THE NEW TRIANGLE OF KNOWLEDGE, TECHNOLOGY AND EDUCATION
AN ITALIAN PERSPECTIVE

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ABSTRACT
The ongoing technology revolution brings forth large possible benefits, but also grave potential risks. Education is key to transform this critical moment of change into a favourable phase of creative innovation and sustainable growth. The knowledge paradigm is taking shape: human capital and technological advance are the pillars to transform economies and societies. Significant investment in good infrastructures – broadly defined - is indispensable. In the past two decades Italy lagged behind not only in terms of insufficient, but also inefficient, infrastructure accumulation. In particular, university/technology education was heavily penalized. This paper offers an analytical framework and outlines solutions for these challenges with specific focus on the role and characteristics of online teaching and learning models in the knowledge society.

KEYWORDS: Cognition, cyber-physical systems, digitization, industrial revolution, intangible capital, knowledge economy, physical capital, servitization, trias politica

INTRODUCTION
We must be grateful to GUIDE for the identification of the theme of this Conference. The emerging technology revolution brings forth huge possible benefits, but also grave potential risks. Education is key to transform a critical moment of change into a favourable juncture for advancement at national and global level, to tame the Schumpeterian (1942) “gale of creative destruction”. Automation and cyber-physical systems will replace workers not only in industry, but across the entire economy. According to estimates presented by the World Economic Forum and its President Klaus Schwab (2017), nearly half of existing jobs could be at risk, but the potential new jobs can more than match this massive displacement.

The specific reference to Industry 4.0 (Roser, 2015; 2016) helps identify the current revolution, but it is perhaps too narrow. Let me broaden the reference scenario from three angles:

1. the perspective of the whole socio-economic system
2. the new features of “servitization” and of “digitization"
3. the “knowledge economy” (par. 2)
To start with the common indication of four technological revolutions (Fig. 1) is too narrow in scope.

Along with many other authors on the epistemology of applied science advance (Kuhn, 1970; Masera ed., 2010), I prefer to identify six overlapping long waves of economic and social innovation, starting with the fixed-steam machines at the end of the 18th century.
The successive technology waves made for dramatic changes in the proportion of workers moving from the primary sector (agriculture, mining) to the secondary sector (industry, manufacturing, construction). More recently a massive shift occurred towards the service industry which comprises banking, insurance, finance, public services, healthcare, tourism, etc.

Currently, with what I indicated as the sixth global wave, the knowledge economy is taking shape. It centres on information technology, education, scientific research, human capital and e-government (some have coined the term of quaternary sector to mark the change). These factors drive human capital and technological advancement and are key in transforming our economies and societies, in making it possible to fully exploit the potential unleashed by the cyber-physical systems and the internet of systems.

The new wave of innovation, as I shall try to show, impacts not only industry, but all sectors of the productive system. Digitization and servitization blur and reshape the boundaries of economic sector and the features of value chains. A holistic network approach is critical to understand and guide the processes in the new complex/interactive socio-economic systems. In this perspective, the importance of good universities and technology-advanced, cost efficient education becomes critical.

The common key distinction between goods and services, summarized in Table 1, fades.

<table>
<thead>
<tr>
<th>Services</th>
<th>Goods</th>
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<tbody>
<tr>
<td>Intangible</td>
<td>Tangible</td>
</tr>
<tr>
<td>Heterogeneous</td>
<td>Homogenous</td>
</tr>
<tr>
<td>Produced in Buyer Seller interaction</td>
<td>Produced in factory</td>
</tr>
<tr>
<td>Production, distribution &amp; consumption takes place simultaneously</td>
<td>All three are separate &amp; independent</td>
</tr>
<tr>
<td>Consumers participate in production</td>
<td>Consumers don’t generally participate</td>
</tr>
<tr>
<td>Cannot be stored Can be stored</td>
<td>Cannot be stored Can be stored</td>
</tr>
<tr>
<td>Transfer of ownership cannot take place</td>
<td>Transfer of ownership does take place</td>
</tr>
</tbody>
</table>

Table 1. The traditional separation of goods and services
Source: H. Bush (2016)
The system becomes characterized by a continuum of goods and services, increasingly “bundled” together. Pure goods and pure services loose importance. This has profound implications for economic analysis, which have not yet been fully systemized. In the classical economy – Smith, Ricardo, Marx, and also in the view of key neoclassical economists, Marshall, Walras, Pareto – the focus was on the production of goods by means of goods. Services were considered of secondary importance: “Services pass out of existence in the same instant that they come into it and are of course not part of the stock of wealth” (Marshall, 1920). These models were superseded by the services wave. In turn, this was regarded as one of the causes of declining productivity growth. Baumol (1962) showed that the secular increase in services – with inherent lower productivity growth – would necessarily undermine the dynamics of total factor productivity.

