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Oliver Kovacs

UNINTENDED CONSEQUENCES OF INDUSTRY 4.0
The Principles of Intelligent Economic Governance

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Olivér Kovács

UNINTENDED CONSEQUENCES OF INDUSTRY 4.0 – THE PRINCIPLES OF INTELLIGENT ECONOMIC GOVERNANCE*

Our working paper aims at going beyond prevailing analyses on the fourth industrial revolution by shifting towards a complexity economics approach. In so doing we concentrate on the complexity of relationships in the development of Industry 4.0 and the Digital Economy by deciphering the major set of unintended consequences calling for cultivating governance. We therefore formulate the basic principles of *intelligent economic governance* that is to contribute to the sustainable development of Industry 4.0 and the Digital Economy.

Keywords: Industry 4.0, digital economy, complexity, governance

JEL codes: D80, O33, O40, P17

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Introduction

Since the outbreak of the 2008 global financial and economic crisis, the global economy has been under extreme stress. However, an increasing number of people is hoping that Industry 4.0 and the Digital Economy will be an effective answer to one of the thorniest challenges of today: to the ailing growth performance of the developed countries. With the new manufacturing philosophy and operation method based on the Industry 4.0 and the Internet of Things (IoT), integrated and online cyber-physical systems are emerging through the interconnection of resources, machines and even that of the logistics systems by creating the so-called smart factories that are barded with independent and self-optimizing local production processes promising ever-more efficiency.

Nevertheless, Industry 4.0 (and the Digital Economy) must be a constituent of an extremely complex socio-economic configuration. Assessing the impacts of Industry 4.0 therefore necessitates a broader approach especially when the global socio-economic situation is so stressful. Hans Selye, known as the "father of stress-theory", once emphasised that we will never know the beauty of a gothic cathedral through the mere chemical test of its building blocks. We must take into account the whole architecture and its interactions with the wider context to give a fairer picture about what beauty is.

In this spirit, our working paper is to present a more realistic picture of Industry 4.0 and the Digital Economy by concentrating on the complexity of relationships in their development in an effort to decipher the major set of unintended consequences. Without these, what we only have is just a confused (*gotico*) picture about the economy. We emphasise that owing to the complexity of the world economy, there is a great deal of uncertainty about whether government interventions designed to foster the development of the Industry 4.0 and the Digital Economy will offer enough capacity to compensate the "losers": it means that reaching Kaldor–Hicks efficiency is extremely difficult.[i] Based on the insights gained in our working paper, we

formulate the basic principles of an *intelligent economic governance* having the potential to contribute to the sustainable development of Industry 4.0 and the Digital Economy.

Complexity of Industry 4.0 - Context and the unintended consequences

One of the most intricate puzzles of economics today is that: Why do we experience secular stagnation in the developed world[ii] (i.e. weakening innovation performance with lessening productivity gains) while an unprecedented range of technologies is available together with overwhelming digitalization that has never seen before? If we apply systems view, a knot of simultaneous and interconnected channels behind the global slowdown can be recognised: *1)* the global financial and economic crisis of 2008; *2)* the decelerating catching up process of major emerging markets with discernible structural adjustments towards a more sustainable and slower growth; *3)* in the developed world, mainly in Europe, the complexity of regulation and the negative effects of weakening competition are more vigorous at a time of recession; *4)* the hobbled character of firms' productivity growth via technology and innovation had been widely observable already in the pre-crisis period; *5)* the harmony between the financial sector and the real economy is broken in favour of the former one of which traditional intermediary, wealth-generating role has been to a large extent relegated with respect to supporting the real economy. Financial investments has become one of the most profitable areas over real economy investments by creating a parasitic-like financial sector and by encoding bubbles, systemic risks, low corporate investment rate, low propensity for innovation;[iii] and *6)* ever-increasing inequality undermining social trust having a negative feedback on withering economic dynamisms in the form of vicious spiral.

Thus, Industry 4.0 and the Digital Economy evolve in an open, adaptive, complex socio-economic innovation ecosystem characterised by the non-linear feedbacks.[iv] Therefore, it is rather strange that available studies are merely focusing on the positive effects of Industry 4.0 while not mapping the interactions that may warn of unintended negative consequences.

