point suggests increases of private investments, private expense on technologies 4.0, and increase of private expense in R&D&I; the second is related the creation of competences linked to skilled managers on themes 4.0, new enrollments to technical institutes on themes 4.0 and Ph.D. doctors in themes 4.0. With the key directions the plan recommends a program of digital infrastructures and public instruments of support.

[3] Chaired by representatives of Robert Bosch GmbH and Acatech

II.2 Digital Manufacturing

The Fourth Industrial Revolution is driven by the presence of consumers of products that are highly custom-designed (Dellaert and Stremersch, 2005). This type of smart and active consumers progressively substitute the Fordist mass consumers. Now the individual, the consumer, is expected rational, smart, he has, probably, deepened the relationships with the artifacts created by himself and has found a stable collocation within the world. He can use the computer to program and uses cyber physical systems to store data and information, (Eurostat, 2017). Technology, in every sector, from healthcare to coffee machine, becomes constituting part of the daily life and is able to interact with the human. We assist, indeed, to a dematerialization of the industrial activities and of the industry, (Roblek et al., 2017). Because there is a passage from the mass production to the customized production, the fabrication needs flexible fabrication solutions that put together the creative spirit of the manufacturer and the routinized processes of the machines that create the product (Mikkola, 2006). The process of digital manufacturing is based on the so called, rapid prototyping, a process of designing that transforms a vectorial file on an informatics base, in a solid object and tridimensional using the subsequent overlapping of layers of materials following a procedure called Additive Manufacturing, (Helper et al., 2012).

In the digital era, the main attention regards the consumer, who is the designer and inventor of the good, confining the role of the firm to merely provide the good itself. Each object will have its specific code, to enable its individuation, modify and share in the net, and to receive possible feedbacks from other clients (Bellos and Ferguson, 2017). Now, indeed, the human being is able to use a computer and to gather and store huge quantities of data in cyber physical devices so making technologies easier and more accessible.

The effective realization of the digitalization process is, however, strictly linked to the adoption, by the firm that is transforming, of the so called "enabling technologies", all those technologies needed to the technological progress of the firm, (Posada et al., 2015). As an example we can quote the most important: the *3D printer* *and scanner*, the *Internet of Things* (IoT), the *BiG Data*, and the *Cloud Computing,* (Pisano et al., 2016).

The 3D printer is based on the productive technique of additive manufacturing which is a technique that permits the creation of materials, semi-finished products and finished products, by means of sums of layers of material. Such a technique performs contrarily to the classic manufacturing, that by means of specific manual works such as pressing, turning and milling of the raw material, used the so-called technique of subtractive manufacturing to reach the final product, (Magee and Devezas, 2017).

Through the utilization of advanced informatics systems, which enable a dialogue between computer and machineries the additive manufacturing is enabled by the development of the internet connection. That technique, developed with the technological evolution of the 3D printer, highly limited the use of materials, lowered costs and largely improved the performance. This technology needs only a computer connected to a 3D printer, to work, and the printing mechanism is relatively easy and can be made by consumers without high education for that it will be necessary only the download the vectorial file and send it to the printer, (Schubert et al., 2014). The most elaborate work is that of project and develop the vectorial file. The advantage of the technology is given by the fact that it permits the *in loco* self-design of the product and so a saving on the transportation costs and the elimination of the waste, as through the additive manufacture only the strictly indispensable material for the development of the product is used. The *Internet of Things* (IoT) defines the set of technologies that have the potential of connect to the Internet all kinds of equipment to monitor, control and transfer information (Tao et al., 2014). Its evolution brought to the connection to internet also of sites that are now able to transfer directly data and information.

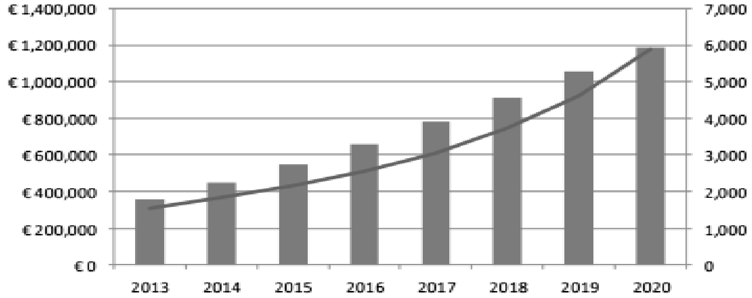

Figure II.2.1: Installed Base and Revenue in EU 2013-2018
(Source: EC, 2013)

The objects are, in this perspective, “smart” because they are able to store the information coming from the external world and transmit them by mean of the Internet. In the Italian context, the main examples of IoT are linked to fields of video surveillance and security in smart houses and smart cities (European Commission, 2016a).

However, they still find difficult application in the more complex areas, where greater funding would be required such as healthcare (eHealth) in which it would be possible to implement systems that tele monitor patients, lowering costs of hospitalization, (WHO, 2016). As shown in Figure II.2.1, the number of IoT connections within the EU28 are expected to grow from approximately 1.8 billion in 2013 (the base year) to almost 6 billion in 2020 both because of the increased connectivity within consumer goods joint with the extensive placement of sensors. IoT revenues in the EU28 will grow from more than €307 billion in 2013 to more than €1,181 billion in 2020. Revenues in fact follow the progression of the installed base.

The increasing use of data bases of big dimensions (*Big Data*) of administrative type and in many fields, such the healthcare, banking, insurance, media telecommunications, trade and manufacture, is creating a new paradigm of economy, the so called “data driven economy”, a digital economy characterized by data and automation. Such data will be informative, from the statistical point of view, on the behavior of firms and the market, (George et al., 2014). To face the change and be prepared to the new challenges of this new economic system a wide quantity of firms are building data bases referring both to open data and to big data and are addressed to services of business intelligence and to data scientists to analyze the macroeconomic situation and take policy decision.

The *cloud computing* is an umbrella term that is used to include the set of technologies that make elaborations, calculations and memorize data using hardware instruments or software found in the Internet (Ruparelia, 2016). Through the cloud transmission services are distributed in the net and through the Internet an elaboration of data is possible in the server in which cloud is installed. Resources from the net are attributed to the customer through automated procedures, starting from resources shared with other customers. The customer must do part of the configuration autonomously, (OECD, 2017a).

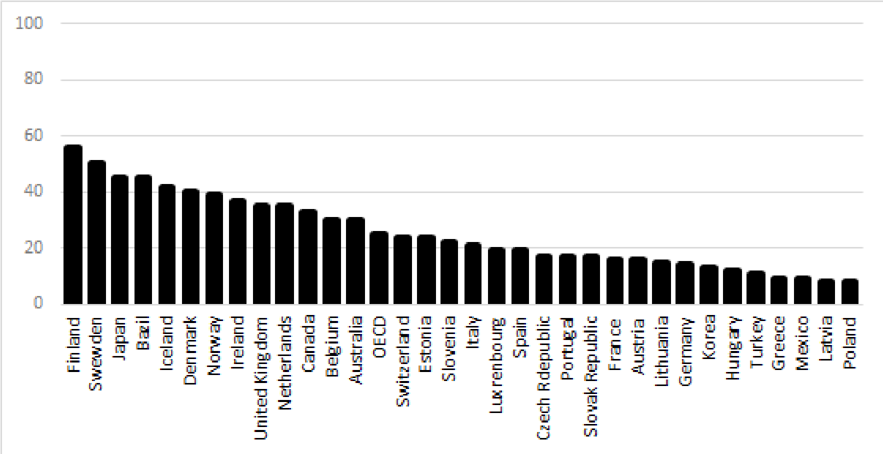

Figure II.2.2: Enterprises using cloud computing services by employment size class, percentage of enterprise in each employment size class year 2016, (Source: OECD,2017a)

The cloud computing is a saving opportunity in terms of cost, it provides to computers major power, providing the virtualized hardware, it permits a saving for the firm in terms of cost of capital and room for the collocation, management of damages of the system. Within the firm, digital technologies are introduced in order to improve and make more efficient the level of connection of software with the machineries in use in all the phases of production of goods and services. The adoption of digital technologies at a firm level implies several advantage and disadvantage that emerge. The main disadvantage linked to the diffusion of the automation consists in higher risks for the privacy and security of data put into action by attempts of informatics hacking. The three main advantage are, in general, summarized by the acronym MRO, that is Maintenance, Repair and Overhaul, (Wezter et al., 2012). They operate through mechanisms of the type: i) Machine to Machine (M2M), ii) Predictive Maintenance, iii) Engagement.(Bloem et al., 2014)

The Machine to Machine (M2M) is the heart of the Fourth Industrial Revolution and can be defined as that mechanism that makes possible the digital interaction between the several machineries, firms' equipment and all the technological and cyber physical devices. Technologies can communicate without the intervention of the human beings and through wireless can directly gather and distribute data. In this way, there is an increase of the efficiency of machineries and, consequently, of the production processes (Sterna and Beckera, 2017).

The European Roadmap for Industrial Process Automation (2013) includes the mechanism M2M, together with the paradigm of interaction human –machine (HMI) and the universal codification of the Internet standard, among that mechanisms that are essential for a wide diffusion of digitalization, (Noble, 2017). The beneficiaries of the M2M applications can be the individuals, companies and organizations in the public and private sectors. Various contexts of applicability have been identified, in the field of education, where it is possible to trace the attendance of students at school and in the construction sector, with smart houses, for alarm plants and fireproof equipment. Applications are also possible in the agricultural context, in the water resources management and in the healthcare, with the monitoring of the patient from remote control and the installation in the body of sensors to monitor the life parameters, (Jeschke et al., 2017). As to the Predictive Maintenance, with the aim of maximum accountability and speed in the productive processes, maintenance interventions are possible and preferably preventive, through sensors on the machineries that make possible to monitor and communicate their condition directly to other machines or to operators. All these proceedings are aimed to cancel the slowdown in the functioning of machineries and the standby times in order to maximize productivity. The preventive maintenance is preferable because, through an ex ante monitoring, it is possible to act directly on the critical point and solve it, before problems and expensive irremediable damages for the system emerge. It is possible to forecast that an old machinery is to be substituted, but is more difficult to forecast, without automatic control sensors, that a new machinery could be next to substitution, maybe because it has been used in a more intensive manner, (Chinniah, 2015).

To conclude, the maximum efficiency in the productive process firm can be reached exploiting all those mechanisms that make possible the interaction of the firm with the customer or, in any case, with the final consumer of the product. Informatics platforms linked to the net are, obviously, the best place for comparison and exchange between firm and consumer, (Song and Sakao, 2017). Through the analysis of data related to consumers' purchases, the firm obtains information about customers' preferences of some kinds of products rather than others and some models or colors rather than others. This interaction improves the distribution of goods and services by the firm,(Tao, 2017).

II.3 *Industria 4.0:* a National Plan for Growth

The project “Industria 4.0” (I4.0) starts from an analysis of the characteristics of the Italian industrial sector on which an intervention is required (MEF, 2017). Some points of strength of the industrial system emerge, such as a strong characterization of the territorial path determined by the presence of small and middle size firms and the key role due to the presence of university and research centers aimed to the development of R&D projects. On the other hand, the existence of few big private industries able to lead the Italian manufacturer transformation, and a very limited group of leading companies that coordinate the evolution of the value chains are considered weak points. From these features, some recommendations emerge on the direction of the public policy. First of all, interventions have to operate in a frame of technologic neutrality, with horizontal actions excluding both vertical and sectorial ones, acting on the enabling technologies of I4.0 (as IoT and Big Data), encouraging productivity and the technological jump while coordinating the main operators.

In this framework, the National Plan “Industria 4.0” reveals itself as an instrument that enables firms to catch the opportunities linked to the Fourth Industrial Revolution. The Plan influences the life cycle of firms that want to improve their competitiveness through the improvement of the productivity of workers and to develop and spread new skills while introducing process and product innovation through the digital transformation of productive processes. The Plan, even if still in its starting phases, has already produced positive consequences, particularly in terms of innovative startups, which in Italy have increased to 31% in 2016, 25% of which operates in services sector, particularly Research and Development. It develops along two Key Directions, namely Innovative Investment and Skill Achievement. The implementations of those directions imply the creation of enabling infrastructures. In fact, innovative investments cannot be accomplished without the availability of adequate net infrastructures and the definition of standard criteria for interoperability. It also requires the consideration of public instruments of support, such as stimulus to private investments, enforcing presence on international markets, support the exchange wage/productivity through a decentralized bargaining. These last measures represent the so-called auxiliary directions. Within these directions, the Budget Law 2017 established the extension of the Nuova Sabatini, until 2018 and endowed it of larger resources (560 million in charge of the balance of MISE that will activate banking financing from 5 to 7 billions). The measure is aimed to provide support to firms oriented to the digital development, which require bank loans. The size of the recourse to these measures on the behalf of small and medium firms, through the Nuova Sabatini, has been relevant: more than 19 thousand requests for a total amount of more than 360 million.

II.3.1 *Industria 4.0: Innovative Investments*

The first Direction, i.e. Innovative Investments, wants to encourage the private expenditures in research, development and innovation and enforce finance supporting venture capital and start–up with I4.0 linked objectives. This direction includes fiscal allowances with the aim of sustaining and offering incentives to private societies that realize investments in capital goods, tangibles and intangibles with the aim of digitalization. These measures consist in the extension of super depreciation to 140% for private investments in technologies, instruments and tangibles goods I4.0 done by the 31st December 2017 (or, when specific conditions occur, by the 30th June 2018). Moreover, an hyper depreciation of 250% for the acquisition of goods for the digitalization of productive processes. Beneficiaries of hyper-depreciation benefit of a facilitation consisting in an increase of 40% on the depreciation cost of investments in immaterial goods, software and system integrator. The Budget Law is aimed also at encouraging investments in Research, Development and Innovation from private sector through the enforcement and the extension to 2020 of the tax credit for R&D expenses, both related to product innovation and process innovation. That measure has been introduced with a rate equal to 50 % until a maximum of 20 million of euros each year.

The area "Finance for Growth" is included in the wider direction of Innovative Investments even if in the budget evaluation it is separately quantified. It includes all those long run measures aimed, in general, at encouraging the rise and development, through the introduction of fiscal incentives for the listing and capitalization of firms, of an environment that encourages investment. An environment, then, that allows firms to manage, in an easy and immediate way, the required financial resources for their growth, also by means of clear and more definite rules. That budget item includes measures that enforce the finance supporting I4.0, venture capital and startups. They consist in a range of actions aimed to guarantee fiscal allowances for investments in startups and small–medium size firms with objectives aligned to I4.0 programs.

Listed companies, when participating at least to the 20% of capital shares of the startup, can deduct the registered losses of the startup in the first four years of life. In addition, Individual Plans of Saving have been introduced (PIR) for enabling the tax reduction on the capital gain, in case of lung run investments, at least of five years. PIRs have their effects only if investments are done from pension funds, insurance companies or retail investors. In conclusion, programs are developed which support the firm accelerators aimed at financing new firms with focus I4.0 ('*Accelerate*IT') and measures for the industrialization of high tech ideas and patents are introduced ('ITAtech'), addressed to investment funds.

Finance for growth ensures a wider range of credit sources, enabling firms to obtain credit directly from the operator, such as securitization companies, credit funds and insurance companies. New rules are introduced by the Authority which regulate Insurance (IVASS) and from the Bank of Italy to permit the entrance of new participants to the market. In addition, investors resident in UE will no more pay withholdings on middle–long term financing. Other measures are aimed to facilitate the access to capital market. Yet in February 2013 Italian Stock Exchange introduced the new segment of negotiation called "ExtraMot Pro" which permits to the not listed firms to issue obligations called "minibonds" directly on capital markets. There has also been operations for approaching saving to investment: the new investment scheme introduced by the Budget Law 2017 recommends the private investment within the financial instruments without taxation on capital gains.

Incentives for investments and mergers are also introduced. These interventions consist in splitting the depreciation time of the business start –up and incentives to capitalization such as tax credit modified for capital increases "Allowance for Corporate Equity." Other supports are addressed to the field of market quotation of the firms through new instruments which provide incentives to the quotation itself (shares with multiple vote and shares with increasing vote…); investments in infrastructures are more immediate for the private sector thanks to the administrative and legislative simplification and the banking sector has been made more stable and competitive.

II.3.2 *Industria 4.0: Skills Achievement*

The Plan Industria 4.0 includes not only measures, interventions and fiscal incentives aimed to support firm investments in Research, Development and Innovation, but it also contains actions aimed to spread new competences and skills linked to the progresses in digitalization of new technologies. To lead human capital toward digital oriented knowledge "National Network Industria 4.0" has risen. It is organized in several sites in the whole National territory, with the scope of providing firms the needed digital competencies. They intend to explain the advantages from the utilization of new technologies in the industrial processes, identify the intervention areas of primary importance, also taking into account the industrial maturity of the particular firm, and encourage investments in project connected with the industrial research both in standard and experimental development suggested by Industria 4.0.

In Italy, there are different points that sustain firms and that distinguish themselves because of services supplied to firms. In details, there are the Digital Firms Points (PID), which have the task to spread basic knowledge on technologies related to Industria 4.0. They map the maturity of firms from the digital point of view, hold formation courses on basic competences needed for I4.0, also through the so-called "Digital Promoter" and of the "Mentor" and do activities of orientation addressed to the firms for the choice of innovation hubs and Competence Centers. Innovation Hubs, spread knowledge about new technologies and deal with mapping the digital maturity of firms, in addition they provide courses on specific more advanced competences for the firms and orient them in the direction of most appropriate Competence Centers.

Also Competence Centers, like the other points, before proceeding with the subsequent phases, map the digital maturity of the firm that needs the advice. They will do paths of high formation, which predict also the analysis of practical cases to permit to firms to touch with hands the situation of improvement brought by new technologies, through demonstrative productive lines and promotion of industrial research projects and experimental development.

Within the macro category of Innovation Hubs there are the Digital Innovation Hub (DIH) and the Digital Ecosystems of Innovation (EDI). The DIHs are developed in collaboration with external partners and with services linked to the financing of I4.0, they do formation activity to the firms and are active within Universities, Research Centers, Fablab ITS and Schools.

The EDI does activities of advice on the product and process innovation and on the advantages deriving from new technologies, gives advice for the access to incentives for innovation, and laboratories for digital creativity, incubation and hackathon. EDI can be transversal for it spreads competences linked to the digital to all the net entering in contact with external partners and with national Competence Centers, but also vertical when it wants to valorize territory answering the needs of particularly relevant sectors of the country.

In addition to these particular sites located in the national territory, the Plan is aimed to involve also all that institutions already existent linked to the formation of new human capital. First of all, Universities, through specific paths and Ph.D. courses on the theme, dedicated technical institutes, and through a more stringent collaboration between the world of education, formation and research and firms (promotion and development of alternation school –labour and incentives to apprenticeship); the main aim is to educate 200 thousand university students with competences to face innovation introduced by I4.0.

At the European level, an initiative that deserves to be cited is the Vanguard Initiative which includes the thirty European regions (among which, for Italy, Lombardia and Emilia Romagna) more innovative from the digitalization point of view. Vanguard is based on the approach "Leading by Example" which is aimed, through the creation of demo plants, which can be used in large scale by many firms, to show the advantage brought by the introduction of innovations (costly and risky investment) on the production process. That pilot plant should be used by firms, to prove the effectiveness of the technology, in the short run. After this test period, in case of positive result, the firm will assume the investment risk.

The latest typology of centre of formation for I4.0 that can be included in the so called National Network are the technological clusters; in Italy the most relevant are: Fabbrica Intelligente, Aerospazio, Agrifood, means and systems for the mobility of earth and marine surface, Life Sciences, Technologies for the life environments, technologies for the Smart Communities.

