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INDUSTRY 4.0 – THE PERSPECTIVE OF INTERNATIONAL ECONOMICS THE CASE OF POLISH-GERMAN RELATIONSHIPS

INTRODUCTION

Industry 4.0 (integrated industry, industrial internet) stands for the fourth industrial revolution[1]. The first one introduced mechanical production in the second half of the 18th century, the second revolution in the early 20th century, involved the electrification and the division of labour, the third one called digital revolution, which is dated back to the 1970s, was associated with usage of advanced electronics and information and communication technologies (ICT). The fourth revolution is built on Cyber-Physical Systems (CPS). These systems comprise smart machines, storage and production facilities which can autonomously exchange information, trigger actions and control each other independently (Hermann et al, 2015). There is no clear specific definition of industry 4.0 but rather a wide array of interdisciplinary technologies - with different levels of maturity and market availability - which facilitate digitization, automation and process integration along the value chains (Kagermann, Wahlster and Helbig 2013). Industry 4.0 or the fourth industrial revolution is sweeping through the globe, mainly advanced economies, and it is gaining the attention of policy makers, in business circles, among industry representatives and scholars (Schwab 2016). Researchers who started dealing with this digital transformation agree as to the scale and scope of changes the fourth industrial revolution would cause, though, they disagree whether it is indeed the fourth revolution or just the next stage of previous one (Roblek et al., 2016; Brettel, 2014; Alcácer et al., 2016; Rüßmann et al., 2015). Regardless the right name, major modifications of policy plans, industry strategies, business models, production methods, value chains governance and attractiveness of places are undoubtedly taking place. Most of the available papers deal with technical, managerial or strictly business aspects of this profound transformation. Whereas scholarly papers touch upon the technical aspects of Industry 4.0, dossiers by international organisations and think-tanks revolve around the expected benefits and challenges this revolution might bring about[2]. Despite the growing popularity of Industry 4.0 there is

[1] In this paper the terms Industry 4.0 and the fourth industrial revolution are used interchangeably.

[2] Compare - G. Porcaro, *The industrial internet will transform policymaking*, 28.09.2016, Bruegel blog post - „So far, the main producers of background studies and policy papers on this issue have been

still a lack of efforts to systematically review the state of the art of this new industrial revolution wave (Liao et al., 2017).

This paper outlines first the broader international context for the advent of Industry 4.0 and reviews its basic premises. Next section presents major gains stemming from this fashionable concept as well as possible threats. Fourth part analyses Polish-German economic relations against the background of Industry 4.0. This case study may offer insight into the international context of industrial revolution as it seeks to evaluate the potential for further cooperation on the eve of this awaited transformation. Final section concludes. Hence, this paper focusses on rather general macroeconomic aspects of Industry 4.0 in cross-border context, whereas majority of available studies deals with the fourth revolution from the business perspective, using entrepreneurship and strategic management lenses. The value added of this paper may lie in the novelty of the topic itself which is the Industry 4.0 and in diagnosing the concrete implications of this revolution on cross-border relations. Certain value derives from presenting the Polish-German case study, i.e. describing selected metrics gauging the likely cooperation potential. Germany is seen as frontrunner in this area designing, adapting and disseminating the advanced technologies constituting the core of Industry 4.0, yet it is the neighbour and Poland's main trade partner. This paper may contribute to the emerging body of literature on cross-border / international aspect of the fourth industrial revolution. It may advance better understanding of challenges for such economic relations in the era of Industry 4.0.

THE INTERNATIONAL CONTEXT FOR THE ADVENT OF THE FOURTH INDUSTRIAL REVOLUTION AND BASIC PREMISES OF INDUSTRY 4.0

Global flows of information and data create currently more value than traditional exchange of goods (Manyika et al, 2016). Since 2005, the cross-border broadband connections increased 45 times. The proliferation of global production networks / globally organised value chains introduced an additional complexity into economic analysis (Benkovskis et al, 2016). Trade in parts and intermediate goods has been growing with the advancement of ICTs enabling companies to unbundle production processes and leading to the emergence of international supply chains. To be able to stand the competition many manufacturing firms expand their offer and embark upon selling services (selling use of engine than engine as such – maintenance) (Aquilante et al, 2016). Hence, industry is undergoing a formidable transformation encompassing production processes, business models and final products. Industrial firms running out of the cost minimisation options are forced to search for new solutions of improving their effectiveness. These aim at safeguarding the profitable functioning of the firm

government agencies, think tanks, civil society organisations, industries and trade associations". Interestingly as G. Porcaro argues „think tanks and other applied research centres will need to develop new skills and capacity to access and process data in real time, otherwise their analytical capacity might become outdated".

and optimal allocation of resources thanks to the collecting and processing of large quantities of data in real time. In Germany, such initiatives are labelled *Industry 4.0*, in USA *Smart Manufacturing Leadership Consortium*. France has its *La nouvelle France Industrie*, the UK - *High-Value Manufacturing Catapult*, and the Netherlands - *Dutch Smart Industry*. The proliferation of such initiatives is welcome, though, all these valuable projects may unintentionally create national silos (Drath et al, 2014). There is a risk of too much inward-looking systems, incompatible with each other and hence, the danger of defining and building Industry 4.0 in each own way what may undermine the cross-country cooperation.