In the followings, we ravel out the above mentioned concerns to have a more systemic view on Industry 4.0. Five areas are, at least, worth mentioning: (*i*) increasing security-related uncertainty; (*ii*) paradox consumption patterns; (*iii*) unintended consequences of automation; (*iv*) distorting measurement; and (*v*) unintended consequences of neglecting other contextual interactions. These all function as a centrifugal force disrupting the delicate processes of Industry 4.0 and the Digital Economy.

Increasing security-related uncertainty

Cyber-physical systems, and the digital universe *per se*, not only raise the issue of cyber security (data security, systems fault tolerance, cyber resiliency etc.) but has already been the subject of serious analyses. Such development of production systems also increases the risk of fragility,[v] thus induces additional uncertainty beside fundamental uncertainties in the innovation ecosystem.[vi] Suffice it to cite the Chapman University's survey about what Americans feared the most in 2016.[vii] The survey revealed that cyber-terrorism ranks second behind corruption. It was followed by the fear of data malpractice first on the business side then on the government side. Theft of personal data, credit and debit card fraud were also named as areas of concerns. Data security and protection against unauthorised persons are becoming hot topics as series of company studies showing that enterprises feel threatened by the risks of cyber-attacks fuelled by Industry 4.0.[viii] And once a widespread perception over inefficient cyber security is here to stay, the speed of technology adoption and diffusion (and trade integration in knowledge-intensive sectors) can suffer by overshadowing productivity outlooks. Another security aspect related to the development of Industry 4.0 and the Digital Economy is that statistical institutions, as authorised and dominant data collectors and providers, are facing a new challenge. The whole gamut of data is not exclusively the result of their own work, not to mention that extracting, recording and interpreting data will presumably

not be limited to be done within the 'firewall' of these offices. As a result, several uncertainties are surrounding the questions of defence and integrity.

Paradox consumption patterns

As time passes, the circle of cheaper technologies for improving energy efficiency is widening that may eventually lead to increased energy consumption (i.e. Jevons-paradox).[ix] It means that considerable government support geared towards the production and the use of renewable resources may induce exactly the opposite effect of what policy originally intended to achieve.[x] Supporting the spread of Industry 4.0 may also have a bubble-generating power when, for instance, there is a conspicuous over-investment in robotics irrespective of the capacity of the state and that of the needs of the innovation ecosystem. China is a case in point. In 2014, there were only 200 companies specialized in robotics in Shenzhen, whereas this number exceeded 3,000 in 2016. In 2014, 227,000 industry robots were sold worldwide, of which 56,000 were imported by China, and one year later, that import rose to 66,000.[xi] After only a few hundred industrial, professional, and household robots in use, their number grew to 3,400 by 2016.[xii] An increasing number of big Chinese cities declared their demand for robotics (36 cities in 2016), 77 local governments have already initiated programs for robotics-development. What is more, fundraising in robotics is of high priority in China's next Five-Year Plan with the aim at tripling their robot production by 2020. Still, there are signs casting doubt on overly sanguine views about the skyrocketing robotics in China. Corruption and fraud have also appeared causing significant distortions (more than 65 per cent (!) of net profits of firms, specialized in robotics development in Nanjing, stemmed from state aid). With ineffective state support, uncompetitive products are being produced that are far from the global frontier. In fact, domestic robot-sales simply remain a wishful thinking (85% of the robots sold in China are imported or built domestically using imported components). Policymakers working on the

European Industry 4.0 should therefore be aware of the fact that supporting measures tailored to robotics, as a radically new physical capital (supporting human capital during cooperation), can spur rent-seeking and they may potentially crowd out capital investments in more traditional fields.

The Jevons paradox requires further investigation on whether greater consumption may be triggered by the fact that warehouses equipped with robots can easily multiply the handling amount of merchandizes, thus they are able to fulfil more orders (Rotman, 2013). The issue of sustainable manufacturing and consumption arise here, especially if one also consider that the information society entailing thriving interconnections gave rise to more efficient mapping of consumer habits having the potential to intensify manipulation to reach out artificially generated demand.[xiii] These are non-linear spillovers necessitating demand and supply-side policies alike in the interest of sustainable development. Regulation on the supply-side (e.g. incentives to promote the principle of minimizing losses) and *nudge techniques* (Thaler and Sustein, 2009) on the demand side may also be worth considering.