The knowledge economy and the bundling of goods and services lead to a different paradigm. An example of the new boundaries is offered precisely by the models of e-Teaching and e-Learning. The traditional university lesson disappeared as it was given, according to the Marshall model. The e-Lesson is now stored and made available through different e-platforms over time and space. It can be “consumed” by the students endlessly and everywhere: it becomes therefore a parcel of the available stock of knowledge. A new service/product is brought into existence: a “durable” cost efficient good/service replaces the “perishable” service. Constant interaction between teachers and students (digital teaching and learning), also through “virtual c@mpuses” (Unimarconi model), and reference to MOOC benchmarks, see for instance Lori Breslow and Coursera, permit and require real time improvement and update of lessons (Breslow et al. 2013; Coursera 2018).

Similar innovation processes take place in respect of many intangibles, which acquire and require physical and electronic characters and become therefore akin to manufacturing products. Many examples could be explored: mobile communications, the automotive sector (where cars have more than half of their value embedded in electronic components, software and connecting instruments, leading to virtual driving). e-Commerce (i.e. Amazon) is another instance of the bundling between goods and services. Rolls-Royce aerospace industry with “power by the hour” has changed the value creation model of a typical industrial firm. Netflix and Spotify deliver media services which replace the need of buying Cds, DVDs, -products. Phillips offers a service LED lighting proposition package to airports (i.e. Schiphol).

In sum, “servitization” becomes a key feature of the new production systems, with technological innovation bundling together industry and services.

“Digitization” is the key corresponding enabling process which is based on the transformation of analogue into discrete digital values in all areas and sectors (Schumann et al. 2018). This was the basis of the internet revolution, which made it possible to blend physical and digital assets. Value creation chains changed and new business models emerged. Dynamic integrated platforms were created by linking together hardware, software and content provisions (Coreynen et al. 2016; Vendrell-Herrero et al. 2017; Gilli 2018).
THE NEW TRIANGLE OF KNOWLEDGE

The knowledge economy can be seen as an extension of the information/internet society (the fifth wave in Fig. 2). The concept was in fact introduced by Peter Drucker (1969) “from Manual to Knowledge worker”, who credits Fritz Machlup for developing his approach. Knowledge generates economic - tangible and intangible – value, which can be incorporated into machines. Knowledge and education become human capital, which is the key productive asset, embodying a large proportion of technical progress. This leads to a total rethink of the original Solow production function paradigm (Solow, 1956).

Comparative advantage gives way to competitive advantage. The traditional workers must acquire specialized computer literacy: the education system correspondingly adapts towards STEM (Science, Technology, Engineering, Math) training. More generally, continuous innovation requires lifelong learning with corresponding changes in teaching techniques and skills. The fundamental difference between knowledge and information societies lies in the capacity to select, transform and enact information into true knowledge and effective action. In turn, this requires adapting and networking all key infrastructures of the system.

Human, physical and computational elements give rise to embedded systems. Similar new architectures are behind both Cyber-Physical Systems (CPS), the Internet of Things (IoT), and the Internet of Services (IoS). A well-known example is the so-called 5C architecture (Connection, Conversion, Cyber, Cognition, Configuration).

![Figure 3. 5C Architecture](source: Bagheri B. and Lee J. (2015))
As the US National Science Foundation (2018) aptly put it: “CPS technologies are transforming the way people interact with engineered systems, just as the Internet has transformed the way people interact with information. New, smart CPS drive innovation and competition in a range of application domains including agriculture, aeronautics, building design, civil infrastructure, energy, environmental quality, healthcare and personalized medicine, manufacturing, and transportation... with major societal implications”.

In the knowledge economy highly-skilled, constant-learning, managers and workers are the drivers of value creation and of oversight of CPS. A necessary condition for a firm to be successful is to become a “learning factory”. Unskilled labour will inevitably become less valuable and will be increasingly displaced by low-wage workers and machine competition. Socio-economic tensions are inherent in this complex process of creative destruction: managing these risks is key in today’s global risk environment (Figure 4).