At the government level, the formation of the competences needed to respond to the changes generated by the I4.0 Plan are spelt out in the national plan for digital school (PNSD). That plan has been implemented to respond to the rather deluding performances made by Italy in the first attempt to introduce innovative elements in the school system (MIUR, 2015). Following the last available report, which refers to the school year 2014 -2015 published by the Technological Observatory of MIUR[4], only the 70% of the classes is connected to the net, with cable or wireless, the 41.9% of classes is endowed with interactive multimedia blackboard and the 6.1% with interactive projector. The 82.5% of laboratories is connected to the net and the 43.6% is endowed with LIM and the 16.9% of interactive projector. In any case we can say that the majority of schools owns forms of online communications school –family, the 69.2% uses the electronic class register, the 73.6% uses the electronic register of the professor and, in conclusion, only the 16.5% uses forms of centralized management LMS (Learning Management Systems, such as Moodle) for didactics and its contents[5].

The National Plan for Digital School (PNSD), a Plan that is included in the Law 107/2015 (La Buona Scuola) and indicates measures aimed to a digital transformation of scholastic infrastructures and to the spread among students and professors of culture 4.0. That document describes a set of actions that has to be done to introduce new technologies in schools and the concept of permanent learning (life-long learning) a learning in continuous evolution, that has to fast adequate itself to the unexpected technological changes. That Plan, with is supposed to expire in 2020, indicate the actuation of 35 actions financed by an amount of resources equal to 1 billion of euro available by the Law Buona Scuola and by The European Structural Funds (Pon Education 2014 -2020).

Up to now, there have been partial modification of the scholastic environment through the introduction, in the time period 2008 -2012 of the LIM (Multimedial Blackboards) in classes, that brings to achieve Classes 2.0 and Schools 2.0, with laboratories and innovative learning environments. In 2010 the action "School Digital

[4]The Technological Observatory of the MIUR is the institution which monitors the process of Digitalisation in the school environment, since 2000.

[5] The latest analysis (which is linked to the school year 2014-2015) was articulated on three main directions: dematerialisation of services (sites and gateway, communication schools-families, electronic register, management of didactic multimedial contents) technological endowment of laboratories and libraries (connections, pc, LIM and educational projectors) technological endowments of the rooms (connections, fixes and mobiles devices available for students and professors, LIM and educational projectors).

Publishing" is started, aimed to achieve digital material in 20 school institutes, distributed among different school levels. In 2013 the Wi-Fi action has been implemented for the introduction of the wireless connection in the schools. Finally in 2013 the "Action Formative Sites", which brings to the creation of 38 interprovincial structures and to the construction of 18 regional structures. Those structures intended to organization and management of formation courses on digital innovation for teachers.

The forecasted actions of PNSD are, at first, designed to provide the convenient instruments for a faster and easier net connection, through fiber and Wi-Fi. Indeed, by 2020, all the schools must have optical fiber and connection in broad or ultra-broad band. Internal structures of the school must be endowed with LAN connection or wireless, accessible by any room being part to the scholastic structure. To this aim, MIUR will recognize to school a financing of 10 million of euros, more each year from 2016, exclusively destined to the internet connection rate, to enable the school to do the teaching activity through digital technologies.

The second category of actions wants to upheave the space, introducing new virtual and innovative environments, but also with consideration of the architectonic and the energetic efficiency and the structural and anti-seismic security; also restructuring with digital perspective and following the applicable construction norms, laboratories and existent schools. In addition, the intention is to introduce the possibility for students to use their own electronic device during the scholastic activities (BYOD, Bring Your Own Device politics). Lecture halls should be wider, open also to more classes and prepared with places for the use of web both from the single individual and a collective level, devices located in mobile trolleys available for all the school. Challenges in technological and social context are defined and monetary rewards are awarded (Challenge Prize) to the school which answers to the challenge in a particularly innovative way.

The plan for laboratories wants to create real innovation sites, at the center of the curricular activity and not in extra scholastic timetable: creative ateliers for elementary school and laboratories for nets, addressed to people who do not work nor study, school friendly Laboratories and Fab Lab. A digital identity card will be introduced for each student and teachers, which will document their personal profiles and their paths of personal growth. The school administration must be digitalized, and also the class register have to be electronic; all the typologies of data related to every aspect of scholastic administration, formative offer and evaluation systems must, in addition be publicized online.

Competences are chosen in such a way that is possible to promote entrepreneurship among students and groups have been individuated at a supranational level in five macro areas: Information, Communication, Contents Creations, Security and Problem Solving. Those macro areas will be structured in different didactic paths, which will concern disciplines such as digital economy, communication, digital interaction, educative robotics, internet of things and digital storytelling.

All these formative and procedural innovations will be introduced taking into account the positive result of previously made experiences by the Ministry of Education of Hackathon on School and Contamination Labs, initiatives proposed with the scope to promote entrepreneurship among students.

II.4 QUEST III – Italy

This section briefly sketches the structure and the features of interest to our application of QUEST III – ITALY, a growth model developed by the General Direction for the Economic and Financial Affairs of the European Commission DG ECFIN with R&D, calibrated for Italy[6]. The endogenization of R&D and the determination of its impact on growth is actually done with relation to a concept of semi endogenous growth à la Jones (1995). The presentation of the model is mainly based on Ratto et al., (2008), Varga, In't Veld, (2009) and Roeger, W., Varga, J., In't Veld, J., (2013).

The economy is composed by different agents: households/workers, trade unions, final and intermediate goods firms, R&D sector, foreign sector, fiscal and monetary authorities. Two categories of households operate in the model. The non-liquidity constrained households (NLCH), also defined as Ricardian, operate on the financial markets, transacting on domestic and foreign financial capital, buy patents of projects produced by the R&D sector, sell licenses to the intermediate goods sector and supply medium and high skilled labour services. The liquidity-constrained households,

[6] An application for Italy. (Annicchiarico, B., Di Dio, F., Felici, F., 2013).

also called non-Ricardian households, whose behavior is limited to consume their disposable income and supply low skilled labour services (Galì and Gertler, 2007), give the second category.

For any typology of skill, it is assumed that both types of households offer differentiated work services to trade unions, which fix wages in labour markets, in monopolistic competition. Trade unions reunite incomes and distribute them in equal proportions among their members. In the model, there is a nominal rigidity in the fixation of wages assuming that households face adjusting costs to change wages.

Firms in the final goods sector produce differentiated goods that are imperfect substitutes for the internationally produced goods. Final goods producers use a set of intermediate and final goods and three categories of workers (low, medium and high skilled work). Firms operating in monopolistic competition à la Dixit, Stiglitz (1977), make up the intermediate goods sector. They produce intermediate products using rented capital inputs, using projects whose licenses are rent from households.

Production of new projects takes place in the R&D sector, employing high skilled workforce and using existing stock of foreign and domestic knowledge. The technological change is modeled as increasing variety of products (Romer, 1990). The capital accumulation is endogenized (Jones, 2005).

II.4.1 Households, liquidity constraints and first order conditions

In the model, utility optimizing agents and profit maximizing firms drive the economy. Agents are represented by a set $h \in [0,1]$ of households. The total amount of households is divided into two categories: the share $(1-\varepsilon)$ of non-liquidity constrained, NLC, households, also called the Ricardian-households, and the share ε of liquidity constrained, LC, households, the non-Ricardian households.

Non-liquidity constrained households maximize the following intertemporal utility function subject to various resources constraints, among which technological and institutional ones; in a context of imperfect information.

$$\underset{\left\{\begin{matrix} C_t^i, L_t^i, B_t^i \\ B_t^{F,i}, J_t^i, K_t^i \\ J_t^{A,j}, A_t^i, ucap_t^i \end{matrix}\right\}_{t=0}^{\infty}}{\text{Max}} \quad V_0^i = E_0 \sum_{t=0}^{\infty} \beta^t (U(C_t^i) + \sum_s V(1 - L_t^{i,s})) -$$

$$
-E_0 \sum_{t=0}^{\infty} \lambda_t^i \beta^t \begin{pmatrix} \left(1+t_t^c\right) P_t^C C_t^i + B_t^i + E_t B_t^{F,i} + P_t^I \left(J_t^i + \Gamma_J\left(J_t^i\right)\right) + P_t^A J_t^{A,i} \\ -\left(1+r_{t-1}\right) B_{t-1}^i - \left(1 + r_{t-1}^F - \Gamma_{B^F}\left(E_t B_{t-1}^F / Y_{t-1}\right)\right) E_t B_{t-1}^{F,i} \\ -\sum_s \left(1-t_t^{w,s}\right) W_t^{i,s} L_t^{i,s} - b_t^s W_t^{i,s} \left(1 - NPART_t^{i,s} - L_t^{i,s}\right) + \Gamma_W\left(W_t^{i,s}\right) \\ -\left(1-t_{t-1}^K\right)\left(i_{t-1}^K ucap_{t-1}^i - rp_{t-1}^K - \Gamma_U\left(ucap_{t-1}^i\right)\right) P_t^J K_{t-1}^i - t_{t-1}^K \delta^K P_t^I K_{t-1}^i - \tau^K P_t^I J_t^i \\ -\left(1-t_{t-1}^K\right)\left(i_{t-1}^A - rp_{t-1}^A\right) P_t^A A_{t-1}^i - t_{t-1}^K \delta^A P_t^A A_{t-1}^i - \tau^A P_t^A J_t^{A,i} \\ -TR_t^i - \sum_{j=1}^{n} PR_{j,t}^{f,i} - \sum_{j=1}^{A_t} PR_{j,t}^{x,i} \end{pmatrix} - \qquad (5)
$$

$$
-E_0 \sum_{t=0}^{\infty} \lambda_t^i \xi_t^i \beta^t \left(K_t^i - J_t^i - (1-\delta^K) K_{t-1}^i\right) - E_0 \sum_{t=0}^{\infty} \lambda_t^i \psi_t^i \beta^t \left(A_t^i - J_t^{A,i} - (1-\delta^A) A_{t-1}^i\right)
$$

$$
s \in \{M, H\}
$$

The main decision variables for each household, in each time-period *t*, are: C_t^i, consumption, L_t^i, labour supplied, (J_t^i), investments goods to be acquired or sold, K_t^i stock of rent physical capital, $J_t^{A,j}$ stock of new patents from R&D sector and A_t^i licenses for already existing ones. The variable, which refers to the value of depreciation of capital, is $ucap_t^i$.

Variables W_t^i and $b_t^s W_t^{i,s}$ are related to the labour market, being respectively wage income and unemployment subsidies, together with NPART, non-participation rate, a policy variable linked to the benefit system.

Other relevant variables are B_t^i and $B_t^{F,j}$ which deal with the financial sector and representing respectively domestic and foreign financial assets. Finally, TR_t^i defines transfers from government, i_t, i_t^K, i_t^A interest income and P_t is the price of final goods in domestic firms.

The non-liquidity households are the owners of all the firms that operate in the economy and share the total profit of both the intermediate $\sum_{j=1}^{A_t} PR_{j,t}^{x,i}$ and final goods firms $\sum_{j=1}^{n} PR_{j,t}^{f,i}$.

After having analyzed the main variables which make up the constrained part of the Lagrangian of the households in eq.(5) we consider the structure of the utility function. The utility function in eq.(5) is additively separable in consumption (C_t^i) and leisure ($1 - L_t^{i,s}$). For consumption, a logarithmic functional form with "external habit persistence" effect has been used:

$$U(C_t^i) = (1 - habc)\log(C_t^i - habcC_{t-1}) \qquad (6a)$$

The external habit persistence parameter (*habc)* evaluates the friction related to the external habit persistence (Abel 1990). Habits are treated as external to the consumer. When habits are external, the stock of habits depends on the history of aggregate past consumption, C_{t-1}, as opposed to the consumer's own past consumption, C^i_{t-1}.

Leisure has been modelled according to the following equation:

$$V(1 - L_t^{i,s}) = \frac{\omega_s}{1-\kappa}(1 - L_t^{i,s})^{1-\kappa} \quad \text{with } \kappa > 0 \qquad (6b)$$

where ω_s measures the specific weight for each ability on leisure and κ is the elasticity of labour supply.

Besides the "external habit persistence" a further friction, introduced in the model, relates to investment decisions, capacity of utilization and wages and is given by the convex adjusting costs hypothesis *a là Rotemberg* (1982). Such a hypothesis is modelled by the following three different equations:

$$\Gamma_J(J_t^i) = \frac{\gamma_K (J_t^i)^2}{2K_{t-1}^i} + \frac{\gamma_I}{2}(\Delta J_t^i)^2 \qquad (7)$$

$$\Gamma_U(ucap_t^i) = a_1(ucap_t^i - ucap_t^{ss}) + a_2(ucap_t^i - ucap_t^{ss})^2 \qquad (8)$$

$$\Gamma_W(W_t^{i,s}) = \sum_s \frac{\gamma_W L_t^{i,s}}{2}\frac{\Delta W_t^{i,s^2}}{W_{t-1}^{i,s}} \qquad (9)$$

where $\Gamma_J(J_t^i)$ are the convex adjustment costs for investment, $\Gamma_U(ucap_t^i)$ for capacity of utilization and $\Gamma_W(W_t^{i,s})$ for wages and $ucap_t^{ss}$ is the capacity used in steady state. Deriving the Lagrangian we obtain the following First Order Conditions FOC:

$$\frac{\partial V_0}{\partial C_t^i} \Rightarrow U_{C,t}^i - \lambda_t^i(1 + t_t^c)P_t^C = 0 \qquad (10a)$$

$$\frac{\partial V_0}{\partial B_t^i} \Rightarrow -\lambda_t^i + E_t(\lambda_{t+1}^i \beta(1 + r_t)) = 0 \qquad (10b)$$

$$\frac{\partial V_0}{\partial B_t^{F,i}} \Rightarrow -\lambda_t^i + E_t(\lambda_{t+1}^i \beta(1 + r_t^F - \Gamma_{B^F}(E_t B_t^F / Y_t)) E_{t+1} / E_t) = 0 \tag{10c}$$

$$\frac{\partial V_0}{\partial K_t^i} \Rightarrow -\lambda_t^i \xi_t^i + E_t(\lambda_{t+1}^i \xi_{t+1}^i \beta(1-\delta) + \lambda_{t+1}^i \beta((1-t_t^K)(i_t^K ucap_t^i - rp_t^K - \Gamma_u(ucap_t^i)) + t_t^K \delta^K) P_{t+1}^C) = 0 \tag{10d}$$

$$\frac{\partial V_0}{\partial J_t^i} \Rightarrow -\lambda_t^i P_t^C (1 + \gamma_K (\frac{J_t^i}{K_{t-1}^i}) + \gamma_I \Delta J_t^i - \tau^K) + E_t(\lambda_{t+1}^i \beta P_{t+1}^C \gamma_I \Delta J_{t+1}^i) + \lambda_t^i \xi_t^i = 0 \tag{10e}$$

$$\frac{\partial V_0}{\partial ucap_t^i} \Rightarrow i_t^K - a_1 - 2a_2(ucap_t^i - ucap_t^{ss}) = 0. \tag{10f}$$

$$\frac{\partial V_0}{\partial A_t^i} \Rightarrow -\lambda_t^i \psi_t^i + E_t(\lambda_{t+1}^i \psi_{t+1}^i \beta(1-\delta^A) + \lambda_{t+1}^i \beta((1-t_t^K)(i_t^A - rp_t^A) + t_t^K \delta^A) P_{t+1}^A) = 0 \tag{10g}$$

$$\frac{\partial V_0}{\partial J_t^{A,i}} \Rightarrow -\lambda_t^i P_t^A (1 - \tau^A) + \lambda_t^i \psi_t^i = 0 \tag{10h}$$

where eq.(10a) indicates the derivative of utility function with respect to consumption. Eq. (10b) and eq. (10c) show the derivative with respect to domestic and foreign financial assets, eq. (10d) the derivative with respect to capital, eq.(10e) with respect to investment, eq. (10f) with respect to capacity of utilization, eq.(10g) with respect to intangible capital and eq.(10h) with respect to R&D investments.

From the eq. (10e) it is possible to express investment as function of Q_t as follows:

$$Q_t - 1 = \gamma_K (\frac{J_t^i}{K_{t-1}^i}) + \gamma_I \Delta J_t^i - \tau^K - E_t(\frac{\gamma_I \Delta J_{t+1}^i}{1 + i_t - \pi_{t+1}^C}) \quad \text{with } Q_t = \frac{\xi_t}{P_t^C} \tag{11a}$$

where Q_t is defined as the discounted actual value of the rental rate of investment in real assets, which, taking into consideration also eq.(10e) becomes:

$$Q_t = E_t(\frac{1-\delta}{1 + i_t - \pi_{t+1}^C} Q_{t+1} + \frac{(1-t_t^K)(i_t^K ucap_t^i - rp_t^K - \Gamma_u(ucap_t^i)) + t_t^K \delta^K}{1 + i_t - \pi_{t+1}^C}) \tag{11b}$$

with t_t^K defined as capital income taxes on tangible and intangible assets paid by households, and τ^A defined as depreciation allowances received.

Non-liquidity constrained households represent the other share of households. Their consumption in real terms, in each time-period is given by:

$$(1 + t_t^c) P_t^C C_t^k + \sum_s \frac{\gamma_W L_t^{k,s}}{2} \frac{\Delta W_t^{k,s^2}}{W_{t-1}^{k,s}} = \sum_s ((1 - t_t^{w,s}) W_t^{k,s} L_t^{k,s} + b_t^s W_t^{k,s} (1 - NPART_t^{k,s} - L_t^{k,s})) + TR_t^k \tag{12}$$

that is wage income net to taxation plus net transfers.

The bargaining in the labour market is regulated by trade unions which fixes the wage mark up on the reserve wage $1/\eta_t^W$ linked to each skill group with the aim to the maximization of household's expected utility, taking into consideration firms' labour demand as follows:

$$\eta_t^w = 1 - 1/\sigma_s - \gamma_W / \sigma_s \left[\beta (sfw\ \pi_{t+1}^w - (1 - sfw)\pi_{t-1}^w) - \pi_t^w\right] \tag{13}$$

Different skill categories supply labour services which are imperfect substitutes across the various skill groups, taking into consideration that constant elasticity of substitution σ_s determines the degree of market power: a lower elasticity of substitution means a higher markup and a lower level of occupation.

Mark-up is subjected to large fluctuations for two main factors: convex adjustment costs of wages and the indexation by a fraction (1-sfw) of workers, of the growth rate of wages to the inflation rate of the previous period. Convex adjustment costs of wages cause large fluctuations in the value of mark-up. The eq. (13) shows that a fraction (1-sfw) of workers indexes the growth rate of wages π^W to the inflation of wage in the previous period, π_{t-1}^w. The wage equation is given by:

.

$$\frac{U_{1-L,t}^{h,s}}{U_{C,t}^{h}} \frac{1}{\eta_t^W} = \frac{W_t^s (1 - t_t^{w,s} - b_t^s)}{(1 + t_t^C) P_t^C} \qquad \text{for } h \in \{i,k\} \text{ e } s \in \{L, M, H\} \tag{13}$$

The left side of the equation is given by the marginal utility of leisure divided for the corresponding marginal utility of consumption (reservation wage) multiplied for the wage mark up. On the right side of the equation the gross wage is adjusted for the labour taxes $t_t^{w,s}$, consumption taxes t_t^C and unemployment benefits b_t^s.