Unintended consequences of automation

The first complex question is the impact of automation on employment. The sustained development of Industry 4.0 and Digital Economy can only be cultivated via inclusive growth that safeguards political stability through strengthened social trust. However, there are voices envisaging enormous job losses due to automation and machine learning.[xiv] It is calculated that 47 per cent and 54 per cent of jobs in the United States (Frey and Osborne, 2013) and in Europe (Bowles, 2014) can be displaced by computerization. The experience has shown that cost-cutting measures usually come with cost-reducing and efficiency-increasing technological developments (automation of routine tasks) primarily at a time of recession.[xv] It implies that the current economic situation tends to encourage automation. Nonetheless, the wider context

and certain tendencies suggest that computerization of mass labour force will only be possible gradually. The chain of reasons is as follows. 1) Automation is likely to be typical in case of jobs with no shortage of labour.[xvi] 2) Developed countries are portrayed not only by jobless growth but also by jobless stagnation (e.g. rising youth unemployment and slow employment of older low-skilled workers)[xvii] due to anaemic growth, computerization will therefore only make things worse, unless the displaced workforce is absorbed elsewhere in the economy. 3) If such absorption fails[xviii], then the position of the already indebted private sector will be more difficult by engendering further increases in the already high ratio of non-performing loans. *Excessive* volume of domestic loans to the private sector (i.e. increasing share of non-performing loans), is one of the top crisis indicators (Balgova et al., 2016). Since excessive borrowings has been prevalent for the past two decades, applying for individual bankruptcy within a year after losing job became three times more likely to happen compared to previous periods (moreover, job loss in the manufacturing sector is 40 per cent more likely to cause bankruptcy) (Keys, 2015). For these reasons, expecting a fast automation of jobs would be naïveté.

The second complex issue is the impact of computerization on people's mental status. Beyond the empirical evidence that dismissal increases criminal activity (Bennett and Ouazad, 2016), digitalization and automation may harm people's mental and physical health. It is hardly by chance that '*The Art of Living with Information and Communication Technologies (ICT)'* branch of literature has emerged (Lemmens, 2017). ICT made employees available 24 hours a day; the real-time data-based analytical methods may increase the expectations of executives from employees to respond and make decisions as early as possible; while more and more people work in the crossfire of more sophisticated monitoring and controlling applications; and as Industry 4.0 is unfolding, employees have to compete even with machines. So stress may arise more vigorously in certain areas, while it may moderate elsewhere.[xix] Additionally,

mental and health risks associated with home, mobile and telework type of jobs are also revealed (i.e. adverse frustration by broken work-life balance, Kovacs (2013)).

All in all, gradualism could help mitigating the risks associated with automation, because the necessary training programs and the development of other horizontal policies are rather time-consuming.

Distorting effects of measurement

The *first* aspect here usually refers to ICT statistics. Uncertainty related to ICT statistics arises from several facts. On one hand, ICT will be found everywhere and in almost everything in the future, which poses a challenge to the methodology of statistical offices in the sense that differentiating products with ICT from products without it is less and less obvious. On the other hand, the fact that statistical data do not necessarily mirror certain economic theories does not by all means require intervention. According to a theory, with increasing investments in knowledge capital (e.g. training, vocational training, product and service design, organisational development) we should have already seen growing trend in productivity statistics. However, this requires much more time (van Ark et al., 2016). According to the prevailing theory and empirics, investments in ICT should also be reflected in productivity statistics. Today, however, considerable investments in ICT equipment (ICT hardware, ICT software, and telecommunication tools) are not as much needed as it were before the appearance of cloud technology and services. In other words, there is a shift from investing in digital fixed assets toward purchasing digital services (data processing, computer and network design, related computer services, etc.). In this respect, there is another statistical distortion as more and more companies do not buy but develop such services on their own. As a corollary, the traceability of technology diffusion from the statistics has become ever-more cumbersome. The puzzle of why we experience secular stagnation in the developed world despite the increasingly

pervasive digitalisation is relevant because if it were proven that we can only hope a modest productivity contribution from digitalisation, business investment decisions and market behaviour would change fundamentally via expectations. All in all, by measuring we are recurrently creating events.