Figure 4. Global risks 2018
Good infrastructures – broadly defined - play a crucial role for economic and social development in the knowledge paradigm (Masera, 2017). Adequate investment in infrastructures is indispensable for supporting companies and public administration in the current evolutionary process, characterized by significant break points. These infrastructural requisites involve innovation, research and development, and human capital, beyond physical capital (Figures 5 and 6). The two types of capital are also “bundled”. The aforementioned arrays (servitization, digitization and twin capital) create a new economic and societal paradigm and pose critical challenges. It is estimated that at world level, over the next two decades, some $60 trillion worth of new infrastructure investments are required: the key is to create good infrastructure in a deepened fruitful partnership between public and private sources.

Figure 5. The infrastructural system: physical capital and intangible capital
A. **Public utility and service systems**

- Legislative, executive and judicial activities (*trias politica*) and public order
- Education system and universities
- Healthcare system
- Selection and financing mechanisms for infrastructure development
- Protection and management systems for environmental, cultural, artistic and historical resources (including green infrastructure)
- Civil protection system
- National defense network
- Financial infrastructures

B. **Physical infrastructure**

- Transport networks (roads, railways, airports, ports and inland waterways)
- Energy networks and infrastructures (electricity, gas, oil)
- Renewable energy and smart grids
- ICT capital
- Aqueducts and water mains
- Networks for integrated waste management
- Land protection infrastructure
- Urban infrastructure

C. **Research & development and innovation facilities**

- Knowledge capital and technology
- Laboratories and research facilities
- Scientific and technological parks
- Patents, trademarks and copyrights
- Software systems and organizational methods

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*Figure 6.* The infrastructures of a country-system broadly defined
Investment in knowledge and research plus selection of human capital according to the principles of ability and merit are fundamental for activating and sustaining virtuous circles of innovation, productivity, competitiveness, and employment.

The above considerations show that massive investment is needed in innovation, infrastructures, and human capital, in Europe and especially in Italy. The close to zero growth rate of labour productivity in Italy over the last twenty years is at the root of not just economic but also social deterioration and one of the causes of the unsustainable increase in the debt-to-GDP ratio. In order to increase labour productivity, we must review EMU and domestic economic policies (Cardinale et al. eds. 2017; Cardinale and R. Scazzieri eds. 2018), but before doing so, and more urgently, Italy must find a lasting solution to the twisted web of corruption, which contaminated public investment in infrastructures in the past decades. The creation of the National Anti-Corruption Authority (ANAC) in 2014 is a highly positive development. The corruptive, illegal processes in public spending for investment destroy wealth and affect productivity, and its capacity for growth and reabsorption of unemployment. When corruption, illegality, and criminality are not only manifest, but even overpowering, and when moral values decline, the inevitable result is a dearth of economic and social growth.

The Trias politica, namely the relationship between democracy, politics, government, the judicial authorities, and law enforcement bodies, represents the basic infrastructure of a civil economic society. Successful interaction and efficient investment in physical as well as R&D infrastructures and human capital - the good infrastructure/innovation nexus - is closely linked to the correct functioning of the Trias politica (Figure 8).
A country’s infrastructures are made up of physical and intangible capital stocks, fed over time by investment flows. Although mainly headed by the public sector, these flows will have to link efficiently with private investment, notably in terms of the “PPP” formula (Private–Public Partnership), and especially in Europe, because of the EU commitments aimed at reducing and reallocating public expenditure as well as diminishing the public debt. The functions of the trias politica extend over a number of powers, that include drawing up good laws and enforcing them; sustaining crime prevention and punishment against illegality.

Figure 8. Democratic society, rule of law, and market economy: prototype links in Italy. The trias politica as a pivotal system infrastructure. An interpretation of Montesquieu (1748)
If we compare the levels and quality of Italy's investment in education in the past decade with international data, the results are bad in absolute terms, not withstanding some positive exceptions. I cannot offer here exhaustive figures, preferring rather to quote, in no particular order, data and statistics mainly from OECD sources (Education at a Glance, 2017).

Graduates in Italy total just 18% compared with a 37% average in other OECD countries. We are last in Europe, far behind not only Germany and France, but also Spain and Portugal, for example. Switzerland stands at 41%, the United Kingdom and United States at 46%. Degrees are mainly concentrated in faculties with little value for the labour market - the arts, philosophy, sociology, and communication sciences - while degrees in all the scientific subjects and also in economics are relatively few and far between. Therefore only a few graduates (25% against, for example, 37% in Germany) leave university with the qualifications that today offer the best job prospects, above all in the Industry 4.0, Fintech, and e-government sectors mentioned above. Finally, there is a lack of STEM graduates (see also Cantoni, 2018). Women are especially penalized because their degrees are mainly in sectors with lower demand on the job market. The quality of public spending in education is questionable, also because today we are seeing the number of "short" diplomas and degrees encouraged and preferred, rather than strict ascertainment of preparation levels, in line with a misleading concept of productivity. Italy is in last place in the OECD area also in terms of overall spending with just 7.1% of total public administration expenditure reserved for education, almost 10% less than in 2010.