II.4.2 Production, Research and Human Capital

Final goods sector is made up by firms in monopolistic competition. The technology used by the j[th] firm is of Cobb Douglas type:

$$Y_t = A_t^{(1-\alpha)(\frac{1}{\theta}-1)} (K_t^P)^{1-\alpha} (L_{Y,t})^{\alpha} (K_t^G)^{\alpha_G} - FC_Y, \qquad \text{where } \sum_{i=1}^{A_t} x_{i,t} = K_t^P \tag{17}$$

Where $L_{Y,t}$ represents the labour aggregate, $x_{i,t}$ the intermediate goods and, subjected FC_Y the fixed costs. Investment in stock of public capital (K_t^G) increases TFP according the exponent α_G.

Final output (Y_t) is produced using A_t, variety of intermediate inputs, with an elasticity of substitution $1/(1-\theta)$.

The investment in public infrastructures (I_t^G) accumulates in the public capital stock K^G following:

$$K^G = (1-\delta_G)K_{t-1}^G + I_t^G \tag{18}$$

where δ_G, is the depreciation rate of public capital.

Another relevant agent is represented by the intermediate sector. It operates in the monopolistic competition buying licenses for projects from domestic households and paying an initial payment of FC_A.

Profit maximization of intermediate goods firms is given as:

$$PR_{i,t}^x = \max_{xi,t} \left\{ px_{i,t}x_{i,t} - i_t^K P_t^C k_{i,t} - i^A P_t^A - FC_A \right\} \tag{20}$$

where

$$px_{i,t} = \eta_t(1-\alpha)Y(\sum_{i=1}^{A_t}(x_{i,t}^j)^\theta)^{-1}(x_{i,t})^{\theta-1} \tag{19}$$

with η_t defined as the inverse of the mark –up of the final goods sector, and i_t^K the rental rate of capital inputs. In eq. (20) technology is linear so a unity of effective capital ($k_i \cdot ucap$) is simply converted into a unity of intermediate good $x_i = k_i$.

R&D sector is the sector where the endogenous growth process takes place. It can be represented by a university or a research center and workers employed within the sector, only high skilled ones $L_{A,t}$, have the task to invent new projects.

The knowledge production function assumes the following form:

$$\Delta A_t = \nu A_{f,t-1}^{*\varpi} A_{d,t-1}^{\phi} L_{A,t}^{\lambda} \tag{23}$$

Where the production of new ideas ΔA_t depends on the aggregate international $A_{f,t-1}^*$ and domestic $A_{d,t-1}^\phi$ already existing ideas, in time period t-1.

Parameters ϖ and ϕ give the size of respectively foreign and domestic spillover effects of ideas. When the level of knowledge is so high to enhance innovation, the phenomenon of "fishing out" takes place and the two parameters assume values less than zero. On the contrary, a situation of "standing on shoulders" occur when the level of existing knowledge facilitates the innovation, and so the endogenous growth process; in this case values of the spillovers parameters are higher than zero.

The condition of fully endogenous growth in relation to the domestic level of knowledge, characterized by strong scale effect, can be reached under the assumption $\phi = 1$. Finally, the parameter ν is the total factor efficiency of R&D production, and λ represents the elasticity of R&D production to the number of researchers (L_A).

The function of discounted profit flow to be maximized by R&D sector is:

$$\max_{L_{A,t}} \sum_{t=0}^{\infty} d_t \left(P_t^A \Delta A_t - W_t^H L_{A,t} - \frac{\gamma_A}{2} W_t^H \Delta L_{A,t}^2 \right) \tag{24}$$

where W^H is the wage of high skilled workers that is subjected to convex adjustment costs which makes expensive for the research institute to hire high skilled workers. From the FOC with respect to $L_{A,t}$ we obtain:

$$\lambda P_t^A \frac{\Delta A_t}{L_{A,t}} = W_t^H + \gamma_A (W_t^H \Delta L_{A,t} - d_t W_{t+1}^H \Delta L_{A,t+1}) \tag{25}$$

where d_t is the discount factor.

As pointed out in the previous paragraph, households own all the firms that operate in the economy and also workers. The category of households gives a clue on which is the skill of the worker. In fact, non-liquidity constrained household perform only high and medium skills tasks, while liquidity constrained households can fulfill only low skilled tasks. The three typologies of skills are aggregate following:

$$L_{Y,t} = \left[s_L^{\frac{1}{\sigma_L}} \left(h_t^L L_t^L \right)^{\frac{\sigma_L - 1}{\sigma_L}} + s_M^{\frac{1}{\sigma_L}} \left(h_t^M L_t^M \right)^{\frac{\sigma_L - 1}{\sigma_L}} + s_{H,Y}^{\frac{1}{\sigma_L}} \left(h_t^H L_t^{HY} \right)^{\frac{\sigma_L - 1}{\sigma_L}} \right]^{\frac{\sigma_L}{\sigma_L - 1}} \tag{26}$$

with $s \in \{s_L, s_M, s_H\}$ defined as the share of population employed in the corresponding skill category. In eq.(26), L^s measures the employment rate of agents s , σ_L is the elasticity of substitution among the different types of labour, and $h_t^s = h_s e^{\psi \Lambda_t^s}$, with $\psi > 0$, measures, in units of efficiency, the corresponding accumulated human capital, where Λ_t^s represents the amount of time devoted to human capital accumulation, which can be approximated by the number of school years, (OECD,2006) and parameter ψ corresponds to a return to schooling estimated by Mincer (1974) .

The exponential functional form is suitable to describe the evolution of human capital with respect to skill, (Jones, 2005).

Final and investment goods are traded in the foreign sector that is completely exogenous. Importers and exporters firms operate in monopolistic competition and require an entry cost for the imported goods, a markup.

The following Taylor rule describes the monetary policy:

$$i_t = \tau_{lag} i_{t-1} + (1 - \tau_{lag})\left[r^{eq} + \pi_t^T + \tau_\pi \left(\pi_t - \pi_t^T\right) + \tau_y ygap_t\right]$$

where i_t is the interest rate, π_t the inflation, $ygap_t$ is the output gap, i.e. the variation of capital and labour utilization trends from the long run benchmark.

With reference to the other variables: r^{eq} is the real interest rate in the long time horizon, π_t^T is the benchmark for inflation, (i.e. inflation target), τ_{lag} is a parameter used for the smoothing and τ_π and τ_y are policy parameters which have the task to manage the reactions of the interest rate to variations in inflation and output gap. For the actuation of this mechanism the equation permits a relevant degree of inertia of the interest rate. Finally, the government budget constraint reads as:

$$B_t = (1 + r_t) B_{t-1} + P_t^C G_t + P_t^C IG_t + TR_t + BEN_t + S_t - R_t^G - T^{LS}{}_t \qquad (29)$$

where $T^{LS}{}_t$ and R_t^G represent Government entries, respectively lump sum taxes and taxes on consumption, tangible and intangible capital and labour income net of tax credits and tax allowances. Note that tax credits and tax allowances made up the system of subsidies of the government S_t to physical capital and R&D investments.

Government expenditure is represented by public consumption G_t, public investment IG_t; B_t represents the public debt, TR_t and BEN_t are, respectively, government transfers and unemployment benefits paid to households, the latest are indexed to wages.

II.4.3 Parametrization and simulation experiments

The computing package used to implement QUEST III is Dynare running in Matlab. QUEST III model is calibrated on quarterly basis with the aim to harmonize the steady state ratios with the specific characteristics of the Italian economy in 2007 also taking into account the estimates of the basic QUEST III (Ratto et al., 2009). In the Table II.4.3.1 (see D'Auria et al., 2009) the parametrization of the version of QUEST which accounts for specific characteristics of Italy in comparison to the parametrization for EU, (Roeger et al., 2008; Roger and In't Veld, 2009, 2010) which is considered the reference country.

The first section of Table 2.4.1 is related to households and labour market.

The total employment rate of Italy is fixed to 63% a lower percentage value in consideration to EU value of 69%. In relation to labour, it is possible to identify the three skill categories highlighted in the previous paragraphs. Low skill category includes all the workers at secondary level education, to the high skilled labour category belong all the workers at third level education in science and technology, while medium skill labour represents the residual category.

In QUEST III-Italy the share of low skilled workers s_L, which corresponds to the share of liquidity constrained households, ε, is represented by the 50% of workforce, and it is the highest share of labour-force, while high skilled workers constitute only the 3%. QUEST III-EU performs a lower share of low skilled workers, $\varepsilon = s_L = 35\%$, and a higher share, with respect to Italy, of high skilled labour $s_H = 6\%$, even if this share remains low. The rate of low skilled employment is 52%, while the rate of employment of high skilled workers is of 81%.

In QUEST III-Italy the elasticity of substitution among labour inputs is 1.22, that means a high wage mark-up for insiders in the labour market. In this model, high skilled workers are not encouraged to acquire a higher education level, the skill premium of high skilled workers on medium skilled workers is, in fact, 37%, a very low percentage, if we consider the EU level of 50%.

The second section of Table 2.4.1 shows the parametrization of final goods sector, a sector of services, and intermediate goods sector, the manufacturer sector. Consistently with Christopoulou and Vermeulen, (2008) who argue that in general markup in services is higher than in manufacture; the net markup in the final goods sector is more than 20%, nearly twice of that reported for intermediate goods sector.

In the model for Italy there are high fixed entry costs, FC_a and FC_y, due to the strict regulation which can represent obstacles for productivity growth and accumulation of capital.

	Model notation	Italy	EU	Source
Households and labour market				
Share of liquidity constrained	s_{LC}	0.5	0.35	EUROSTAT
Share of non liquidity constrained	s_{NLC}	0.5	0.65	EUROSTAT
Habit persistence on consumption	*habc*	0.7	0.7	QUEST III - estimates
Preference parameter on leisure	κ	5	4	Calibration
Population share of low-skilled	s_L	0.5	0.35	EUROSTAT
Population share of medium-skilled	s_M	0.47	0.59	EUROSTAT
Population share of high-skilled	s_H	0.03	0.06	EUROSTAT
Employment, low skilled	L_L	0.52	0.57	EUROSTAT
Employment, medium skilled	L_M	0.74	0.74	EUROSTAT
Employment, high skilled	L_H	0.81	0.84	EUROSTAT
Employment rate	L	0.63	0.69	EUROSTAT
Skill elasticity of substitution	σ_L	2	1.4	Katz and Murphy (1992)
Wage premium, high v. medium (%)		37	50	EUROSTAT
Wage premium, medium v. low (%)		27	24	EUROSTAT
Benefit replacement rate		0.4	0.4	Estimates
Final and intermediate goods sectors				
Net markup (%)	final $\mathbf{MU}_P - 1$	21	24	EUKLEMS
Net markup (%)	intermediate $\mathbf{MU}_{PX} - 1$	10	12	EUKLEMS
Depreciation rate, tangible capital (%)	δ_K	1.5	1.5	Calibration
Fixed entry costs, final sector	FC_Y	0.15	0.1	Calibration
Fixed entry costs, intermediate sector	FC_A	0.45	0.38	Djankov et al. (2002)
Overhead labour (%)	FC_L	1.17	3.94	Calibration
R&D sector				
Elasticity of R&D wrt labour	Λ	0.37	0.73	Bottazzi and Peri (2007)
Elasticity of R&D wrt domestic ideas	Φ	0.64	0.53	Bottazzi and Peri (2007)
Elasticity of R&D wrt foreign ideas	Π	0.34	0.45	Bottazzi and Peri (2007)
R&D efficiency	N	0.2	0.35	Calibration-implied
Taxes, public spending and public debt				
Labour tax (%)	t^L	51	34	Calibration
Tax rate on tangible capital income (%)	t^K	33	45	Warda (2006)
Consumption tax (%)	t^C	17	17	EC
Transfers (% GDP)		27	16	EUROSTAT
Government consumption (% GDP)		20	18	Calibration

Table II.4.3.1: QUEST III with R&D – Calibration for Italy and the EU
Source: Annicchiarico,B., Di Dio, F., Felici, F.,(2013)

For what concerns R&D sector, Italian economy gives only a weak contribution to the knowledge creation process. Bottazzi and Peri (2007) in their study based on Jones,(1995, 2005) estimate the value of 0.37 for the parameter of contribution of labour to knowledge creation in R&D, Λ, much lower than the European value of 0.73; moreover the intensity of R&D is 1.10% (1.84% for EU).

In conclusion, the last section of Table II.4.3.1 is devoted to fiscal system, public spending and public debt. It emerges an environment characterized by high taxation on labour income (51%) and high share of transfers with respect to GDP, (27%)

On the contrary, the tax rate on tangible capital lies under the QUEST III-EU value. The type of performance of QUEST III Italy can be caught by the simulation of the results of two issues of political economy somehow preliminary to the application that we want to develop.

II.4.4 Preliminary Results

Before the analysis of the outcomes of the measures linked to the National Plan *Industria 4.0* we would like to give a preliminary evaluation to the simulations that regard fiscal policy and total factor productivity TFP. The simulation called SIM_G1 requires a simple measure, which consists in an increase of public expenditure of 1% not financed by taxation.

Results are shown in Table II.4.4.1 for the first 20 quarters and in Figure II.4.4.1 in graphical form. The last three columns are referred to real data, in levels, in millions of euro, as reported by Istat, 2017 and applying the variation rate with respect to baseline. As shown in the first column of the Table II.4.4.1 the effect on production, in terms of percent variation with respect to the initial steady state, is positive and more pronounced in the quarters of the initial year and it is of 0.357% in the second quarter, 0.357% in the third and 0.195% in the fourth. In the third quarter of the second year it reaches the minimum with a value of 0.141%, from this moment a recovery of GDP starts and it reaches the 0.274 in the fourth quarter of the fifth year.

The trend of consumption, IT_C, represented in the second column of the same Table gives negative percent changes with respect to the initial steady state. This is because consumption expenditure is the result of the sum of two components. The consumption of liquidity constrained households IT_CLC and consumption of non-liquidity constrained households. In relation with the consumption of non-liquidity constrained households, IT_CNLC, given the fact that they are forward looking, they expect that the increase of public expenditure is permanent. Therefore, they assume that it will be financed by means of taxation and, for that reason; this type of operators will adjust themselves to this expectation, crowding out the present consumption.

	IT_Y	**IT_C**	**IT_CNLC**	**IT_CLC**	**IT_I**	**IT_E**	**IT_EL**	**IT_EM**	**IT_EH**	**IT_B/Y**	**Y** (level)	**C** (level)	**I** (level)
							Initial Year						
1° Q	0	0	0	0	0	0	0	0	0	0	395,783	238,563	68,602
2° Q	0.356	-0.266	-0.379	-0.011	-0.020	0.155	0.142	0.158	0.100	-0.235	397,194	237,928	68,588
3° Q	0.256	-0.482	-0.644	-0.144	-0.034	0.198	0.186	0.194	0.075	-0.054	396,798	237,411	68,578
4° Q	0.195	-0.645	-0.821	-0.312	-0.041	0.197	0.191	0.181	0.010	0.139	396,556	237,023	68,574
							2° Year						
1°Q	0.161	-0.761	-0.934	-0.478	-0.041	0.182	0.183	0.154	-0.056	0.312	396,423	236,746	68,574
2° Q	0.146	-0.842	-1.004	-0.628	-0.036	0.167	0.174	0.126	-0.112	0.456	396,361	236,554	68,577
3° Q	0.141	-0.896	-1.046	-0.759	-0.026	0.156	0.167	0.104	-0.154	0.572	396,342	236,425	68,584
4° Q	0.143	-0.932	-1.069	-0.872	-0.015	0.150	0.164	0.086	-0.184	0.665	396,349	236,339	68,592
							3° Year						
1° Q	0.148	-0.955	-1.080	-0.971	-0.002	0.148	0.163	0.073	-0.205	0.739	396,372	236,283	68,601
2° Q	0.156	-0.970	-1.085	-1.057	0.012	0.149	0.165	0.063	-0.220	0.799	396,404	236,247	68,610
3° Q	0.166	-0.980	-1.085	-1.134	0.026	0.152	0.168	0.056	-0.230	0.848	396,441	236,225	68,620
4° Q	0.176	-0.984	-1.082	-1.202	0.041	0.156	0.172	0.051	-0.238	0.887	396,482	236,214	68,631
							4° Year						
1° Q	0.187	-0.986	-1.078	-1.262	0.057	0.162	0.176	0.047	-0.244	0.918	396,525	236,210	68,641
2° Q	0.199	-0.985	-1.073	-1.316	0.072	0.168	0.181	0.044	-0.250	0.942	396,571	236,212	68,652
3° Q	0.210	-0.982	-1.067	-1.363	0.087	0.174	0.861	0.041	-0.256	0.960	396,618	236,218	68,662
4° Q	0.223	-0.978	-1.062	-1.405	0.102	0.180	0.190	0.039	-0.262	0.972	396,666	236,229	68,672
							5° Year						
1° Q	0.235	-0.972	-1.056	-1.442	0.117	0.187	0.195	0.037	-0.268	0.980	396,715	236,243	68,683
2°Q	0.248	-0.965	-1.050	-1.475	0.132	0.194	0.199	0.035	-0.275	0.983	396,765	236,260	68,693
3° Q	0.261	-0.957	-1.045	-1.502	0.147	0.201	0.204	0.034	-0.282	0.983	396,816	236,280	68,703
4° Q	0.274	-0.947	-1.040	-1.526	0.161	0.207	0.208	0.032	-0.289	0.978	396,868	236,302	68,713

Table II.4.4.1: Results of simulation SIM_G1 in numerical form
(percent changes w.r.t.baseline and levels[7], quarterly results)

Following to an increase in GDP, we could expect an increase in consumption of liquidity-constrained households, IT_CLC, but that happens because of the decrease of transfers and of an increase of lump sum taxes which give rise to a decrease of the expenses in consumption, even if in a lower way than the IT_CNLC. Disabling the dummy for the variable tax (Taxdum) we obtain net effects of an increase of the public expense of 1% on IT_CLC.

The dummy tax is an automatic stabilizer that, when active lead to the non – liquidity constrained households to cover all the public debt (taxes are regressive), if it is disabled (its value is equal to zero) public debt is not covered and both consumption of non-liquidity constrained and liquidity constrained households continue to diminish compressing the economic growth.

[7] Data in millions of euros

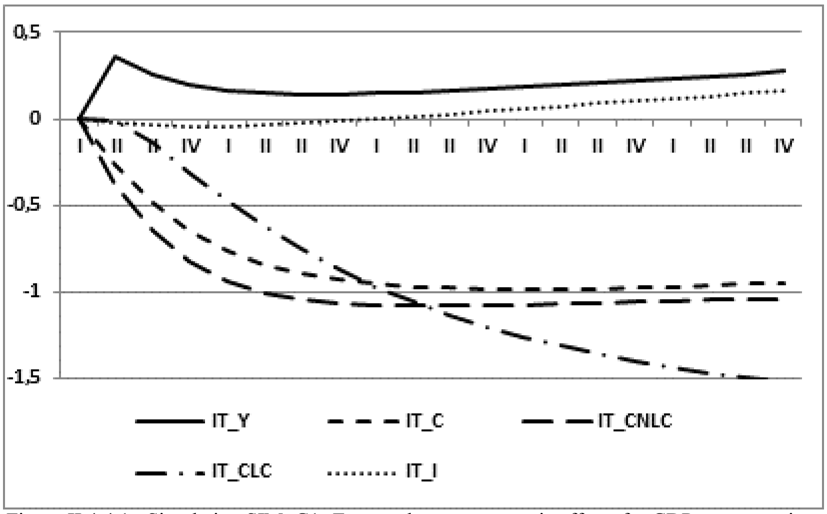

Figure II.4.4.1: Simulation SIM_G1- Expected macroeconomic effects for GDP, consumption, investment, (percent changes w.r.t. baseline, quarterly results)

In relation to investments, showed in the fifth column of Table II.4.4.1, they exhibit negative rates of variation with respect to the initial steady state. That result is linked to the Tobin's Q, which takes values lower than 1 until the 14th period and then it again establishes on values slightly higher than 1%. From the third quarter of the third year, also investments slightly increase.