The *second* aspect deals with the risk of distortion lurking in Big Data-based approaches. Contrary to the growing belief, we argue that Big Data *complements and by no means replaces* scientific research and business analyses. Too much data do not inevitably make us more informed by leading to better decisions. Big Data is expected to accelerate our scientific understanding about the world in a way of "*numbers speak lauder than words and often speak for themselves*". At the same time, Big Databases do always contain discretionary correlations given primarily by the size and not by the nature of the data (Calude and Longo, 2016).[xx] There may be several hidden errors in these databases and even a tiny failure can lead to misinterpretations. There is a lack of capacity for monitoring the consistency of databases and that of the credibility of data[xxi], particularly if it is a public, free to use and modify database (i.e. there is a possibility for 'fishing in the dark'.) An important lesson here is that albeit Big Data do help in better documenting the past, the human factor providing moral and social dimensions will still be the *conditio sine qua non* of proper decision making.

In the era of Industry 4.0, one of the cardinal areas for using Big Data is to refine forecasts, i.e. when we attempt to extract more and *near* real-time data that paint presumably a clearer picture about what is really happening in the socio-economic system. This new research field, called *nowcasting*,[xxii] is usually an Internet-based search approach (e.g. Google Trends) or it is based on more granular micro-transaction data (such as FRED, Data.gov, SWIFT, Pulse Index, etc.). Some believe that this new approach offers more accurate predictions in certain areas (e.g. evaluating demand for products and services of Industry 4.0; monitoring of diffusion etc.).[xxiii] Scientific debates on the applicability of this technique suggest that the extensive

observation of high-frequency indicators through *nowcasting* procedures makes our models and, what is more, our picture of reality even noisier.

In addition, many fail to acknowledge the fact that psychology explains the volatility of financial markets and the evolution of sovereign debt much better than macroeconomic fundamentals. This is a challenge for Big Data because of the crucial importance of non-quantifiable, difficult-to-measure aspects. We should therefore go beyond the Mephistophelian reasoning that *'What you don't count on can't be true, What you can't weigh won't weigh, of old, What you don't coin: that can't be gold'*. Gennaioli et al., (2015) has illustrated vividly the undeniable role of psychological site. Their model–based analysis revealed that we tend to overestimate the likelihood of an event that is relatively more likely to happen in the light of recent data and observed (experienced) events. Hearing good news, investors tend to calculate positive scenarios and to underestimate the possibility of a negative event. The same investors tend to regard bad news as temporary aberrations, so they do not react sufficiently, while they tend to overreact when a troublesome situation occurs. This psychological insight not only allows us to better understand the anatomy of boom-bust cycle, but it also implies that our real-time concept of the economy is significantly different from what we are weighting from a historical perspective (i.e. fluctuations are weighted in a broader context and always with hindsight).

Bearing the above in mind, in the age of Industry 4.0 and Digital Economy, the differentiated application of Big Data in economic policy is in order (especially for forecasting). The normal business cycle does not necessarily require monitoring as it may result in distortional noises (i.e. unfounded or misconstrued interventionism causing hectic fluctuations). This draws attention to *the arrow of time* in the spirit of complexity science, that is to say, *there are irreversibilities in the system* (e.g. the impact of a policy triggering hectic and negative effects cannot be fully eliminated from the system, it lives further in memories, in expectations,

collectively in the psychic capital). Hectic fluctuations can be rather harmful for the socio-economic innovation ecosystem by disrupting the trust infrastructure and the overall innovation dynamism. Never forget one of the basic characteristics of large databases: even a small error could cause significant distortion (and, of course, data manipulation is also in the cards, e.g. lobbyists manipulate to get certain interventions favourable only for them). Contrary to 'high flying' futurists 'down to earth' economists should therefore recognise that using Big Data during the business cycle is more likely to encode instability into the system and to paint a confused (*gotico*) picture about reality. By the same token, application of Big Data seems to be more appropriate in case of *sudden-stop* type situations and in recessionary periods.

Unintended consequences of neglecting contextual interactions

The *first* set of unintended consequences stems from the negligence of the interaction between developed and emerging countries. The *second* one occurs when the scientific community is skating over the different time horizons of the financial markets and that of the industrial policy. The *third* one is given by the ignorance of the interplay between labour market flexibility and industrial policy.