Teachers and lecturers earn less than in almost all European countries. Austerity has hit schools particularly hard and Italy is the only country in the OECD area that has allocated the same amount to the support of primary and secondary education since 1995. Eurostat confirms that Italy is also in last place in terms of percentage of public spending on education in the EU. In our country, more than one youngster out of five aged 15 to 19 is unemployed, does not study or follow any kind of professional training course: we hold the sad record in Europe for NEETs (Not Engaged in Education, Employment or Training), with the emerging risk of Hikikomori syndromes (Crepaldi, 2018). The vicious circle started and fuelled by the above summarized trends is particularly worrying. An OECD survey called PISA (Programme for International Student Assessment) reveals that students are often no longer interested in a university education, yet another aspect that emphasizes Italy's negative trend. Education models are adopting IT and tech innovation tools and methods and many countries are doing this; Italy lags behind also from this point of view notwithstanding early warnings and indications on the need to develop this type of education (Briganti, 1998; 2014; Masera, 2014).

Even if this is clearly not the focus of our Conference, let me indicate that similar considerations can be made with reference to the quantity and quality of investments in physical infrastructures in Italy. Not only has spending on this type of investment dropped greatly (by 30% over the last five years), but the accounting-financial data are overestimated, as only part of the money actually spent translated into an increase in the value of capital because investments were not selected in terms of social and private returns. Non-transparent and inefficient processes in tender procedures, and corruption led to an unacceptable increase in work duration and costs, as documented by the OECD, the Bank of Italy, and the Italian Court of Auditors.
These problems, linked also to overlapping, inefficient, uncertain rules, hinder the necessary public–private co-funding. In sum, the challenge is not only insufficient, but also inefficient infrastructure.

**CONCLUDING REMARKS**

Digitation and servitization are key megatrends, which reshape business models and value creation in all sectors of economic systems. Human and physical capital become intertwined: education is key to master these processes.

Italy is today at halfway between: i) a relaunch of Humanism (Pico della Mirandola, 1486) based on education and human capital, which reinterprets the centrality and dignity of man, and ii) the so-called “degenerative attractions”. There is an evident need to restore values and qualities, pursue excellence in all sectors, and re-establish ethical and moral principles.

Education, research and development, innovation and safeguarding the environment are the crucial infrastructures necessary to relaunch economic, civil and social growth. We especially need to interrupt the vicious circle that fuels a lack of confidence and low education levels in the young generation. Meritocracy must return as a benchmark, ousting aggregation processes that stem from personal benefits, groups of power, and the connivance that encourage corrupt practices. The elements needed for change are present and positive signals can be seen. These objectives should be pursued with tenacity. Investment in good, innovative education is key to brave the challenge.
Bagheri Berhard, Lee Jay (2015), *Big future for cyber-physical manufacturing systems*, University of Cincinnati
www.designworldonline.com


Briganti Alessandra (1998), *Nuove tecnologie e industria della conoscenza*, in *L’istruzione a distanza nelle strategie per lo sviluppo*, Roma, Forcom Editore

Briganti Alessandra (2014), *Open online Higher Education in a time of economic crisis*, Rome, Università degli Studi Guglielmo Marconi

Bush Henry (2016)
https://www.emaze.com/@AFITZRTW/marketing-henry-b


Coursera (2018), *LTTO MOOC Learning to teach on line*, Massive open online courses

Crepaldi Marco (2018), *Hikikomori e abbandono scolastico: cosa può fare la scuola?*, Hikikomori Italia


Masera Rainer (2010), *Saggi sulla metodologia della ricerca in economia*, Roma, Gangemi Editore


Masera Rainer (2017), *Dalle buone infrastrutture il rilancio della crescita*, Roma, Guerini e associati

Montesquieu (1748), *De l’Esprit de Loix*, Paris, Chatelain

OECD (2017), *Education at a glance*, Paris

Oliver Wyman (2018), *Global Risks Report*
http://www.oliverwyman.com


Roser Chris (2015), *A Critical Look at Industry 4.0*
AllAboutLean.com


Schumpeter Joseph (1942), *Capitalism, Socialism and Democracy*, New York, Harper


US National Science Foundation (2018), *Cyber-Physical Systems* (NSF 18-538)