For what concerns data in levels, the trend of GDP is increasing, and the decreasing trend of consumption and investment expenditure confirms the crowding out effect, due to high public expenditure. In fact, only in the fourth period, the trend begins to increase. The last three columns of the Table show results for income levels of the consumption expenditure and investment applying growth rates simulated equal to initial values registered by quarterly data reported in Istat for 2017, (Istat, 2017).

A second simulation regards the macroeconomic effects of a change in total factor productivity TFP. The simulation called SIM_A1 considers a productivity shock of 1% on the exogenous component of productivity included in the final good production function. As shown in the Table II.4.4.2 there are positive permanent effects on the change of GDP, Y, on consumption, C and investment, I. The effect of the shock on output is rather wide for the response of the endogenous R&D to the productivity shock.

	Y	C	I	L	B/Y
			Initial Year		
1° Q	0	0	0	0	0
2° Q	0.727	0.320	0.144	-0.137	-0.699
3° Q	0.977	0.491	0.277	-0.124	-0.718
4° Q	1.130	0.641	0.391	-0.066	-0.788
			2° Year		
1° Q	1.230	0.761	0.487	-0.004	-0.870
2° Q	1.296	0.852	0.565	0.046	-0.946
3° Q	1.339	0.921	0.629	0.082	-1.009
4° Q	1.368	0.972	0.680	0.104	-1.060
			3° Year		
1° Q	1.386	1.010	0.720	0.115	-1.098
2° Q	1.397	1.038	0.751	0.117	-1.126
3° Q	1.403	1.060	0.776	0.113	-1.145
4° Q	1.406	1.076	0.795	0.104	-1.156
			4° Year		
1° Q	1.406	1.088	0.808	0.092	-1.161
2° Q	1.405	1.098	0.819	0.074	-1.161
3° Q	1.404	1.105	0.826	0.064	-1.155
4° Q	1.401	1.110	0.831	0.050	-1.146
			5° Year		
1° Q	1.399	1.114	0.834	0.035	-1.132
2° Q	1.397	1.117	0.837	0.021	-1.116
3° Q	1.395	1.119	0.838	0.008	-1.097
4° Q	1.394	1.120	0.839	-0.003	-1.076

Table II.4.4.2: Simulation SIM_A1 – Expected macroeconomic effects for GDP, consumption, investment, employment, public debt/GDP ratio (percent change w.r.t. baseline, quarterly results)

The channel of this magnification is the intermediate sector in which new firms enter, which hence require more patents (this activates R&D sector) and creates higher output of intermediate goods (higher variety of intermediate goods) which are bought by the firm and this leads to a higher final output. The increase of the efficiency level of labour has a positive permanent effect on GDP, higher than that of a standard neoclassical growth model.

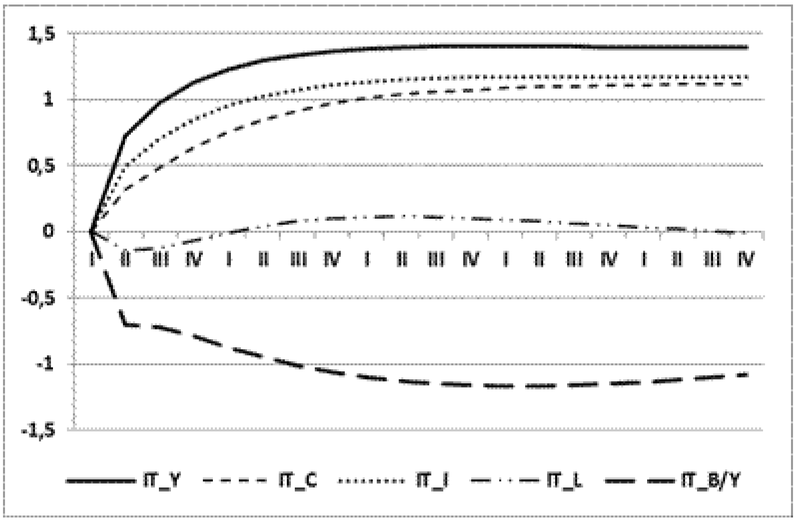

Figure II.4.4.2: Simulation SIM_A1 – Expected macroeconomic effects for GDP, consumption, investment, employment, public debt/GDP ratio (percent changes w.r.t. baseline, quarterly results)

The model generates a wider GDP effect in presence of an endogenous reaction of endogenous R&D to the TFP shock in the final goods sector. The increased demand of investment goods stimulates the entry of firms in the intermediate goods production sector. This mechanism increases the capital efficiency. Technological progress has a negative impact on the growth rate of employment, L, as shown by the fifth column of Table II.4.4.2 in the long run, because of price rigidities which leads firms to not fully adjust price to marginal cost (externality of demand). As price does not decline, firms have a fall in the demand, given the new level of productive capacity and find benefits in reducing employment. In the medium run, the effect is positive because the productive capacity increases, hence there is new employment. In the long run, the change of labour with respect to the initial steady state is negative because most productive workers substitute labour with leisure.

II.5 Simulation experiments for *Industria 4.0*

II.5.1 *Industria 4.0: Innovative investments*

The measures in *Industria 4.0* established in the Balance Law 2017 consist, in two lines of actions referred, on one side to "Innovative Investments", on the other side to the "Skills Achievement" anticipated in National Plan for Digital School (PNSD). In this Section, we would like to provide, through QUEST III Italy, an evaluation of the potential macroeconomic impact of the first line of actions, leaving to the next paragraph the evaluation of interventions *Industria 4.0: Skills Achievement* related to PNSD.

NUMBER OF SCENARIO	CORRESPONDING GOV. MEASURE	DESCRIPTION
1	SKILLS ACHIEVEMENT (LH)	Shift of 200.000 low skilled workers tasks to high skill tasks, 0.5% public expenditure w.r.t.GDP
2	SKILLS ACHIEVEMENT (LM)	Shift of 200.000 low skilled workers to medium skilled tasks, 0.5% public expenditure w.r.t.GDP
3	SKILLS ACHIEVEMENT (LMH)	Shift of 200.000 low skilled workers: 100.000 to medium skilled and 100.000 high skilled tasks, 0.5% public expenditure w.r.t. GDP
4	INNOVATIVE INVESTMENTS	Productivity shock of 0,43% in five years due to major investments in physical capital (R&D) in 2017-2018
		Decrease of taxes on capital rents equal to 4.2 per cent of GDP in 2017 and 1.3 of GDP in 2018
		Reduction of labour taxes for low income workers equal to 0.02 per cent of GDP

Table II.5.1.1: Synthesis of the four scenarios quantifying
the Governmment Measures "Industria 4.0"

The total fiscal burden of the measures belonging to the category "Innovative Investment" is equal to 83% of the designated funds for "Industria 4.0" quantified in 15 billions of euros. Interventions included in the analysis are referred to hyper - depreciation, extension of super-depreciation for a year, empowerment of tax credit for activities of R&D ad activities related to productivity award and firm welfare.

In the model, this hypothesis has been introduced in the simulation of the fourth scenario in Table II.5.1.1 (SimIND17), through: i) a decrease of taxes on capital rents equal to 4.2 per cent of GDP in 2017 and 1.3 of GDP in 2018; ii) a reduction of labour taxes for low income workers equal to 0.02 per cent of GDP in relation to productivity award and firm welfare. These measures, that create a fiscal saving for firms and have effect on several following years, are assumed as related only to investments made in 2017 and in 2018.

In the same simulation, it is also suggested a shock on total factor productivity (TFP), as consequence of major investments in physical capital and intangible capital (R&D) obtained in 2017-2018 equal to 0.43 per cent in five years[8]. When building the simulation experiment, we take the estimate contained in Griffith et al. (2004). In his paper the aim was to detect the two possible functions of R&D, as direct determinant of rate of innovation and as a mean to increase the absorptive capacity of the industry. To this aim he regresses the R&D intensity in levels to capture the effect on innovation.

[8] The long run of simulation consists in 1100 quarters,but, since from the structure of the model then converge to zero at 1100, actually the real long run is considered until 2031 (14 years, 56 quarters).

	2017	2018	2019	2020	2025	Long run 2031
IT_Y(4)	0.231	0.214	0.309	0.475	0.712	0.735
IT_C(4)	-0.038	-0.629	-0.567	-0.233	0.590	0.742
IT_I(4)	0.364	0.730	0.726	0.714	0.590	0.497
IT_E(4)	0.134	0.105	0.060	0.084	0.009	-0.041
IT_WL(4)	-0.028	-0.107	-0.143	-0.123	0.156	0.319
IT_WM(4)	0.035	0.095	0.117	0.133	0.203	0.300
IT_WH(4)	0.064	0.164	0.185	0.196	0.234	0.317

Table II.5.1.2: GDP, total consumption, investments, total employment, low skilled, medium skilled and high skilled employment in the fourth scenario[9]
(percent changes w.r.t. baseline, yearly results)

The results is obtained interacting the R&D intensity with the TFP measure to control for cross country differences in hours worked (so the coefficient 0.43 is obtained); and it shows the fact that R&D generates, directly, innovation, moreover an interaction with relative TFP facilitates the adoption of new technologies. (Griffith et al., 2004).

To the aim of quantifying positive effects on productivity deriving from the accumulated knowledge following an increase in productive activity, we considered an estimate of the so-called *learning by doing,* as intended by Romer (1986). The increase of additional resources for new investments, are assumed to yield an increase of TFP, with respect to basic scenario, equal to 0.43 per cent in five years.

The yearly macroeconomic effect of these measures is registered in Table II.5.1.2 in terms of percent deviation with respect to steady state[10]. These interventions would generate a medium annual increase of GDP in two years 2017-2018 equal to 0.214 percentage points. In the long run the growth rate of GDP with respect to baseline is equal to 0.735 of the initial level.

[9] See Table II.5.1.1 for the description of scenarios
[10] Annual data are computed as mean of quarterly data

Figure II.5.1.1: SIM_IND17-GDP, consumption expenditure and investments expenditure in the fourth scenario (percent changes w.r.t. baseline, quarterly results)

The fiscal stimulus, although temporary, translates itself in a medium increase of investment equal to 0.730 per cent, increasing in that way the structural endowment of the capital stock and determining expansive effects in the following years.

As shown in Figure II.5.1.1, Investments increase significantly since marginal productivity of capital increases and such effect is relevant. On the other hand consumption expenditure decreases of 0.629% and shows a gradual recover which is effective in four years, then coming to assume positive values in 2021 to reach the value of 0.590% in 2025 and 0.742% in the longer run.

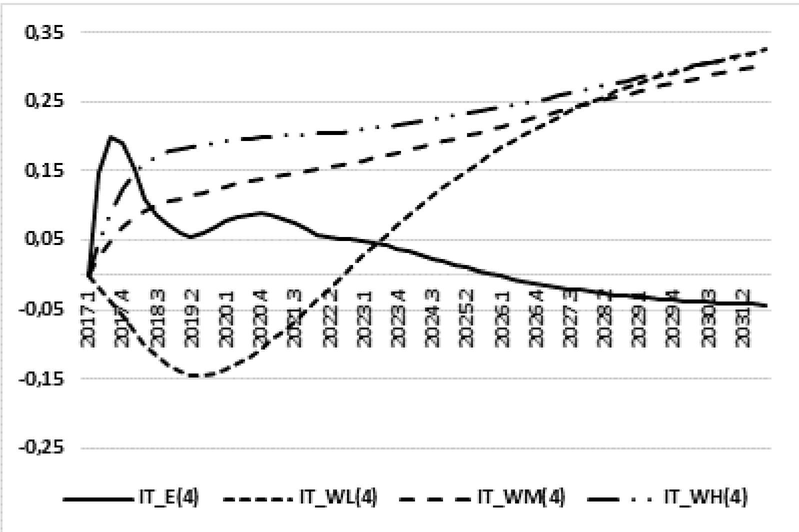

Figure II.5.1.2:SIM_IND17-Total employment, wages of low-medium-high skilled workers in the fourth scenario (percent changes w.r.t. baseline, quarterly results)

Employment seems to be in slow decline to establish itself at the rate of 0.041% in the long run. The growth with respect to the base year of wages of high skilled workers, WH has an initial decrease during the first five years to converge to the growth rates of lower skills wages.

II.5.2 *Industria 4.0: Skills Achievement*

As shown in the previous section, interventions related to Piano Nazionale Scuola Digitale, (PNSD) are included within policies of Industria 4.0, under the denomination of skills achievement as they are referred to interventions aimed to promote culture I4.0 among students, create competences and stimulate research. Our simulation experiment, which we denominate SIM_COMP17, is done for evaluating the impact on the main macro-economic variables of a change in the human capital composition with respect to skills.

In order to build the policy scenario we will consider the hypothesis to direct the education of new human capital entirely towards high skilled competencies, to achieve through the creation of centers of excellence, competence center. For achieving this target 900 millions of euros are to be allocated: 200 millions by privates and 700 millions by public institutions for years 2017-2020. We assume a consequent increase of public expenditure of 0.5% with respect to GDP. As established by PNSD, we assume that the annual expense for education of 200,000 students is financed.

	2017	2018	2019	2020	2025	Long run 2031
IT_Y(1)	0.202	0,148	0,162	0,205	0,481	0,889
IT_C(1)	-0.348	-0,858	-0,973	-0,983	-0,733	-0,211
IT_I(1)	-0.024	-0,030	0,020	0,080	0,352	0,647
IT_E(1)	0.137	0,164	0,152	0,171	0,300	0,438
IT_WL(1)	0.017	0,054	0,078	0,100	0,254	0,576
IT_WM(1)	0.010	0,021	0,010	-0,008	-0,088	-0,123
IT_WH(1)	-0.306	-1.193	-2.082	-2.935	-6.826	-10.929

Table II.5.2.1: SIM_COMP17 Expected macroeconomic effects of measures “Industria 4.0”: PNSD for GDP, consumption, Investments, total employment,low skilled, medium skilled and high skilled employment
(percent changes w.r.t. baseline, annual results)

We calculate the number of students that are to be financed, net of the abandon rate, calculated in 16% by Istat, which is equal to 168,000 units (Istat, 2016). On the basis of the Istat data of high school students, equal to 7,878,661, we determine the ratio between students to be financed and high school students.

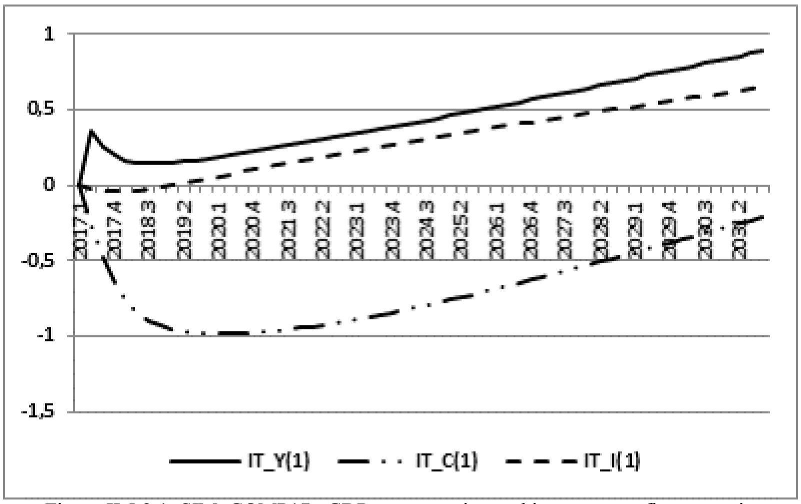

Figure II.5.2.1: SIM_COMP17 –GDP, consumption and investments, first scenario
(percent changes w.r.t. baseline, quarterly results)

In this shock we decrease the share of low skilled workers of 1% and we increase the share of medium skilled workers of the same amount and so we improve the level of education of low skilled workers. Simultaneously we increase public expenditure of 0.5% of GDP. Investments slightly decrease in a first phase (-0.030) in 2018 to progressively increase in the long run, 0.020 in 2019 and 0.080 in 2020 to stabilize at 0.647 in 2031 and increase in the longer run.

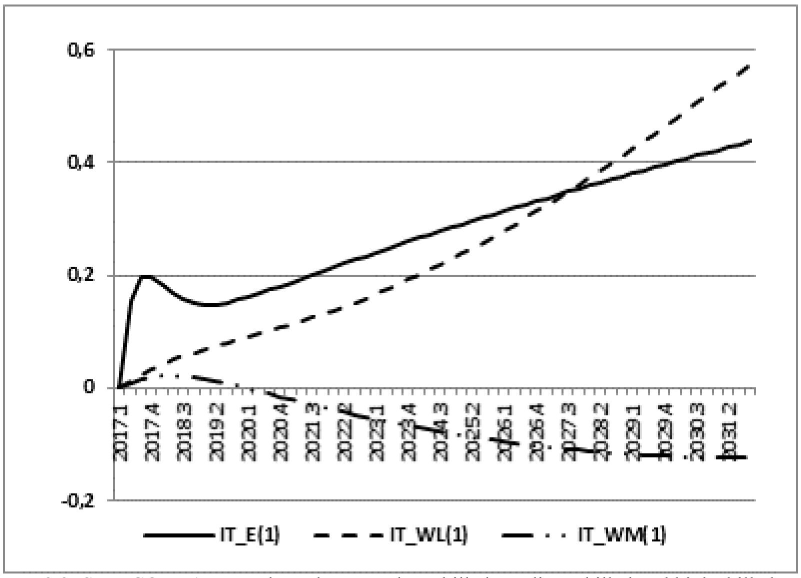

Figure II.5.2.2: SIM_COMP17 –Total employment, low skilled, medium skilled and high skilled wages
(percent changes w.r.t.baseline, quarterly results)

Low skilled employment and wages increase, while medium skilled wages and high skilled wages decrease, the latter in a more pronounced way. The reason is given by the fact that the greater part of employed people in Italy belongs to the low skilled category, and, due to the convex adjustment costs in wages of high skilled workers, employers generally prefer to continue to hire low skilled people rather than high skilled ones. This leads also to the high unemployment of high skilled people, that once educated are not assured the job, mainly because of the loss of infrastructural support to R&D. Quantifying the impact of structural reforms on the main macroeconomic variables is a task of high complexity so that some cautiousness has to be performed. All the results have been generated through the use of a model which provides only a representation of the stylized facts, even if built with the aim of evaluating the effects of structural reforms. The theoretical assumptions involved in QUEST, as well as the policy efforts considered, are to a certain extent subjective and impose limitations in the analysis of the outcomes. Moreover, the time delays in the reform implementation, the spill-over among countries and the complementarities and trade offs among reforms in different contexts make problematic the separation of the effects of reforms implemented from the other factors of performance. Furthemore, the main implicit assumption is that the declared reform plan are fully reliable and the agents have perfect information and certainty on the reforms effects.