As far as the first set of unintended consequences is concerned, it is very likely that Industry 4.0 and the emergence of the Digital Economy are hacking the wage-competition model of international competitiveness. If new production processes and the production of available technologies become cheaper, the global power of wage-based competition will dampen. Undoubtedly, most if not all *emerging markets and developing countries will confront with this challenge,* hence the global value chain will go through a dynamic transformation. Available evidence supports this scenario by confirming the fact that productivity of ICT-producing industries has improved as the prices of ICT products and services have fallen, thus overall real wages could also decline (Hoon and Phelps, 2006; Byrne and Corrado, 2016).[xxiv]

If manufacturing sectors providing the tools and services of Industry 4.0 follow a similar path, then expecting even stagnating real wages would be a rather pollyannaish view, which still does not help us reducing inequality and making job-saving growth more inclusive, either. Furthermore, this path may also limit fiscal capacities by threatening the sustainability of the generous welfare states in Europe (e.g. the option of universal basic income in the new digital age arises again).

As regards the second set of unintended consequences, there is an inconsistency in terms of time horizons between the financial sector and industrial policy aiming at fostering Industry 4.0 and the Digital Economy. The financial sector prefers short-term returns over longer term investments due to a series of inherent factors (ESDN, 2012)*;* while industrial policy must be engaged in longer-term considerations acknowledging sustainable development. The current context of low-productivity, thus low-growth and low-inflation, and the uncertainty rising from it only further enhances the culture of short-termism in the financial markets.[xxv] Nevertheless, the sustainable promotion of Industry 4.0 requires longer-term lending culture to take root. This *inter alia* calls for regulatory changes, appropriate incentive regimes and good governance in general.[xxvi] Without addressing the different time horizons, the effectiveness and efficiency of industrial policy will fall far below the original ideas.

The third set of unintended consequences is given by the interaction between labour market flexibility and industrial policy. Industrial policy at national or EU-level should take into account the regulatory environment of the labour markets. Importantly, making the labour market more flexible is not without side effects. According to a conventional wisdom of the innovation-related economics literature, a flexible labour market facilitates while a stricter one stifles innovation thus the productivity potential. In principle, a more flexible labour market makes innovative companies able to rapidly hire or fire employees with lower costs when innovating. In addition, the use of various analytical methods and processes build on Big Data

would also require more flexible labour market regulation ('*people analytics*' – for selecting, enrolling, monitoring and developing the best labour force etc.). Note, however, that the United States with one of the most flexible labour markets has been facing a rather sluggish wage growth for decades (i.e. stagnating median income of households) while the EU12 with stricter labour market regulation has seen some increase.[xxvii] It *per se* implies that stagnating productivity has been partly the result of stagnating wages (i.e. the impaired practice of performance-related pay) demotivating workers to spark innovation. All of this suggests that more flexible labour market regulations are not necessarily leading to positive improvements. In contrast to the often expressed view, the relationship between wages and productivity is not a one-way street (Storm and Naastepad, 2012). If productivity increases, wages could be higher. However, increasing a relatively low and stagnating wage level might spur the overall innovation performance by ameliorating productivity. There are inherent hindrances in our socio-economic innovation ecosystem to the rapid diffusion of automation-enabler technological and non-technological innovations. Consequently, the deregulation of EU labour markets *in a non-differentiated way* may lead to decreasing wage growth in certain countries by potentially dissuading innovation and also by harming the sustainability of public finances through weakened productivity.

Notwithstanding the arguments outlined above, automation and digitalisation serve as a driver of labour market deregulation with the aim at reducing the costs of employment and fostering the quick absorption of redundant employees elsewhere. Whereas strict employment protection increases the labour costs of companies, they are more likely to curb R&D and innovation activity while preferring high-skilled labour force. It transpires that, paradoxically, low-skilled workers are not protected by the system! Cette et al., (2016) revealed that adopting the US-like low-level employment protection to Europe would significantly lower the share of high-skilled and better educated workers within the total employment at the expense of the

low-skilled workers. The highest fall in the share of highly qualified workers would be found in France (-22 %), while a 13 percent shrinkage is expected in case of Austria and Germany. They are those whose work involves more sophisticated activities of which automation and robotization promise more savings for employers. For this reason, not only the low but also the highly skilled workers are facing increasing unemployment which violates the declared requirement of inclusiveness and affects negatively the sustainability of public finances. This highlights the importance of differentiated diagnosis and gradualism when (industrial) policy is to increase the flexibility of labour markets. Not to mention that low level of employment protection could deteriorate employee's loyalty, weaken organisational memory, devaluate different types of trainings and establish the anxiety culture. But do not forget that the flexible labour market of the United States has been developed in an organic way. Additionally, psychological studies also pinpoint the fact that we are twice as sensitive to losses as to gains, hence people in the EU will probably have to abandon the existing level of employment protection that would not be particularly conducive to the sustainability of welfare states, either. The clear inference is that expecting productivity improvement from the deregulation of labour markets in Europe can easily be just a forlorn hope.[xxviii]