PART III

SKILL BIASED TECHNOLOGY AND INNOVATION OF PROCESS IN TWO VARIANTS OF QUEST III - ITALY

In this section an attempt is made to modify the mechanisms of QUEST III-Italy. We want to take into consideration the issues, that have emerged in the previous part, related to need of overcoming the neutrality of technology and recognizing the role due to manpower skills as able to modify the physical-capital productivity and impact on the innovation of process in the Digital Era. In particular chapter III.1 proposes a set of modifications in the model design. New equations are introduced to model endogenously the behaviour of the skill shares, and other equations are modified to account for the augmented productivity of physical capital due to R&D spillovers. Parameters determination is performed with reference to the results emerging from the literature adapted to the Italian context and is shown in chapter III.2. In chapter III.3, comparisons among various simulations are implemented in the search of higher performances in the growth rates of macro-variables of the economy as stated in III.3.5.

III.1 Skill biased technology and innovation of process in QUEST III – Italy

In the study of digitalization, core framework of the policy measures in Industria 4.0 under the profiles of both innovation investments and skills achievement, the hypothesis of non-neutrality of technological progress has to be explicitly assumed. *Skill biased technical change* SBTC and *innovation of process* are strictly linked phenomena and distinctive of the new digital era to which the model does not give an analytical collocation.

An increase of the skill premium has been detected in the literature (Haskel, et al., 2012). In particular, it has been observed that the increase of inequality is due to the increase of the income of an apical social class of workers, highly skilled and highly payed the so-called *superstars*. In the United States from the '70s they held a share of 8% of the total households income which reached the 18% in 2000 and slightly decreased during the recession. The discussion has led to the conclusion that technology is complementary to the skilled and non-routinized tasks but indeed substitute for the routinized, skilled tasks. In order to obtain evaluations of the impacts on the growth of this phenomenon our attempt will be that of including this mechanism in the model.

Equation (23) of QUEST III Italy, shown in the previous part, defines the labour supply in terms of accumulated human capital, $L_{Y,t}$, as sum of three types of skills available labelled by indexes L, M e H. Those skills have to be reinterpreted now as: *R* as routinized tasks of skilled workers, NR non- routinized tasks of skilled workers and S tasks of superstar workers, highly skilled and highly payed.

The accumulated human capital $\left(h_t^z L_t^z\right)$ following the three types of skills ($z \in$ *(R,NR ,S))* is determined by the employment rates L_t^z times the skill of each kind of capital h_t^z and calculated as the share of each type of competence $s_z^{\frac{1}{\sigma}}$.

Equation (23) becomes:

$$L_{Y,t} = \left[s_R^{\frac{1}{\sigma_L}} \left(h_t^R L_t^R\right)^{\frac{\sigma-1}{\sigma}} + s_{NR}^{\frac{1}{\sigma}} \left(h_t^{NR} L_t^{NR}\right)^{\frac{\sigma-1}{\sigma}} + s_{S,Y}^{\frac{1}{\sigma}} \left(h_t^S L_t^{SY}\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{39}$$

Where the shares of the three types of skills will be now endogenously determined:

$$s_{SY} = \frac{\exp[\hat{\theta}_0 + \hat{\theta}_1(A_t - A^*)]}{1 + \exp[\hat{\theta}_0 + \hat{\theta}_1(A_t - A^*)] + \exp[\gamma_0 + \gamma_1(A_t - A^*)]} \quad (40)$$

Eq. (40) warrants that the range of the share of high skilled and high payed workers is located between zero and one. A logistic function has been chosen since in this way the link between share and new ideas can exhibit an increasing trend. Similarly with reference to the share of non-routinized skilled workers in eq. (41).

That equation introduces a complementarity effect between new ideas (technologies) and share of non-routinized skilled workers, as we assume that the non-routinized skilled labour, will have its own relevant role in the digital era.

$$s_{NRY} = \frac{\exp[\hat{\gamma}_0 + \hat{\gamma}_1(A_t - A^*)]}{1 + \exp[\hat{\theta}_0 + \hat{\theta}_1(A_t - A^*)] + \exp[\gamma_0 + \gamma_1(A_t - A^*)]} \quad (41)$$

The share of routinized skilled workers can be written in terms of the two former equations as $s_{RY} = 1 - s_{SY} - s_{NRY}$. The share of routinized skilled workers, then, is residual with respect to the shares of the other skills. Subtracting from unity, representing the 100% share, the value of the other two shares; from which, by substitution we obtain:

$$s_{RY} = \frac{1}{1 + \exp[\hat{\theta}_0 + \hat{\theta}_1(A_t - A^*)] + \exp[\gamma_0 + \gamma_1(A_t - A^*)]} \quad (42)$$

In steady state condition, that is $A_t = A^*$ we obtain that:

$$\bar{s}_{SY} = \frac{\exp(\theta_0)}{1 + \exp(\theta_0) + \exp(\gamma_0)}$$

$$\bar{s}_{NRY} = \frac{\exp(\gamma_0)}{1 + \exp(\theta_0) + \exp(\gamma_0)}$$

$$\bar{s}_{RY} = \frac{1}{1 + \exp(\theta_0) + \exp(\gamma_0)}$$

From which we obtain the values of the two parameters θ_0 and γ_0 based on the ratio of the different skill categories in steady state respectively as:

$$\theta_0 = \ln\left(\frac{\bar{s}_{SY}}{\bar{s}_{RY}}\right)$$

$$\gamma_0 = \ln\left(\frac{\bar{s}_{NRY}}{\bar{s}_{RY}}\right)$$

The total effect of the three equations generates, then, substitutions between routinized skilled workers (s_{RY}) and new ideas, $(A_t - A^*)$ mediated through the effect on the remaining shares.

Beyond the human capital, new ideas tend to modify also capital productivity through the process innovation. The model has been therefore modified to consider the process innovation, in terms of the higher value of productivity of the already existing physical capital due to immaterial knowledge embodied in it. We have to anchor the physical capital productivity to the knowledge accumulation, that is to the intangible capital, with the aim of capturing the further positive and cost free spillovers linked to knowledge accumulation, which augment the capital productivity without increasing its costs. A^* gives the value of the knowledge accumulation in the steady state. The productivity of new capital will then be an increasing function of the intangible capital changes with respect to the initial state, that is the gap between actual and initial value of it $(A_t - A^*)$.

With the aim of modelling the increased productivity of capital, induced by the intangible goods, an equation has been introduced that explains these kinds of productivity increases. Following the assumption that the capital productivity increases when knowledge (i.e. new ideas) increase, we introduce the following equation:

$$IT\_SPILL_t = \max(1, \exp(\hat{\mu} \cdot (A_t - A^*))) \tag{43}$$

where $\hat{\mu}$ represents the elasticity of the productivity of new capital to the stock of ideas (patents). Since the productivity of capital caused by knowledge spillovers is determined in efficiency units, we need at first to calculate the productivity of capital determined by the entire knowledge and then rescale it to isolate the knowledge spillover effect.

The private capital accumulation in efficiency units within the model is given by:

$$K_t^i = J_t + (1 - (\delta^K + WGTFP + WGPOP))(K_t - \Delta K_t)$$

With the introduction of the variable IT_SPILL that equation becomes:

$$K_t^i = IT\_SPILL\ (J_t + (1 - (\delta^K + WGTFP + WGPOP)))(K_t - \Delta K_t) \qquad (44)$$

Due to these changes eq.(5) becomes:

$$\begin{aligned}
\underset{\left\{\begin{matrix} C_t^i, L_t^i, B_t^i \\ B_t^{F,i}, J_t^i, K_t^i \\ J_t^{A,J}, A_t^i, ucap_t^i \end{matrix}\right\}_{t=0}^{\infty}}{Max} \quad V_0^i = {} & E_0 \sum_{t=0}^{\infty} \beta^t \left(U(C_t^i) + \sum_s V(1 - L_t^{i,s})\right) - \\
& - E_0 \sum_{t=0}^{\infty} \lambda_t^i \beta^t \begin{pmatrix} \left(1 + t_t^c\right) P_t^C C_t^i + B_t^i + E_t B_t^{F,i} + P_t^I (J_t^i + \Gamma_J(J_t^i)) + P_t^A J_t^{A,i} \\ - (1 + r_{t-1}) B_{t-1}^i - \left(1 + r_{t-1}^F - \Gamma_{B^F}\left(E_t B_{t-1}^F / Y_{t-1}\right)\right) E_t B_{t-1}^{F,i} \\ - \sum_s (1 - t_t^{w,s}) W_t^{i,s} L_t^{i,s} - b_t^s W_t^{i,s} (1 - NPART_t^{i,s} - L_t^{i,s}) + \Gamma_W(W_t^{i,s}) \\ - (1 - t_{t-1}^K)(i_{t-1}^K ucap_{t-1}^i - rp_{t-1}^K - \Gamma_U(ucap_{t-1}^i)) P_t^J K_{t-1}^i - t_{t-1}^K \delta^K P_t^I K_{t-1}^i - \tau^K P_t^I J_t^i \\ - (1 - t_{t-1}^K)(i_{t-1}^A - rp_{t-1}^A) P_t^A A_{t-1}^i - t_{t-1}^K \delta^A P_t^A A_{t-1}^i - \tau^A P_t^A J_t^{A,i} \\ - TR_t^i - \sum_{j=1}^{n} PR_{j,t}^{f,i} - \sum_{j=1}^{A_t} PR_{j,t}^{x,i} \end{pmatrix} \\
& - E_0 \sum_{t=0}^{\infty} \lambda_t^i \xi_t^i \beta^t \left(K_t^i - J_t^i - (1 - \delta^K) K_{t-1}^i\right) - E_0 \sum_{t=0}^{\infty} \lambda_t^i \psi_t^i \beta^t (A_t^i - J_t^{A,i} - (1 - \delta^A) A_{t-1}^i) -
\end{aligned}$$

$s \in \{M, H\}$

where the second last addend has been conveniently modified with the introduction of the variable IT_SPILL, as follows:

$$- E_0 \sum_{t=0}^{\infty} \lambda_t^i \xi_t^i \beta^t \left(K_t^i - IT\_SPILL \cdot (J_t^i + (1 - \delta^K) K_{t-1}^i \right)$$

Consequently the the first order conditions will be modified. In particular the eq.(11a) becomes:

$$IT\_SPILL \cdot Q_t - 1 = \gamma_K \left(\frac{J_t^i}{K_{t-1}^i}\right) + \gamma_I \Delta J_t^i - \tau^K - E_t\left(\frac{\gamma_I \Delta J_{t+1}^i}{1 + i_t - \pi_{t+1}^C}\right)$$

where

$$Q_t = \frac{\xi_t}{P_t^C}$$

+

In the derivative of the utility function with respect to investments

$$Q_t = E_t\left(\frac{1 - \delta}{1 + i_t - \pi_{t+1}^C} Q_{t+1} \cdot IT\_SPILL_{t+1} + \frac{(1 - t_t^K)(i_t^K ucap_t^i - rp_t^K - \Gamma_u(ucap_t^i)) + t_t^K \delta^K}{1 + i_t - \pi_{t+1}^C}\right.$$

Where Q_t represents the Tobin's Q that is the discounted present value of the expected rate of return of the investment in real capital.

III.2 Determination of parameters in the two variants of QUEST III

The determination of the parameters of the equations introduced, will be done with reference to the values found in the literature on the topics connected with the equations presented, through an adjustment of such figures to the Italian context.

With reference to the impacts of the different levels of skills, interesting fallouts are shown in Blanco et al., (2013).The direct spillover effect of R&D in the long run is determined for the U S. and, as expected, it is shown to fluctuate through the different states with different impacts on the skill of the human capital.

A wider absorption of the new knowledge created by R&D is encouraged by the presence of higher skilled workers. From that complementarity, highlighted in literature, among the others, by Hall et al. (2010), the benefits of R&D would be more relevant for those states with higher levels of human capital. The coefficient that significantly links the stock of R&D for US states with the largest expenses in R&D (High Group) is equal to 0.086, for the Medium Group equals 0.064 and for the Low group equals 0.058.

In Piva et al. (2005) an empirical analysis has been carried on a sample of Italian manufacturing firms which identify as possible determinants of the skill bias, the technological change and the reorganization, in a country endowed with an average productivity technology. Data are taken from a database of the Italian manufacturing firms with not less than 11 employees. The database consists on the answers to three waves of questionnaires made by Mediocredito Centrale (MCC) in years 1991,1994 and 1997. Referring to the skills, the authors identify two wide categories of homogeneous workers: white collars, including the entrepreneurial and family assistants, the junior and senior managers and the employees, and the blue collars, workers, with the intention to determine characteristics of complementarity and/or substitution.

In the cases where technological change and organizational renewal are jointly considered, authors find significant relationships which attest phenomena of substitution and complementarity between these and blue collars and white collars tasks. In addition, authors underline that the result is consistent with the vision of Italy given by

Fuà (1988), in relation to the importance of the organizational and entrepreneurial factor in reforming the profile of that Italian firms which are not based only on their own R&D activity as source of change.

In this work emerges a coefficient that links technological organizational change and white collars equal to 0.08. While white collars to blue collars coefficient is -0.11. Consistently with this evidence we assume that the value of the parameter $\hat{\theta}$ in eq. (40) is equal to 0.086 consistently with the result of the *High Group* in Hall et al. (2010) and with the result for the white collars in Piva et al. (2005). For equation (41) we assumed the value $\hat{\gamma} = 0.064$. The sign of the coefficient for blue collars, class with the lowest level of skill in Piva et al. (2005) does not contradict our hypothesis of substitution between skilled routinized workers, category with the lowest level of skill in our model, and new ideas (R&D), a phenomenon of substitution not considered in (Hall et al., 2010).

As to the spillover effects regarding the increase of capital productivity in the process innovation, the parameter to be determines is $\hat{\mu}$ in eq. (43). Works that deal with the quantitative determination of the relationship of the capital productivity and intangible goods (knowledge) are, until now, rare, almost inexistent.

Hence, we have to start from the estimates of the impact of R&D on the Total Factor Productivity, and modify it rescaling according to the capital productivity coefficient (1-α), in the production function of final goods. For this aim, we consider Higon's work (2002) which estimates an impact of R&D on the sectoral TFP_UK as comprised between 0.083 and 0.027 according the sector.

Blanco et al. (2013) estimate this value using two different estimators, dynamic OLS and PMG. In our case, we consider an average value among the suggested values. After rescaling and considering a precautionary margin, due to the fact that in general only a minor part of the value of capital is owed to the knowledge spillover, we consider the value of $\hat{\mu}$ _norm =0.00546 and is included in a range between $\hat{\mu}$ _sup = 0.00819 and $\hat{\mu}$ _inf =0.00273.

III.3 Simulations results

Simulations have been performed on scenario conditions designed on both aspects of the National Plan Industria 4.0 (NPI4.0), i.e. *Innovative Investments* and *Skills Achievement* (Table II.5.1.1). The aim is the quantitative determination of the expected growth paths in the most relevant macroeconomic aggregates with a model able to take into consideration both the non-neutrality of technological change, in terms of Skill-Biased-Technical-Change, and the innovation of process.

Simulation results obtained with QUEST III-Italy will be identified with the prefix IT. Simulations with the two modified versions of the model, will be labelled with prefix A when obtained with variant A of the model (QUEST III-A) where only the spillover effect on physical capital is considered; and B obtained with variant B (QUEST III-B) that takes into account both the spillover effect and the endogenization of skill shares. In this way, IT_Y will identify GDP obtained in simulations with QUEST III-Italy, and B_Y will be the variable associated to GDP in simulations with QUEST III-B, i.e. QUEST III modified with both spillover effect and endogenization of skill shares.

The figure among parenthesis, as 2 in B_Y(2), will identify the result obtained under scenario nr.2 of Table II.5.1.1. In this case, B_Y(2) will denote GDP in the simulation with the policy assumption that the total shift of workers, specified in Table II.5.1.1, takes place from the routinized skilled workers, R, to the non-routinized skill workers, NR. As we pointed out in chapter III.2 the class of workers identified as Low (L) skilled in QUEST III-Italy finds a correspondence in the Routinized (R) skilled workers category in the modified QUEST models. This is also true for the Medium (M) skill and High (H) skilled categories, which become respectively Non Routinized (NR) and Superstar (S).

Besides various simulation experiments have been run for determining the spillover effects of the increase of capital productivity in the innovation of process. This has been done using a range of change for the parameter of SPILL, $\hat{\mu}$, in the eq. (43) centred on the value *norm* = 0.00546 which goes from the maximum value equal to *sup* = 0.00819 and the minimum value equal to *inf* = 0.00273. To discriminate the various outcomes, further labels have been introduced, namely *sup, inf, norm.,* so that label B_Y(2) sup will identify the outcome of GDP in a simulation where a shift of workers is allowed from the routinized to the superstar class and the highest bound of parameter $\hat{\mu}$ is used.

III.3.1 Gross Domestic Product

The first set of simulation results refer to the policy measures National Plan Industria 4.0, *NPI4.0: Skills Achievement* and are shown in Figure III.3.1.1. It quantifies the percent change of GDP in the cases where the innovation of process acts through the capital productivity, (QUEST III-A), in the three cases *sup, inf, norm*. Results in Figure III.3.1.1, put, therefore, in comparison the growth rate of GDP, determined in the previous section through QUEST III- Italy, labelled IT_Y, with its variant B_Y, in the three different values of the spillover parameters. These are linked to the introduction of the innovation of process, in the case of shifting the skills by means of an education program that moves human capital from the routinized skilled category to superstar category (first scenario in Table II.5.1.1). This hypothesis has been chosen because it seems to be the closest to the intentions declared by the policy maker in *NPI4.0: Skills Achievement*.

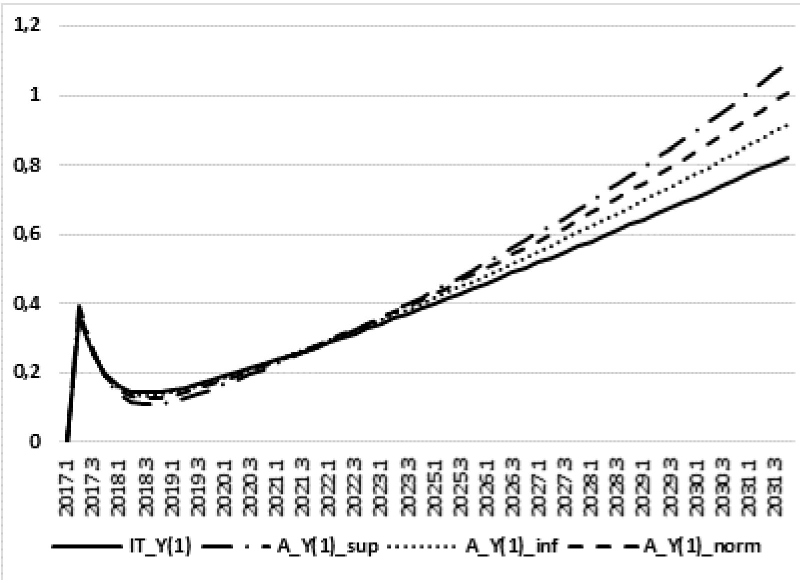

Figure III.3.1.1: GDP in QUEST III-Italy and QUEST III-A, first scenario
in the three values of the band *(inf, norm, sup)* (percent changes w.r.t. baseline, quarterly results)

From the quarterly results shown in Figure III.3.1.1, we note a first period, from the third quarter of 2017 to the second quarter of 2021, in which the growth rate of GDP, in the QUEST III - Italy model, IT_Y, prevails over the others, (see Figure

II.5.2.1). From the 2025 and then in the long period, on the contrary, the growth rate of A_Y(1)sup prevails at first and then A_Y(1)norm and A_Y(1)inf. This happens because in the long run the effects of the endogenous growth emerge amplified in the case where the innovation of process has been introduced.
In annual terms results, shown in Table III.3.1.1, accounts for the fact that from 2017 to 2020, IT_Y goes from 0.148% to 0.20% standing over the trends of the other simulations while from 2025 that growth rate will be overcome by the other simulations with wider distance for those in which the spill effect is higher.

	2017	2018	2019	2020	2025	Long run 2031
IT_Y(1)	0.202	0.148	0.162	0.205	0.421	0.798
A_Y(1)_sup	0.210	0.119	0.134	0.187	0.467	1.048
A_Y(1)_inf	0.203	0.142	0.157	0.203	0.440	0.884
A_Y(1)_norm	0.205	0.147	0.148	0.198	0.456	0.968

Table III.3.1.1 GDP in QUEST III Italia and QUEST III-A, first scenario, in the three values of the band(percent changes w.r.t. baseline; annual results)

These are the results of a shock aimed to increase the level of high skilled workers and decrease the level of low skilled workers. With a higher level of R&D activities we would expect a higher level of output, due to the fact that R&D implies an increase of the quality, and of the productivity of physical capital. This process, however, takes place in a slow and gradual manner. Data show in fact that in the first twenty periods of growth the prevailing effect is that of depriving the final good sector of workers. This fact leads to lower growth rates of GDP in the modified model, where, in fact, the increase of productivity, introduced by process and product innovation pushes the R&D sector towards its maximum expression as process and product innovator.

The increasing trend shown in Figure III.3.1.1 until 2017.3 is given by public infrastructural investments anticipated in *NPI4.0: Skills Achievement*. The initial rate of change suffers a decline in the following quarters caused by the mentioned subtraction of workers, due to the education process. On the other hand the decrease is also a consequence of the reduction of consumption expenditure of the non liquidity constrained households, due to the increase of public expenditure, which will be recovered only in the long run. The highest increase of GDP in the long run is also due to the fact that low skilled workers acquire high skills and will be effectively active in the R&D sector in generating growth and new products using new machineries.

Table III.3.1.2 shows annual results of the simulations related to the *NPI4.0: Skills Achievement*, in case of introduction in the model also of the different shares of skilled labour. As we can observe, the total effect is expansive and more pronounced in the case of simulations with values of parameter of the spillover $\hat{\mu}$ equal to its maximum border.

	2017	2018	2019	2020	2025	Long run 2031
IT_Y(1)	0.202	0.148	0.162	0.205	0.421	0.798
B_Y(1) _ sup	0.209	0.122	0.138	0.191	0.472	1.060
B_Y (1)_ inf	0.202	0.144	0.159	0.205	0.444	0.978
B_Y (1)_norm	0.205	0.135	0.151	0.201	0.461	1.081

Table III.3.1.2: GDP in QUEST III - Italy and QUEST III-B, first scenario in the three values of the band (percent changes w.r.t. baseline; annual results)

The results shown until now are related to the simulations of the interventions related to the formation of human capital suggested in NPI4.0, that is the interventions suggested in measure *NPI4.0: Skills Achievement*. Simulations of the effects of the policies related to *NPI4.0: Innovative Investments* are, instead, shown in Table III.3.1.3.

	2017	2018	2019	2020	2025	Long run 2031
IT_Y(4)	0.231	0.214	0.309	0.475	0.712	0.736
B_Y(4)_sup	0.232	0.217	0.314	0.483	0.738	0.783
B_Y(4)_inf	0.232	0.215	0.311	0.478	0.721	0.752
B_Y(4)_norm	0.232	0.216	0.312	0.481	0.729	0.767

Table III.3.1.3: GDP in QUEST III Italy and QUEST III-B, fourth scenario, in the three values of the band (percent changes w.r.t. baseline; annual results)

Results show that growth rates of GDP in the first three years remain close by. They exhibit, indeed, the same figures until the second decimal. However, we can observe that in the hypothesis of QUEST III-B_sup the results always remain higher. From year 2020 more pronounced differences on growth rates begin to emerge. They widen progressively as shown in Figure III.3.1.2. It seems to emerge long run effects of the increases of productivity (TFP) that the measure forecasts exhibit the complete effect in five years, (results of QUEST III-Italy in Figure II.5.1.1).

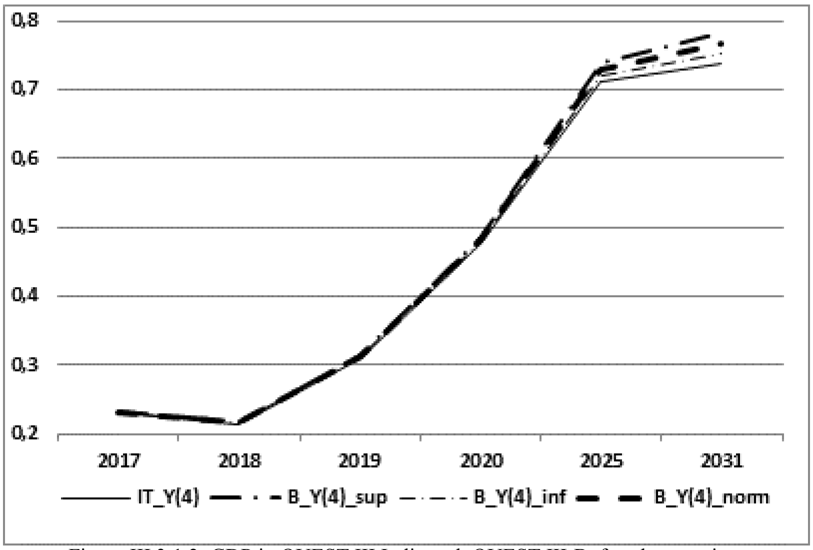

Figure III.3.1.2: GDP in QUEST III Italia and QUEST III-B, fourth scenario, in the three values of the band (percent changes w.r.t. baseline; annual results)

The GDP trend for NPI4.0: Innovative Investments, depends on the policy implementation. After the initial increase due to the tax cuts and to the incentives for the adoption of I4.0 oriented machines, it suffers the consumption expenditures reduction due to the non liquidity-constrained households expectations. In this case however the productivity shock prevails generating the endogenous growth process.

III.3.2 Consumption and investment expenditure

The total consumption expenditure trend, in the simulation linked to NPI4.0: Skills Achievement, is labeled by variable B_C(1) in Figure III.3.2.1 It presents negative percent change rates with respect to the base year always more pronounced until the fourth quarter of 2020 and then the trend is inverted while remaining negative. In the same picture the growth rates of the two components of expenses for consumption are plotted. B_NCLC(1) represents the expenditures of the non-liquidity constrained households and B_CLC(1) gives the expenditures of the liquidity constrained households. Non-liquidity constrained households are forward looking, so they expect that the increase of expenditure planned in NPI4.0: Skills Achievement will be permanent and that will be financed through taxation. Aware of this situation they tend to decrease the present consumption. On the other hand the liquidity constrained households, which are non-forward looking consumers, take their consumption

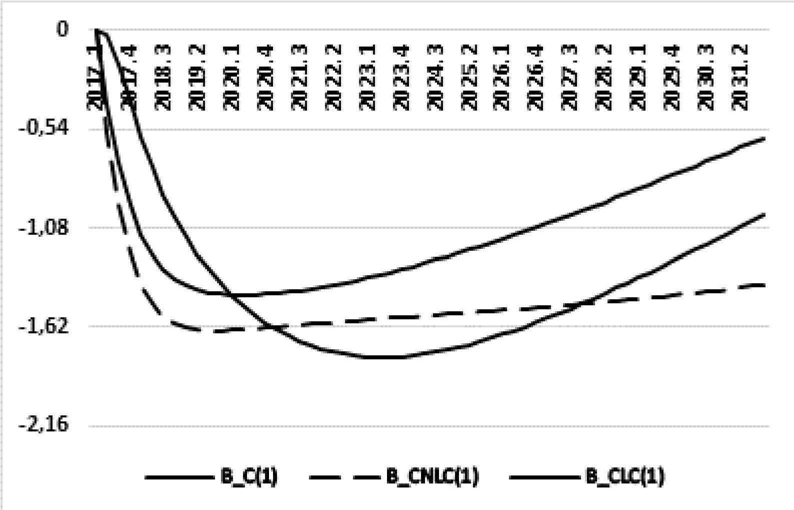

Figure III.3.2.1: Consumption expenditure in QUEST III-B, first scenario, *sup* hypothesis
(percent change w.r.t. baseline; quarterly results)

decisions only in the current period and investments as they have not the possibility to invest. The forecasted shock on public expenditure which is expected to increase consumption, in this case causes its decrease. The reasons are to be attributed to the increase of the labour taxes and to the decrease of the transfers. Since within the model, many automatic stabilizers are involved, any time in which fiscal policy is not covered, stabilizers activate imposing the coverage of the deficit which will be financed by the liquidity constrained households avoiding excessive disequilibria. In fact, when taxes increase, in this case because of the debt, consumption of liquidity constrained households decreases.

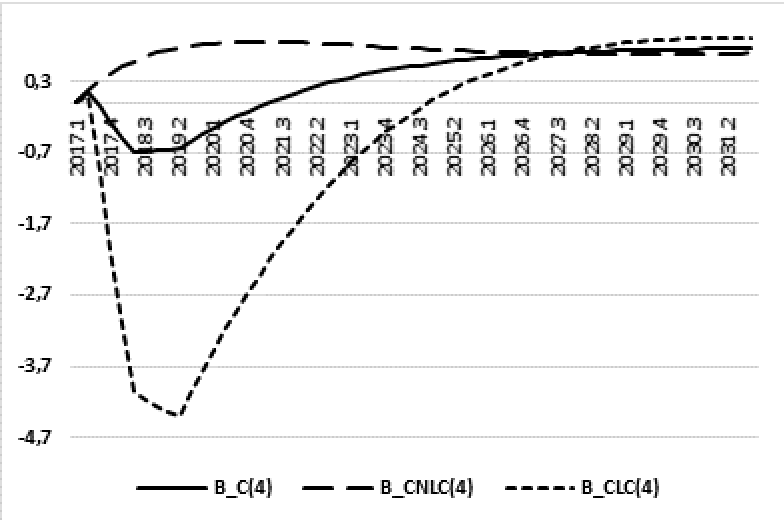

Figure III.3.2.2: Consumption expenditure in QUEST III-B, fourth scenario, *sup* hypothesis
(changes w.r.t. baseline; quarterly results)

Figure III.3.2.2. shows the trend of the components of consumption expenditures related to the measures recommended by *NPI4.0: Innovative Investments*.

The somehow adverse effects of the fiscal policy in the simulations in the previous figure are, in this case, more limited. As shown by Table III.3.2.1, the growth rate of consumption expenditures has negative values but limited, less than -0.632, with respect to the previous situation. Year 2020 seems to be the last year in which the aggregate consumption shows a negative rate of growth equal to -0.237. While the growth rate of consumption of liquidity constrained households, through the mechanism described in the previous case, reaches a value of –4.148 in year 2019 to become positive in the long run corresponding to the decrease of public debt.

This is a case where compensative transfers could be introduced in favor of liquidity-constrained households.

	2017	2018	2019	2020	2025	Long run 2031
			Industria 4.0: " Skills Achievement PNSD"			
B_C(1)	-0.518	-1.253	-1.418	-1.441	-1.187	-0.627
B_CNLC(1)	-0.686	-1.509	-1.632	-1.630	-1.538	-1.399
B_CLC(1)	-0.148	-0.812	-1.261	-1.523	-1.704	-1.059
			Industria 4.0 "Innovative Investments"			
B_C(4)	-0.039	-0.632	-0.571	-0.237	0.592	0.756
B_CNLC(4)	0.224	0,610	0.787	0.837	0.728	0.695
B_CLC(4)	-0.736	-3.905	-4.148	-3.067	0.234	0.917

Table III.3.2.1: Consumption expenditure in QUEST III-B, first and fourth scenarios, *sup* hypothesis (percent changes w.r.t. baseline; annual results)

The annual results shown in Table III.3.2.2 are related to separate simulations on two scenarios of PNI 4.0. In the upper part of the table, growth rates of investment expenses related to *PNI 4.0:Skills Achievement* obtained with the original QUEST III-Italy.

Variable IT_I (1), are put in comparison with three different simulations obtained with QUEST III-B that includes the effects spillover and skill endogenization in the three different cases in which there exist a shift in human capital between the three different categories of skills, as described at the beginning of the paragraph. These results are described respectively from the variables B_I(1), B_I(2), B_I(3).

	2017	2018	2019	2020	2025	Long run 2031
			Industria 4.0 "Skills Achievement"			
IT_I(1)	0.364	-0.029	0.019	0.079	0.351	0.629
B_I(1)	-0.0004	0.062	0.179	0.304	0.938	1.854
B_I(2)	-0.011	0.012	0.082	0.153	0.424	0.661
B_I(3)	-0.005	0.037	0.130	0.228	0.683	1.273
			Industria 4.0 "Innovative Investments"			
IT_I(4)	0.364	0.730	0.726	0.713	0.590	0.497
B_I(4)	0.372	0.756	0.763	0.760	0.667	0.599

Table III.3.2.2: Investment expenditure in QUEST III Italy and QUEST III-B, first,second, third and fourth scenarios *sup* hypothesis(percent changes w.r.t. baseline; annual results)

The growth rates related to the variable IT_I(1) are lower than any other result in the scenarios inspired by the *NPI4.0:Skills Achievement.* As shown by Figure III.3.2.3, linked to the quarterly results, the comparison with the measures *NPI4.0:Innovative Investments*, for these scenarios the results are higher at least in the first period, until the 2023. The percent changes with respect to the initial steady state are, however, overcome in the longer run particularly in quarter 2023.4 by B_I(1), in quarter 2025.3 by B_I(2) and in 2030.2 by B_I(3) In 2031.1 the growth rate related to *NPI4.0:Innovative Investments* are overcome from the simulation with QUEST III-Italy, *NPI4.0:Skills Achievement*, which has been already detected as the lower growth hypothesis. Furthermore, we note that simulations related to the measures *NPI4.0:Innovative Investments*, run with QUEST III-B, generate growth rate of investments wider than the model without modifications.

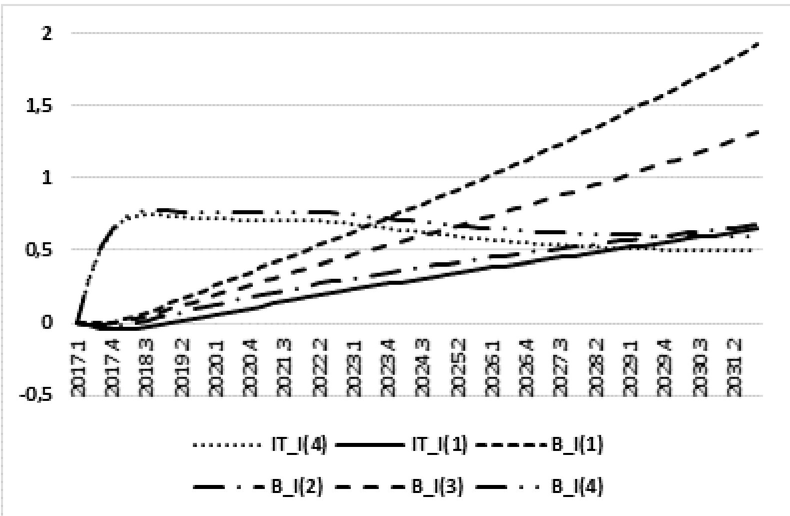

Figure III.3.2.3: Investment expenditure in QUEST III Italy and QUEST III-B, in the fourscenarios,*sup* hypotesis (percent changes w.r.t.baseline; quarterly results)

For the sake of simplicity all the simulations related to expenditure in investment were run under the hypothesis of higher value (*sup*) of the range of variation of the parameters for the QUEST III QUEST III-B.

III.3.3 Employment

The growth of employment caused by the measures <u>*NPI4.0:Innovative Investments*</u> is shown in Table III.3.3.1 by the variable B_E(4) (continuous line). The expansive effects have a limited time horizon, only five years as expected, with more relevant impact in the first two years equal to 0.135 in year 2017 and to 0.106 in 2018. However in the long run the growth rate of employment is negative for all the categories of workers and exhibits a value equal to – 0.041 in 2031. The long run results seem to suggest a strong decrease of the employment, due to the so called "technological unemployment" generalized to all the categories of workers. We also observe the tendency to substitute routinized skilled employment (B_ER), with non-routinized skilled (B_ENR) and superstar employment (B_ES). The decrease of non-routinized and superstar employment is less pronounced in the long run. More detailed quarterly results are shown in Figure III.3.3.1.

	2017	2018	2019	2020	2025	Long run 2031
B_E(4)	0.135	0.106	0.060	0.084	0.0096	-0.041
B_ER(4)	0.160	0.240	0.267	0.309	0.080	-0.061
B_ENR(4)	0.112	0.006	-0.086	-0.075	0.027	0.017
B_ES(4)	0.182	0.075	0.051	0,044	0.040	0.028

Table III.3.3.1: Employment for different *skills* in QUEST III-B, fourth scenario, *sup* hypothesis, (percent changes w.r.t. baseline; annual results)

The effects on employment, labeled with variable E_QUESTIII Mod in the Table III.3.3.2 and in the Figure III.3.3.2, of the measures of <u>*Industry 4.0:Skills Achievement*</u> (first scenario) are, at aggregate level, expansive. The total employment after a fluctuation in the four years 2017-2020 establishes itself on a trend of increasing growth rates which in 2031 reach the 0.416.

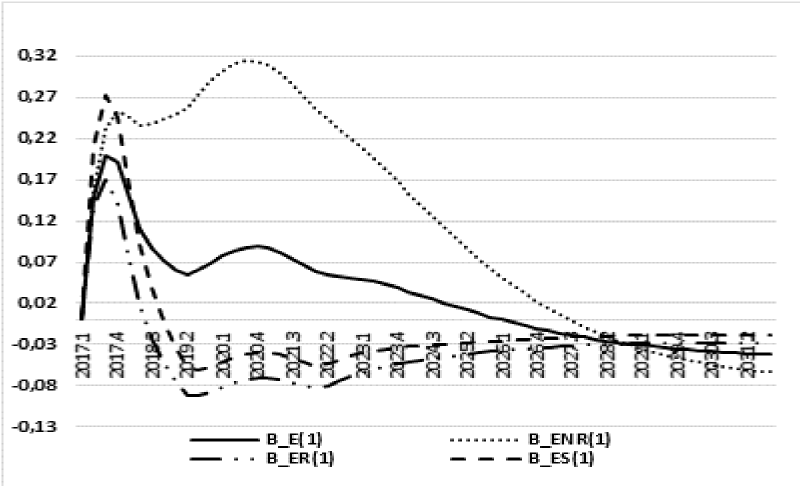

Figure III.3.3.1: Employment for different skill in QUEST III-B,
fourth scenario, *sup* hypothesis (percent changes w.r.t. baseline; quarterly results)

The growth rates of the routinized skilled and non-routinized skilled employment show positive values for the whole period, slightly increasing for the non-routinized skilled workers and slightly decreasing for the routinized skilled workers. Contrary to the expectations and to the declared aims of the *NPI4.0:Skills Achievement*, the growth rates of the superstar employment are negative in increasing manner in the long run. It is likely to observe a contradiction between the *NPI4.0:Skills Achievement* recommendations and those of *NPI4.0:Innovative Investments.*

	2017	2018	2019	2020	2025	Long run 2031
B_E(1)	0.140	0.142	0.123	0.146	0.283	0.416
B_ER(1)	0.127	0.135	0.116	0.130	0.191	0.171
B_ENR(1)	0.140	0.106	0.048	0.037	0.033	0.043
B_ES(1)	0.053	-0.139	-0.234	-0.256	-0.411	-0.608

Figure III.3.3.2: Employment for different skills in QUEST III-B, first scenario, *sup* hypothesis
(percent changes w.r.t.baseline; annual results)

The positive trend of low skilled workers is tied to the fact that in Italy they represent the major share of all workers' categories (Istat, 2013). Moreover when an innovation is introduced, the specialized skills (superstars) required need complementary low skilled workers (routinized) whose number is determined by a factor of five or more with respect to the specialized workers (Moretti, 2010; Goos, Konings and Vandemeyer, 2015). For this reason rate of change of employment of routinized workers will exhibit an increasing trend in the initial time span. It will remain positive with decreasing rate in the medium run. It will become negative when the tasks will be substituted by technologies. However the introduction of new technologies is a slow process because of social economic and legal obstacles, and this will make the substitution of workers with technologies not immediate (Berger and Frey, 2016; OECD, 2015a).