Conclusion

Economics teaches us temperance both in terms of self-confidence and modesty. With the presented bright palette of unintended consequences of Industry 4.0 and the Digital Economy as signals of their complexity, our working paper is to inveigh against over reductionist or utopian recommendations.[xxix] The success of this transformation depends not only on its technical feasibility but also on its social acceptability. If the latter precondition is not met, supporting the transformation might be politically excessively destabilizing. We therefore

formulate the basic principles of an *intelligent economic governance* which can contribute to the sustainable development of Industry 4.0 and the Digital Economy.

Festina lente: The undisputable nature of the *festina lente* (make haste slowly) principle is given by the outlined unintended consequences emerging inevitably due to the increasingly complex socio-economic system. In the context of sluggish growth, low inflation, limited fiscal space, and with a view to the fundamental resources needed to develop Industry 4.0 and the Digital Economy (initial investments, trainings and learning time, more flexible labour markets, etc.), and by taking into account the risks associated with the wide and rapid transition to Industry 4.0, our conclusion is, without all the jazz, that graduation is more a virtue rather than a sign of helpless policymaking. This principle must be reflected both in the time horizon and the institutional functioning of relevant policies (e.g. sustainable, unbiased support system with accountability, transparency and discipline) in an effort to achieve Kaldor–Hicks efficiency (i.e. to continuously create the capacity for compensating the "losers" of the transformation).

Systems approach: The transformative power of Industry 4.0 and digitalisation calls for a much broader policy and business perspective to map and better understand the interactions featured with non-linearity, reflexivity and spillovers (e.g. the interaction between the financial sector and the real economy). Systems view recognises that *today's innovation is no longer coming from well-defined areas but from the intersections of various disciplines*. Systems view rests on broader and interdisciplinary collaborations and on the development of policies stabilizing and strengthening the trust infrastructure within the social-, economic-, and environmental innovation ecosystem (e.g. cooperation in fields like Big Data based predictive analytics among public innovation laboratories, independent fiscal and monetary bodies, and EU institutes). Such collaboration may provide a greater scope for taking into account potential

unintended consequences. Similarly, testing and evaluating maturity for Industry 4.0 also require a systemic approach.

Differentiated diagnosis and intervention: European economies have different formal and informal institutions together with different regulatory bases, thus their capability for structural change is also varying across the board. Consequently, in some areas standardization is in order (e.g. creating international standards to give new élan into the spread of Industry 4.0; handling and regulating cross-border data; capacity building of statistical offices; product and service market reforms, etc.), while other areas need more context-dependent interventions (e.g. fiscal consolidation with development functions in peripheral countries; labour market reforms). Policies with systems view, including industrial policy, should focus on *creating interactions* to strive to really productive public investments (that are regenerating and resuscitating private sector investments as well) in supporting the diffusion of the positive impacts of Industry 4.0.

Widening and outbalancing opportunities (equability): Cultivating sustainable development and promoting well-being still remain the *raison d'être* of good governance which is fully aware of the need for *structural change* by incorporating the complexity of Industry 4.0 and the digital transformation. If secular stagnation described in our working paper played a significant role in the development of the modern innovation ecosystem being pervaded by increasing income inequalities and coupled with the underutilisation of the human capital, then supply *and* demand side policies are required for a healthy ecosystem (e.g. encouraging social innovations on the demand side). This requires a governance approach that focuses on the development of individual opportunities (*equability*) rather than the total elimination of income inequalities. There is a need for a governance that revises the paradigm of pursuing the further extension of the welfare state whereby the *culture of entitlements* can be mitigated, talent

development can be stimulated, the overall innovation performance and the development ability can be improved that are essential in the era of Industry 4.0 and the Digital Economy.[xxx]

To telegraph the punchline, our world economy has become ever more complex, which has implications both for governance and the economic profession in general.