After the positive effects caused by the fiscal cuts the rate of change of medium and high skill workers increases at a decreasing rate. Then it stabilizes on a positive value near zero in the very long run also because the hiring costs of these typologies of workers are very high and firms still prefer hiring low skilled workers despite the introduction of new technologies.

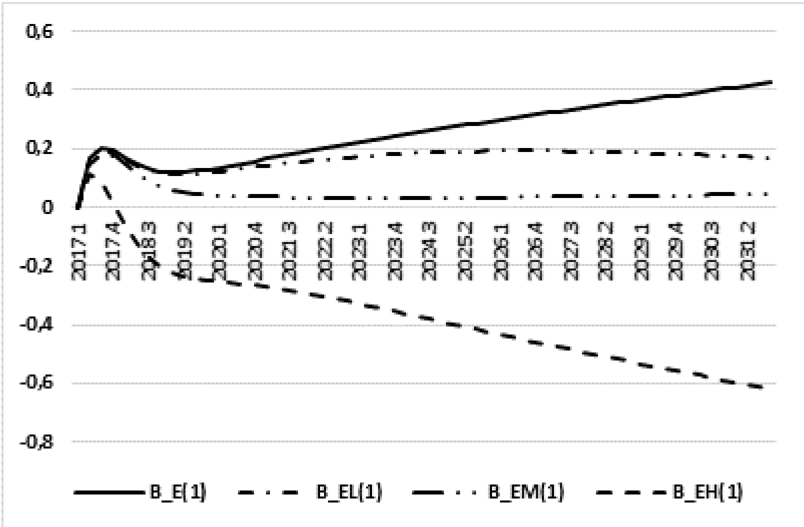

Figure III.3.3.2: Employment for different *skill* in QUEST III-B first scenario, *sup* hypothesis (percent changes w.r.t.baseline; quarterly results)

III.3.4. Wages and Wage Premia

The effects of the measures <u>*NPI4.0:Innovative Investments*</u> on the growth rates of wages for the different types of competences are shown in the Table III.3.4.1. In the first five years the rates of variation of the wages related to employment with different level of competences seems to differ from each other. We can see a negative growth of the wage for routinized competences (WR), with a minimum in year 2019 equal to -0.132 until 2025 when it becomes positive and proceeds towards a convergence with the growth rate of the wage of non-routinized skilled workers, (WNR). The growth rate of the wage for superstar competences is always positive and above the others(WS).

	2017	2018	2019	2020	22025	Long run 2031
			WAGE Industria 4.0: "Innovative Investments"			
B_WR(4)	-0.027	-0.101	-0.132	-0.108	0.201	0.405
B_WNR(4)	0.038	0.104	0.133	0.156	0.264	0.404
B_WS(4)	0.067	0.174	0.203	0.221	0.299	0.427
			WAGE PREMIUM Industria 4.0 "Innovative Investments"			
B_WSR(4)	0.094	0.276	0.336	0.329	0.098	0.022
B_WSNR(4)	0.030	0.070	0.070	0.065	0.034	0.023

Table III.3.4.1:Wage and wage premium in QUEST III-B, fourth scenario, *sup* hypothesis, (percent changes w.r.t. baseline; annual results)

The quarterly results on wages are shown in Figure III.3.4.1. It emerges a positive growth rates of wage premia, consistent with the theoretical expectations linked to the phenomenon of Digitalization . Indeed the wage premium of superstar employment with respect to routinized skilled employment, (WSR) in the same Figure, has always kept positive with a jump in the third quarter of 2019. Always positive but more smoothed the effect on the growth rate of superstar/non-routinized skilled employment wage premium. In the long run both converge on a low positive value. Results on both the wage premia seem strictly linked to the persistence of temporary measures related to <u>*NPI4.0:Innovative Investments*</u>, they tend to zero still remaining positive when their short run effects of <u>*NPI4.0:Innovative Investments*</u> are ceased. As remarked, the model is able to reproduce the stylized fact related with the trend of wage premia in the Digital Era.

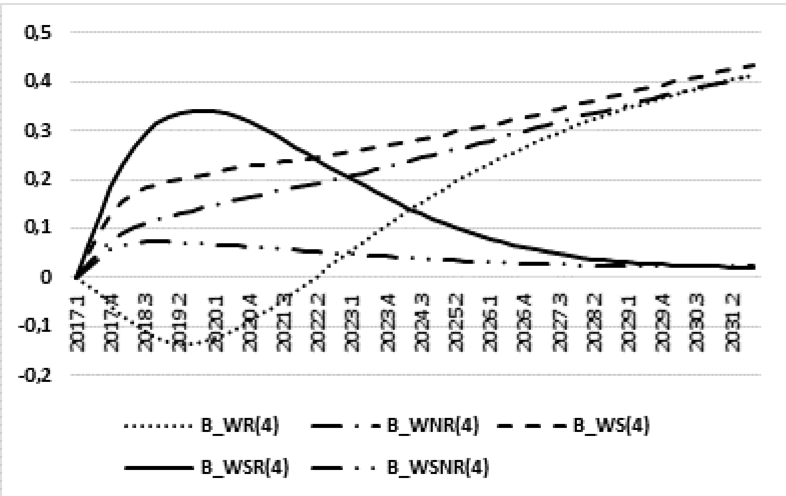

Figure III.3.4.1: Wage and wage premium in QUEST III-B, fourth scenario, *sup* hypothesis (percent changes w.r.t. baseline; quarterly results)

The effects of the reforms <u>*Industry 4.0:Skills Achievement*</u> on the growth rates of wages for the different types of competences are shown in Figure III.3.4.2. Wages of routinized skilled workers have a slightly increasing positive growth, while the non-routinized skilled workers present positive growth rates until the fourth quarter of 2018, then they exhibit negative growth rates for a period from the first quarter of 2019 to the first quarter of 2022, and keep the increasing trend in the long run. On the contrary, the superstar workers have negative growth rates of wages, at increasing rate.

That result can be considered coherent with the expectation because when the supply of labour of superstar workers increases, due to <u>*Industry 4.0:Skills Achievement*</u>, which injects superstar workers, their wage diminishes, in fact, the marginal productivity of each labour input is always decreasing. This fact generates also a fairer income distribution. The growth rates of wages of routinized skilled workers, who proportionally diminishing, exhibit slightly increasing growth rate of wages. In addition, increasing the share of superstars, their marginal productivity increases. Growth rates of non-routinized skilled workers wages fluctuate around zero until 2022, and then begin to increase in the second trimester of 2022.

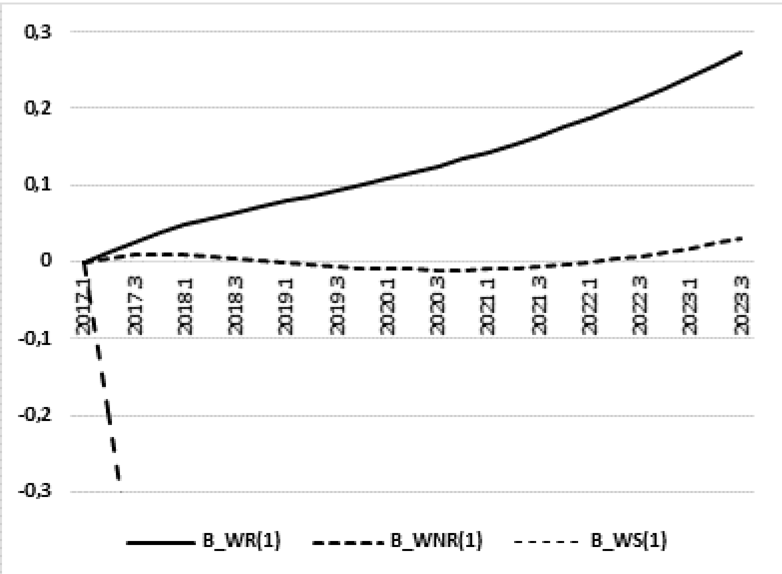

Figure III.3.4.2: Wages in QUEST III-B, first scenario, *norm* hypothesis
(percent changes w.r.t. baseline; quarterly results)

The Table III.3.4.2 shows the annual results obtained. In the upper part the trends of the growth rate of the wage for three different levels of skills are reported, and in the lowest part, we can see the growth rates of wage premium. The growth rate of the wage with respect to base year for routinized labour is 0.059 in 2018 to reach 0.416 in 2025 and 1.138 in the long run to continue an increasing trend. The growth rate of the wages of superstar workers decreases very fast; while with reference to non- routinized skilled workers there is a long period of fluctuation that seems to be due to, as the theory suggests, a crowding out caused by a deskilling of the category.

	2017	2018	2019	2020	2025	Long run 2031
			WAGE Industria 4.0: "Skills Achievement"			
B_WR(1)	0.019	0.059	0.089	0.120	0.416	1.138
B_WNR(1)	0.005	0.006	-0.004	-0.010	0.104	0.599
B_WS(1)	-0.031	-1.206	-2.092	-2.930	-6.626	-10.241
			WAGE PREMIUM Industria 4.0: "Skills Achievement"			
B_WSR(1)	-0.329	-1.254	-2.167	-3.035	-7.013	-11.266
B_WSNR(1)	-0.316	-1.212	-2.088	-2.923	-6.730	-10.788

Table III.3.4.2: Wage and wage premium in QUEST III-B, first scenario, *norm* hypothesis, (percent changes w.r.t. baseline; annual results)

Hence we may expect that with the introduction of the digitalization non routinized skilled tasks will continue to exist, and that the size of these tends to diminish. This category will be progressively absorbed in the routinized skilled category, for what concerns the tasks that, with the evolution of the digitalization will be made by Artificial Intelligence. On the other hand, for what concerns the tasks which use creativity and genius, they will be progressively included in the superstar category.

The second part of the same table shows the trend of the rate of change with respect the initial steady state of wage premium, both wage superstars with respect to that of routinized labour (WHR) and the wage of superstars with respect to that of non-routinized skilled workers (WHNR). Both, coherently with the expectations, show negative rates of variations, more pronounced for WHR, due to the suggested insertion by *Industry 4.0:Skills Achievement* of new superstar workers from the routinized skilled category.

III.3.5: R&D intensity, Debt to GDP ratio and Trade Balance

An indicator that can be considered relevant for the growth perspectives of the country, since linked to the sector from which the mechanism of endogenous growth has its origins, is the R&D intensity, represented in Table III.3.5.1 by variable

B_RDINT(.) obtained in the simulations with QUEST III B and scenarios 1 and 4. The percentage change of this variable with respect to the baseline in the hypothesis *Industria 4.0: Skills Achievement* B_RDINT(1) is always negative. In particular in 2017 the value is of -1.406 and it diminishes in 2018 to -1.684 and then it gradually increases till the 2025 to fall down to -2.134 in the long run.

This outcome seems to be non-coherent with the consideration that with the digitalization the number of patents increases generating a higher R&D intensity. However the negative trend of our results for this variable arises from the fact that the price of output decreases lower than the price of patents in the value of patents/value of output ratio as shown by variables B_PPAT(1) and B_PY(1) in Table III.3.5.1. They show in quantitative terms the fact that prices of production (PY) diminish because endogenous growth increases the production and provokes a decrease in prices, and the price of R&D (PPAT) decreases because more patents are produced and so the endogenous growth process is generated. However in this case the price of R&D under goes a faster decrease with respect to that of production.

	2017	2018	2019	2020	2025	Lonc run 2031
			Industria 4.0: " Skills Achievement"			
B_RDINT(1)	-1.406	-1.684	-1.463	-1.341	-1.330	-2.134
B_DTY(1)	-0.029	0.609	0.951	1.077	0.699	-0.135
B_PPAT(1)	-1.096	-1.525	-1.597	-1.757	-2.704	-3.653
B_PY(1)	0.078	0.057	0.010	-0.016	-0.113	-0.130
			Industria 4.0 "Innovative Investments"			
B_RDINT(4)	1.639	1.381	1.111	0.986	0.444	0.279
B_DTY(4)	0.485	3.176	3.044	1.769	-1.105	-1.005
B_PPAT(4)	1.710	1.145	0.878	0.888	0.680	0.719
B_PY(4)	0.050	-0.065	-0.194	-0.266	-0.407	-0.340

Table III.3.5.1: R&D intensity Debt to GDP ratio Price of Patents Output Value in QUEST III-B, first and fourth scenarios, *high* hypothesis,(percent changes w.r.t. baseline; annual results)

On the contrary, in the hypothesis Industria 4.0: Innovative Investments, the variable R&D intensity, B_RDINT(4) in Table III.3.5.1, always takes positive values coherently with the consideration following that through digitalization the number of patents increases and generates an higher R&D intensity; even if this happens with a decreasing trend that goes from 1.639 in 2017 to 1.381 in 2018 to 0.279 in the long run, probably due to the fact that existent infrastructures are not able to substain that rhythm in the growth of patents.

The debt to GDP ratio is for sure one of the indicators of leading importance also with regard to foreign operators. In Table III.3.5.1 this variable appears as B_DTY(1) and B_DTY(4) in simulations QUEST III first and fourth scenarios. With reference to the measures Industria 4.0: Skills Achievement it is shown in 2017 a negative variation of -0.029 that becomes positive the following year (0.609), it continues its increasing trend (0.951 in 2019, 1.077 in 2020) and decreasing from 2025 (0.6999), to become negative in the long run (-0.135). With reference to the measures Industria 4.0: Innovative Investments, in 2017 there is a percent variation of 0.485 to take a value higher than 3 in the following two years and negative from 2025.

	2017	2018	2019	2020	2025	Long run 2031
			Industria 4.0: "Skills Achievement"			
B_TOT(1)	-0.160	-0.310	-0.388	-0.434	-0.556	-0.719
B_TBY(1)	0.005	0.139	0.200	0.216	0.186	0.109
			Industria 4.0: "Innovative Investments"			
B_TOT(4)	-0.256	-0.489	-0.563	-0.568	-0.388	-0.365
B_TBY(4)	0.053	0.237	0.274	0.219	0.007	-0.027

Table III.3.5.2: Terms of Trade and Trade Balance in QUEST III-B,
first and fourth scenarios, *high* hypothesis,(percent changes w.r.t. baseline; annual results)

Beyond the debt to GDP ratio and R&D intensity also the simulations referred to variables Terms of Trade have a substantial importance in the relationship with the international community. These are shown in Table III.3.5.2. Variable B_TOT(.) shows the simulations linked to trends of Terms of Trade as ratio between price index of Italian exports and imports.

Simulated results for *Industria 4.0:Skills Achievement* regarding Terms of Trade are shown in Table III.3.5.2 using variable B_TOT(1). They indicate a progressive worsening of Terms of Trade from -0.160 in 2017 to -0.719 in the long run. Analogously the negative trend is shown in results for *Industria 4.0:Innovative Investments*.

The percent variation of this variable with respect to baseline is always negative, therefore there is a worsening of the Terms of Trade,(increase of prices of imports with respect to that of exports). The reason can be found in the fact that Italy for the import of Know how and high tech equipment is more and more integrated with abroad.

With reference to the Trade Balance in the two hypothesis of scenario represented by variables B_TBY(1) and B_TBY(4) is shown that the percent variation with respect to baseline is always positive. This result is linked to the fact that prices of imports increase and exports are cheaper. The trend will be to decrease import and export more, except for cases of rigid demand goods.

Differently from what is happened within the main industrialized, from 80s, and in more recent years in a significative amount of north European countries, in Italy the increase of the technological intensity of manufacturer imports hasn't found an adequate balance in the increase of technological intensity of exports. Commercial deficits of the country in high tech productions derive from a structural disequilibrium between demand of technology – coherent with that of countries high industrialized- and supply of technology, and the widening of this gap in the long run is nothing but the result of the worsening of this disequilibrium. The dependence of the innovative processes from the use of instrumental goods, which are the major component of the high tech production, has worsen this disequilibrium.

III.3.6 Emerging Remarks

Simulations of *Industria 4.0:Skills Achievement* appear largely unsatisfying since employment, wage and wage premium show negative rates since the very beginning of the simulation horizon. This also happens with regards to production that grows only in the long run. The overcharging burden of public expenditure resulting from the number of workers to be educated, seemingly causes a crowding out effect on the consumption expenditures of both non liquidity and liquidity constrained households in the short and in the medium term. This event has suggested reducing the numbers of workers to be shifted into the superstar category. In the new simulation the shift of workers reduces the number of workers to 150,000.

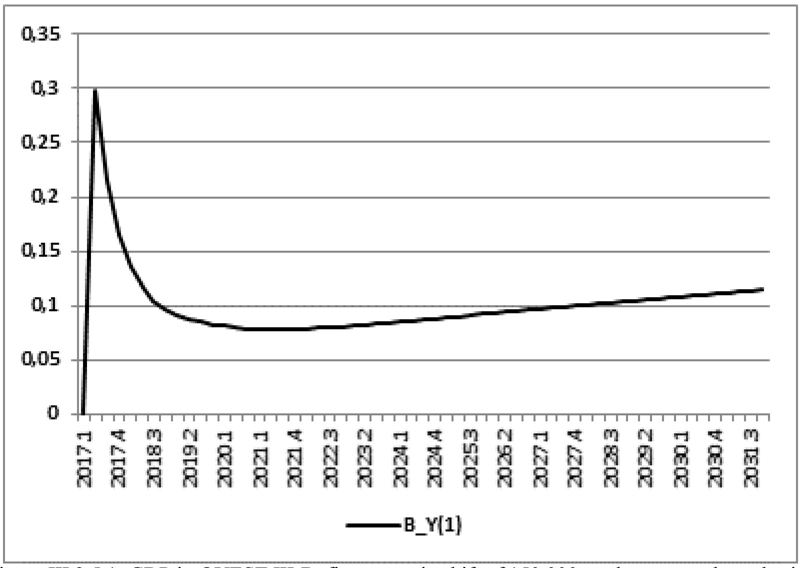

Figure III.3.5.1: GDP in QUEST III-B, first scenario,shift of 150,000 workers, *norm* hypothesis, (percent changes w.r.t. baseline; quarterly results)

Form Figure III.3.5.1 GDP growth in this case of reduction of the workers shift, appears lower than in the case shown in Figure III.3.1.1, so that in terms of GDP growth is less effective since it stabilizes slightly over 0.1 in the long run. However the this shift appears more effective from the employment and wage standpoint.

Results on wage, employment and wage premium are presented in Figures III.3.5.2, III.3.5.3 and III.3.5.4.

The percent change in wages for superstar and non-routinized skilled take positive values in the initial period (until 2023). The higher values of the wages of superstar workers is due to the fact that superstar workers supply is low, because of the unavailability of this category of workers in the initial years.

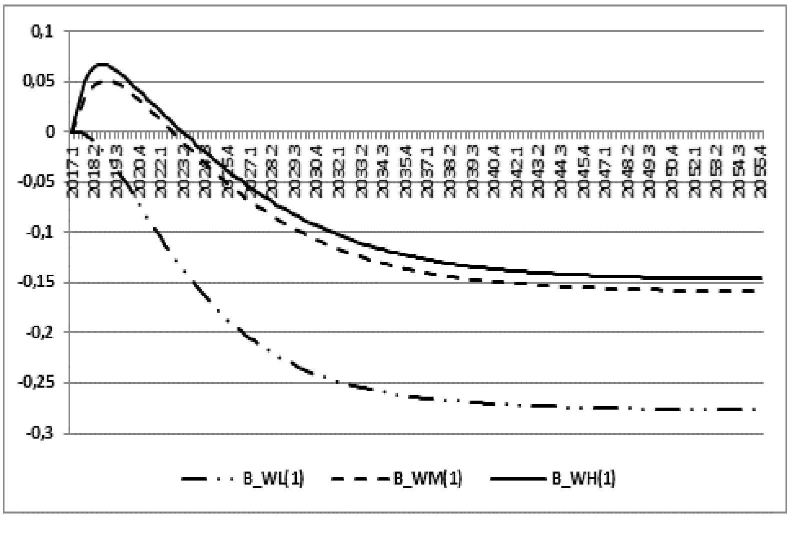

Figure III.3.5.2: Wages in QUEST III-B, first scenario,shift of 150,000 workers, *norm* hypothesis, (percent changes w.r.t. baseline; quarerly results)

While in the medium /long term, as education progresses, it tends to diminish and stabilize around a non positive rate of -0.1 %. The percent change of the wages of routinized skilled workers assumes negative values since the very beginning of the period given the sostituability of this work category with machineries stabilizing in the long period around -0.27%.

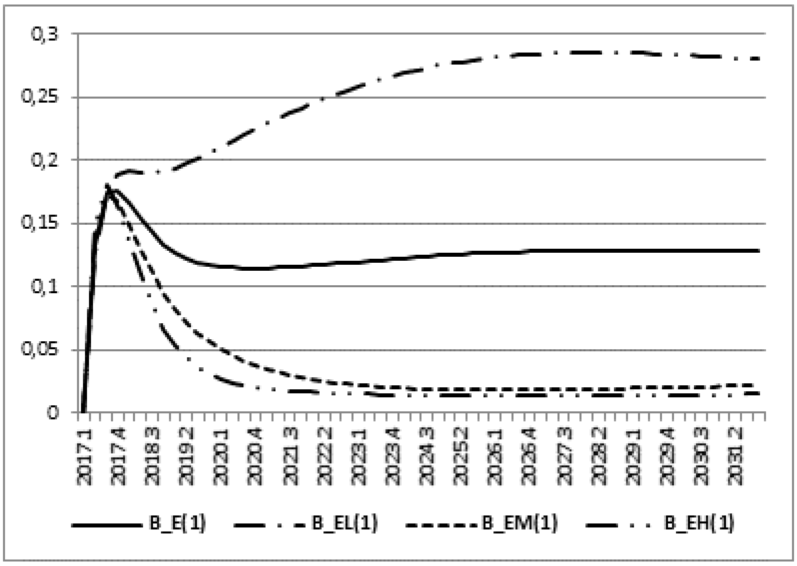

Figure III.3.5.3:Employment in QUEST III-B, first scenario, shift of 150,000 workers, *norm* hypothesis, (percent changes w.r.t. baseline; quarterly results)

As shown in Figure III.3.5.3 routinized skilled employment increases for the reasons already mentioned in the discussion of Figure III.3.3.2. For the other employment categories, in the long period, the rate of change keeps always positive, even if more limited with respect to the values in the initial period. This linked to the fact that when education operates, a larger number of skilled workers progressively are available. This fact shows that the tecnologic structure in Italy is less efficient in maintaning the initial employment rate of change.

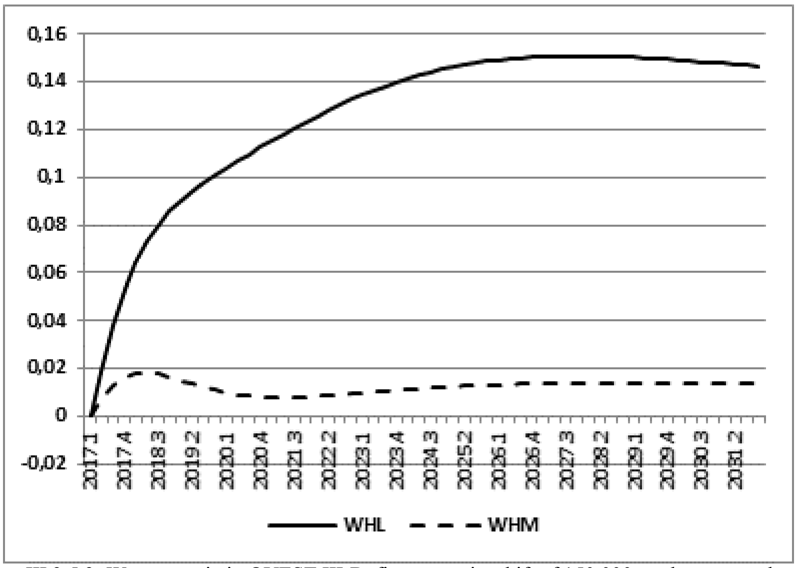

Figure III.3.5.3: Wage premia in QUEST III-B, first scenario, shift of 150,000 workers, *norm* hypothesis, (percent changes w.r.t. baseline; quarterly results)

Wage premium also takes positive change rates, the wage premium of superstar on the routinized is higher than that on the non-routinized skilled workers. This is consistent with the skill premium theory and then of the premium for education given to the superstar workers. The prevalent viewpoint about the firm, assumed in the National Plan Industry 4.0, is merely technical, somehow inspired by most traditional visions. That belief is based on the idea that it is possible to invest on skills of workers without a robust investment in infrastructures, able to make effective new entrepreneurial models, earlier than the implementation of new technologies.

Government has not been able to build satisfactorily an educational and formative system that answers to the needs of economy and society. The full-blown learning by doing has been actuated in a mere school-job alternance that did not permit to integrate the formative and working aspects maintaining the separation of the three worlds: school, university and firm.

Conclusions can be delineated in a way that considers 200,000 a valid choice for economic growth but it has to be supported by effective infrastructural investments able to absorb and make effective the high skilled work of the newly educated people.

Conclusions

The economic context of developed countries has been recently exposed to radical changes. This applies also to the interaction between economics, society and technology. Such relevant transformations have led the scholarly opinion to refer to the notion of Fourth Industrial Revolution to delineate such changes.

The realization of the maximum growth rate in the traditional economic sectors that, in the past, have warranted high growth rates of GDP and welfare reveals nowadays has become unsuccessful and fruitless target for a developed economy. These circumstances are complicated by a context that rather seems to warrant a zero growth, in spite, or maybe because of, the rapid process of digitalization.

For many scholars the only way out is to be found in the empowerment of the innovative role of the technological progress. However, the traditional views on the role of technology within the economic structure somehow appears obsolete and ineffective.

In studying the role of technological progress, the traditional growth theory often relies on the idea of neutral technical progress. Therefore, also under the profile of the methodological instruments of analysis, the shift from the traditional theory of growth to a context with innovation requires some reconsideration.

Workers with different degrees of competences may eventually condition the productivity of the physical capital. This fact stresses the relevance of human capital, skill, and innovation spillover diffusion. This logic path transforms the neutral technological change into skill biased technological change, a related topic of the digitalization.

European countries seem to see the innovation as the unique solution to the problem of growth, each of them in similar terms but with different priorities. For that reason, we have observed, in the last years, a flourishing of initiatives aimed both to limit the possible drawbacks and to prospect interventions aimed to redefine the issue of growth in a context of innovation. The majority of European countries has faced the shift from the ICT era to that of digitalization, the main features of the third and fourth industrial revolution, with the design and the implementation of national plans for facilitating growth. In Italy, the government reforms, known as “Industria 4.0”, try to give an answer on the two fronts.

All these topics, that have been referred and described in detail in the first half of the thesis, have led to the choice of the QUEST III-Italy as the simulation tool for analysing the results of the policy measures *Industria 4.0* on the main macroeconomic variables, and for proposing further variants of the model.

Separate simulations of the two policy scenarios emerging from *Industria 4.0,* i.e. *Industria 4.0: Innovative investments* and *Industria 4.0: Skills Achievement,* lead to the conclusion that measures Industria 4.0: Innovative Investments are likely to have effects which finish in a shorter term than those generated by measures of *Industria 4.0: Skills Achievement*. Measures *Industria 4.0: Skills Achievement*, even if producing more limited growth rates until 2025, generate an higher GDP growth rate, after that year.

However simulations with *Industria 4.0: Skills Achievement* scenario seems to suggest a reduction in the planned number of workers to be shifted into the high skilled category as if the technology at hand would somehow refuse, in terms of low GDP growth, a change in the skills of the amount proposed. They seem to launch doubts on the strength of the Italian technological potential and on its ability to provide the proper support to a growth heavily driven by digitalization.

In addition, the application has proposed two modifications to the model. In the first, productivity increases of the physical capital, due to the *spillovers* of new ideas are introduced (QUEST III-A). In the second, endogenously determined skill shares are added (QUEST III-B). This allows for the analysis of complementarity of high skilled and medium skilled workers with technology and of substitutability of low skill workers with technology.

With reference to GDP, from the comparison between the trend of GDP growth rates in the original model with that in the modified models, it emerges that, in the scenario *Industria 4.0: Skills Achievement* the effect on GDP, in the first periods is lower than the GDP growth rate in the original model. This is due to the fact that the immediate effect is that of depriving the final goods sector of workers, who need to be educated and acquire a higher level of skills, before being hired in the R&D sector. The effect deriving from the more productive capital utilization, due to R&D spillovers, emerges in the longer run. This expansive effect holds also in the simulation *Industria 4.0: Innovative Investments* after a first period of analogous growth rates in the two models. The introduction of this characteristic allows highlighting the different connotation of technological progress as “non neutral” or, rather, “skill biased”.

For what concerns employment and wages, we can observe, in the results, the more pronounced crowding out of the category of medium skilled (non-routinized) workers, rather than that of low skilled (routinized) workers, as we could expect from the initial hypothesis of the model. However, the crowding out of the non-routinized workers is not contrary to the theory and, in addition the trend of low skilled workers in the long run in consistent with the initial hypothesis of the model.

In relation to the presence of skill biased technological change the results of wage premium confirm that the size of the non-routinized skilled tasks tends to decrease and that the category will be progressively absorbed in the low skilled one, in relation to the tasks to be assumed by the artificial intelligences. The tasks that require the use of creativity and intellectual skills will be progressively included in the high skilled category.

In a perspective of future development and of larger data availability, the study of wage premium may become the key issue in the research and identification of skill bias imposed by the technological change under both a technological and redistributive profile.

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APPENDIX

APPENDIX: Changes performed on the Dynare code for variant B of QUEST III-Italy

```
#####

15 %New variables of the variant of QUESTIII-RD Italy
16 var IT_SPILL;
17 var IT_SHY  IT_SLY IT_SMY;

#####

112 model;
113 IT_CNLC = exp(IT_EPS_CNLC)*1/((1+IT_INOM-IT_INFC(1)-
114
IT_THETA)*(1+IT_TVAT)/(1+IT_TVAT(1))+IT_HAB)*(IT_CNLC(1)+IT_HAB*(1+IT_
INOM-
115 IT_INFC(1)-IT_THETA)*(1+IT_TVAT)/(1+IT_TVAT(1))*(IT_CNLC-
IT_DCNLC)) ;
116 Consumption, non-liquidity constrained households
117 IT_F = IT_B/IT_PY+IT_E*IT_BW/IT_PY+IT_V*(1+IT_EPS_V) ;
//Financial
118 wealth
119 IT_LAMNLC = IT_UCNLC/((1+IT_TVAT)*IT_PC/IT_PY) ;    //Lagrange
120 multiplier, non-liquidity constrained households
121 IT_UCNLC = (1-IT_HAB)/(IT_CNLC-IT_HAB*(IT_CNLC-IT_DCNLC)) ;
//Utility
122 function derivative wrt. consumption, non-liquidity constrained
households
123 IT_CLC = (1-
IT_TLL)*IT_WRL*IT_LL*IT_PY/(IT_PC*(1+IT_TVAT))+IT_BENL*(1-
124 IT_NPARTL-IT_LL)/(IT_PC*(1+IT_TVAT))+IT_TR/(IT_PC*(1+IT_TVAT))-
125 IT_TAX/(IT_PC*(1+IT_TVAT))+IT_EPS_CLC ; //Consumption, liquidity
constrained
126 households
127 IT_LAMLC = 1/IT_CLC/((1+IT_TVAT)*IT_PC/IT_PY) ;    //Lagrange
multiplier,
128 liquidity constrained households

#####

155 IT_LCES = (IT_SLY^(1/IT_SIGMA)*(IT_EFFL*IT_LLY)^((IT_SIGMA-
156 1)/IT_SIGMA)+IT_SMY^(1/IT_SIGMA)*(IT_EFFM*IT_LMY)^((IT_SIGMA-
157 1)/IT_SIGMA)+IT_SHY^(1/IT_SIGMA)*(IT_EFFH*IT_LHY)^((IT_SIGMA-
158 1)/IT_SIGMA))^(IT_SIGMA/(IT_SIGMA-1)) ;    //Labour CES-aggregate
159 IT_LLY = IT_SL*IT_LL ;    //Low-skilled in final goods sector
160 IT_LMY = IT_SM*IT_LM ;    //Medium-skilled in final goods sector
161 IT_LHY = IT_SH*IT_LH-IT_LRD ;    //High-skilled in final goods
sector
162 IT_WRL = IT_WL/IT_PY ;    //Real wage, low-skilled
163 IT_WRM = IT_WM/IT_PY ;    //Real wage, medium-skilled
164 IT_WRH = IT_WH/IT_PY ;    //Real wage, high-skilled
165 IT_WCES = (IT_SLY*IT_EFFL^(IT_SIGMA-1)*IT_WL^(1-
166 IT_SIGMA)+IT_SMY*IT_EFFM^(IT_SIGMA-1)*IT_WM^(1-
167 IT_SIGMA)+IT_SHY*IT_EFFH^(IT_SIGMA-1)*IT_WH^(1-IT_SIGMA))^(1/(1-
IT_SIGMA)) ;    168 //Nominal wage, CES-aggregate

#####

204 IT_K = IT_SPILL*(IT_I+(1-(IT_DELTA+W_GTFP+W_GPOP))*(IT_K-IT_DK));
```

```
//Private capital accumulation
(IT_GAMI+IT_EPS_I)*(IT_I/IT_K-
(IT_DELTA+W_GTFP+W_GPOP))+IT_GAMI2*IT_DI-1/(1+IT_INOM-
IT_INFC(1))*IT_GAMI2*IT_DI(1) =IT_SPILL*IT_Q-1 ;    //Q
(1-IT_TC)*(IT_IK*IT_UCAP-DYN*(IT_A1*(IT_UCAP-1)+IT_A2*(IT_UCAP-1)^2)-
IT_EPS_RPREMK)+IT_TC*IT_DELTA = (1+IT_INOM-IT_INFC(1))*IT_Q-(1-
IT_DELTA)*IT_SPILL(1)*IT_Q(1) ;    //Rental rate of tangible capital
```

#####

```
%New equation related to positive spillover of knowledge on new investments
and the existing stock of capital
IT_SPILL=max(1,exp(0.00546*(IT_PAT-1)));
%extra eq #1
IT_SHY=(exp(-2.459485414+0.08*(IT_PAT-1)))/(1+exp(-2.459485414+0.08*(IT_PAT-
1))+exp(0.283030039+0.06*(IT_PAT-1)));
%extra eq #2
IT_SMY=(exp(0.283030039+0.06*(IT_PAT-1)))/(1+exp(-2.459485414+0.08*(IT_PAT-
1))+exp(0.283030039+0.06*(IT_PAT-1)));
%extra eq #3
IT_SLY=1/(1+exp(-2.459485414+0.08*(IT_PAT-1))+exp(0.283030039+0.06*(IT_PAT-
1)));
end;
@#define simul_vec = ["TC_SCHOOL17",”TC_INDUS11”]
@#FOR simul_type in simul_vec
```

#####

```
@#IF simul_type == "TC_SCHOOL17"
%phasing -in 1100 quarters
T=1100;
%create the policy vector
shock_vec=zeros(T,1);
for j=1:160
%0.021323/160
size=0.00013327*j
shock_vec(j,1)=size;
end;
for j=161:1100
size= 0.021323;
shock_vec(j,1)=size;
end;

shocks;
var IT_SL;
periods 1:1100;
values(0.500331465483312-shock_vec);

var IT_SH;
periods 1:1100;
values(0.031399192+shock_vec);

var IT_EPS_G;
```

```
periods 1:1100;
values(0.005);

end;
@#endif

@#IF simul_type == "TC_INDUS11"

%phasing -in 1100 quarters
T=1100;
%create the policy vector
shock_vec=zeros(T,1);
for j=1:20
%0.0043/20
size=0.000215*j
shock_vec(j,1)=size;
end;
for j=21:1100
size= 0.0043;
shock_vec(j,1)=size;
end;

shocks;
var IT_A;
periods 1:1100;
values(1+ shock_vec);

var IT_TC;
periods 1:4, 5:8;
values 0.1243,  0.2663;
var IT_EPS_TLL;
periods 1:1100;
values(-0.0002);
end;
@#endif

#####

simul(periods=1100);
save quest3_simul_IT_@{simul_type} IT_*;
@#endfor

load 'quest3_simul_IT_TC_SCHOOL17.mat';

filename =
'C:\Clio\Esercizio0407\quest3_simul_IT_TC_SCHOOL17.xlsx';


xlswrite('C:\Clio\Esercizio0407\quest3_simul_IT_TC_SCHOOL17',[(IT_Y -
1)/1*100 (IT_C-0.57186437064952)/0.57186437064952*100 (IT_I-
0.209354975749922)/0.209354975749922*100 (IT_L-
0.630451545905025)/0.630451545905025*100 (IT_BYRATIO -1.0519)*100
(IT_CNLC- 0.829381339784789)/0.829381339784789*100 (IT_CLC-
0.314688607264936)/0.314688607264936*100  (IT_LL-
0.5196)/0.5196*100
(IT_LM-0.7368)/0.7368*100 (IT_LH-0.8108)/0.8108*100 (IT_PAT-
1)/1*100
(IT_WL-0.729826925265862)/0.729826925265862*100 (IT_WM-
0.923831550969445)/0.923831550969445*100 (IT_WH-
```

```
1.2680242681727)/1.2680242681727*100 (IT_EX-
0.257448017680174)/0.257448017680174*100 (IT_IM-
0.257448017680174)/0.257448017680174*100 (IT_WHLRATIO-
1.73743147077067)/1.73743147077067*100 (IT_WHMRATIO-
1.37257086190883)/1.37257086190883*100 (IT_PPAT-
0.458333333333333)/0.458333333333333*100]);
```

#####