As for governance, the kind of intelligent economic governance following the principles mentioned above can enshrine the worldview of Hans Selye quoted in the introduction: to observe what everyone is watching but no one sees. In this way, policy is more likely to successfully identify the positive and negative effects of Industry 4.0 and the Digital Economy together with the key interactions. Because of the complexity policymakers face, avoiding really bad outcomes rather than pushing policymaking to perpetually optimise the good ones is a more instructive way forward.

As far as the economic profession is concerned, complexity implies that economists should not concentrate merely on structures (gothic cathedral) but also on processes and their dynamic relationships. Wassily Kandinsky, the great Russian painter, considered the 19th century as an age of *either-or*, while the 20th and 21st centuries can be interpreted as an age of *and*, when: age of multiplicity, simultaneity, connections, growing networks, asymmetrical interdependency, globalization of side-effects, non-linear changes, fluctuations on microscale having impacts on macroscale, and cumulative causation are all in the cards. Our socio-economic system is an open, dynamic and adaptive system embracing a large number of diverse interacting parts and being imbued by spillovers, non-linear processes, far-from equilibrium situations. After all, our working paper is a clarion call for a broader research canvas, for a new economic thinking which is *to marry economics with the approach of complexity* science to draw a more realistic picture about economic phenomena (Industry 4.0). Metaphorically, we must paint a new Arnolfini Portrait in the spirit of Jan van Eyck who made a distinct shift from gothic style towards more realism.

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[i] See: Kaldor (1939), Hicks (1939).

[ii] See: Teulings and Baldwin (2014). The growth of the total factor productivity in the Eurozone was almost halted between 2000 and 2015 (on average, the annual increase was 0.2%), while it was also infinitesimally low in the US (0.4%) (McQuinn and Whelan, 2015).

[iii] This is reflected in the *excessive credit consumerism* (*Berend*, 2013, p. 108-112), and in the fact that there are extensive intra-financial exposures in derivatives markets (see: European Systemic Risk Board (2016)). Turner (2015) documents that the financial system has been striving to lend the savings of the upper class by grounding indebtedness in the broad strata of the society. Consequently, income inequality has been soaring.

[iv] Since 2016, ten directorates at the OECD address the interdisciplinary issue of digital transformation. It *per se* indicates that a wider scientific thinking has started to gain momentum.

[v] Open source malwares can attack and disrupt public services. This was exactly what happened to the Finnish heating system in November 2016. Or, just think of ransomwares, WannaCry and Petya resulting in unprecedented havoc in 2017.

[vi] Our socio-economic system is a far-from equilibrium system, in which the spontaneity of entrepreneurial spirit is of immense importance and it, by very nature, maintains fundamental uncertainty (i.e. innovation and uncertainty are the dynamic sources of each other). See: Kovacs (2014).

[vii] See more: http://www.usatoday.com/story/news/nation-now/2016/10/12/survey-top-10-things-americans-fear-most/91934874/ Accessed on: 20.06.2018

[viii] The security issue of 3D printers connected to the Internet is still at loose ends, which can result in serious industrial sabotages and costly recalls of various products (Gupta et al., 2016). Regarding *IoT*, there is a crucial need for secured and standardized connections.

[ix] Besides, increasing the national income is vital since evidence from the last 40 years showed that energy intensity could be reduced in countries that were getting richer and richer (Csereklyei et al., 2016).

[x] Subsidising biofuels had first moderated the consumption, then they reduced the prices of traditional fuels which finally triggered even higher consumption for them (Holland et al., 2013). Another example for the work of Jevons paradox is the systemic failure of green logistics initiatives in the last decades. See: Klumpp (2016).

[xi] International Federation of Robotics.

[xii] Ministry of Industry and Information Technology, China.

[xiii] Our modern economy is interspersed with manipulation and deception (Akerlof and Shiller, 2015) which can result in excessive credit consumerism and in excessive indebtedness of corporate and household sectors.

[xiv] Senior managers and employees are willing to leave their company for another one being at the forefront of digitalisation (Kane et al., 2016). This type of syphoning effect also encourages faster digitalisation.

[xv] This was demonstrated by Hershbein and Kahn (2016) in case of the Great Recession (2007-2009).

[xvi] Kane et al., (2015)

[xvii] The decreasing employment in manufacturing in developed countries has been accompanied with an increase in the emerging markets like China (Palvia and Vemuri, 2016). Still, the weakening jobless growth in the developing countries aggravated further the income and wealth inequalities (Piketty, 2014) by encoding a *chronic instability* into the world economy.

[xviii] It is likely that the pace of absorbing displaced workers by other sectors will be slower as compared to previous industrial revolutions. Albeit Gregory et al., (2016) reveals that the aggregated labour demand has increased in

the EU between 1999 and 2010; the authors forget to take into account the followings: 1) the spatial distribution of labour has dramatically changed (certain regions are emptying); 2) the middling jobs (semi-skilled workers, with low or medium wages) have been to a great extent hollowing out due to the automation (Autor, 2015); 3) the boom in the construction sector was the primary reason behind the measured increase in aggregate labour demand in the period considered. The current revolution is very much likely to bring more powerful changes. And since every previous revolution had a *deskilling feature* (de Pleijt and Weisdorf, 2017), workers have to upskill themselves to acquire better and higher positions.

[xix] O'Neil (2016), a renowned data scientist and hedge-fund manager, sensitively illustrated that quantophrenic behaviour (i.e. extensive quantification) has negative effects on workplace morale and collective ethos.

[xx] Candidates' credibility for a job is popularly evaluated on the basis of their credit history. This is more like a malpractice: it tends to reproduce and further generate poverty and income inequality because poorer candidates may inherently have worse credit history and they can live in neighbourhoods with higher crime rates. Another example is the case of a Big Data based face-recognition technology used by US police departments. The database contains 117 million portraits taken from driving licenses and ID cards. It implies that most of the portraits in the database refer to innocent people. The software is therefore more likely to bring up matching portraits that are in fact false. See: New Scientist (2016). Police Mass Face Recognition in the US Will Net Innocent People, 29 October 2016, p 19

[xxi] See: UN (2016).

[xxii] See: Ettredge et al. (2005), or Wu and Brynjolfsson (2015).

[xxiii] This technique is used mainly for deciphering labour market and consumption patterns. See: Askitas and Zimmermann (2009), Choi and Varian (2009), and McLaren and Shanbhogur (2011). But, the evidence on its effectiveness is rather mixed. Furthermore, Basistha et al. (2016) found that the positive added value of nowcasting seems to be eliminating in case of stock prices or in case of exchange rates.

[xxiv] This forces China to speed up robotization, otherwise the benefits from low wages will diminish.

[xxv] Current economic climate is full of uncertainty, thus more and more capital flows to businesses that are not necessarily more productive but have higher net values. See: Gopinath et al. (2015).

[xxvi] Fostering '*positive finance'* that feeds into the transformation process. See: Guez et al. (2015).

[xxvii] For the data, see Nolen et al. (2016).

[xxviii] The power of highly flexible labour market seems to be ailing even in Denmark (Andersen, 2015). Such system stands or falls on at least two things: an effective activation policy and high job creation. But, Industry 4.0 together with extensive digitalisation (incl. automation) make these prerequisites less and less feasible.

[xxix] For such a utopian idea, based on ICT modernisation to control the production and the economy as a whole, enough to think of the Chilean *CyberSyn* system of Salvador Allende.

[xxx] Old recognitions have not been reversed into the oblivion. Adam Smith recommended *The Wealth of Nations* to read together with *The Theory of Moral Sentiments* in which Smith looked beyond the invisible hand of the market and emphasised the crucial importance of morale in real socio-economic development. Importantly, even the state can have a destructive effect on morale, especially if it strengthens and deepens dependency culture rather than supporting the equalisation and extension of opportunities, as the Nobel-laureate Amartya Sen (1993) highlighted. A fully equal society cannot be a policy target unless policy is to stifle down innovation and long term development. Inequality means uncertainty that makes people work harder and innovate. In this sense, a certain degree of inequality is of paramount importance since it represents a key driving force of innovation. This was once recognised by Kaldor (1955-1956). What is therefore worth pursuing is equability (*equal opportunities*) in the world of Industry 4.0 but not through inexorably expanding the welfare state, which would strengthen the dependency culture, but by the efficiency-increasing dismantling of it to eliminate the obstacles to broadening the opportunities of people, as Wilhelm Röpke suggested (see: Röpke (1979)).