The definition adhering to Aristotle's rules of *genus proximum and differentia specifica*, identifies four main concepts underlying the Industry 4.0 which are Cyber-Physical Systems (CPS), Internet of Things, Internet of Services and Smart Factory (Hermann et al, 2015). The first component CPS epitomise the fusion of virtual and physical world and is mostly related to RFID (Radio-Frequency Identification) technology. „Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa." (Lee, 2008, p.363). The second component is Internet of Things (IoT) defined as "things and objects, such as RFID, sensors, actuators, mobile phones, which, through unique addressing schemas, (...) interact with each other and cooperate with their neighbouring smart components to reach common goals" (Giusto et al, 2010, p.5). Smart factories or smart homes are examples of application of IoT. The third component is Internet of Services (IoS) which enables vendors to offer their services via the internet. It is made up of participants, adequate infrastructure, business models and the services themselves. IoS can be related to the modular assembly stations that can be flexibly modified or expanded. „Services are offered and combined into value-added services by various suppliers; they are communicated to users as well as consumers and are accessed by them via various channels" (Buxmann et al, 2009, p.341). The final component is Smart Factory capable of assisting people and machines in execution of their tasks. Given the above mentioned other components of Industry 4.0, the Smart Factory can be defined as a place where CPS communicate over the IoT and assist people and machines in the execution of their tasks. Summing up, Industry 4.0 can be understood as „collective term for technologies and concepts of value chain organization." (Hermann et al, 2015). This comprehensive definition has led to deriving six design principles of Industry 4.0. Interoperability implies that companies, CPS and humans connected over the IoT and IoS require specific standards critical for communication. It means that CPS within the plant can communicate with each other "through open nets and semantic descriptions". Virtualisation means that virtual copy of the physical world is created and it can monitor the physical developments. Decentralisation draws on the fact that higher expectations for individual products make it increasingly difficult to control systems centrally. Thanks to the embedded computers, CPS can make decisions on their own. Real time capability implies that data is collected and analysed in real time which secure that reactions are faster. Service orientation means that services, CPS, and humans can be made available and utilised thanks

to the IoS by other participants, also outside the company borders. Modularity can be understood as the ability to flexibly adapt to changing requirements, by replacing or expanding individual modules. Hence, modular systems can be adjusted when needed (e.g. due to seasonal fluctuations).

According to the 2014 Roland Berger Report „Industry 4.0, the new industrial revolution", countries readiest to adopt this revolution are Sweden, Germany, UK and France, whereas Poland along with Croatia, Portugal, Spain and Estonia belong to „hesitating" economies. More clearly the distance between Poland and leading economies US and Germany in implementing the Industry 4.0 is stressed in 2016 Boston Consulting Group Report (Owerczuk et al, 2016).

Industry 4.0 links machines, processes, systems and products into smart networks which oversee each other. As argued by experts, in the future manufacturing would epitomise the intelligent interconnected technological systems, not the way we know it now. Although, not all authors agree to call the observed transformation, a fourth revolution and stick to the label of "third industrial revolution", they reckon the changing nature of the competitive advantages of: places, strategies of firms, and the governance structure of international business (IB) networks" this revolution brings about (Alcácer et al, 2016). Though, whether thus "world has become flat or remains spiky across a wider range of locations" is still hotly debated. Certainly, contemporary transformations imply that "locational dispersion of activities coordinated by the multinational enterprises (MNE), the competitive advantages of firms, and the structures of IB networks have been adapting". There are indices, that wider adoption of modern technology, such as 3D printing, has the potential to at least partially reverse the trend toward fragmented, specialized, and globally dispersed supply chains. Hence, the process of global value chains (GVCs) restructuring might lead to some renewed geographic concentration and favours locations close to end-users. New technologies open new options for firms to disperse their activities; yet, on the other hand, they enable fewer production stages and a more integral product architecture. These changes may increase the power of MNEs as coordinators of GVC, or conversely, empower many small dispersed members of networks or chains. We may hence witness some transition from international transactions internalized within MNEs, to GVCs open IB network structures. Predicted changes in GVC configuration and lengths would be certainly accompanied by changes in the roots of firms' advantages. The capacity to create and capture value would hinge upon the capability of building new networks, and most importantly upon becoming an insider of thereof and acceptance into segmented business networks; shortly upon the *insidership*. For MNEs internalization advantages could hence relate more to the span of IB networks orchestrated or controlled by the firm, than to the range of activities carried out in facilities that the firm owns.

As it seems for analysing the future Industry 4.0-embedded international cooperation crucial becomes the upgrading along the GVC, defined as a move from a lower value-added activity towards a higher value-added one (Barrientos et al. 2010; Milberg–Winkler 2011). Regardless of the type of upgrading (Humphrey–Schmitz

2002) such processes epitomise the evolution of the whole value chains – modification, development, reorganisation, diversification etc. It might be top-down induced and hence defined as governance or truly bottom-up initiative and hence labelled as upgrading (Lee–Gere 2015). Seen from the perspective of the participating firms upgrading is a must, and crucial for survival (Éltető et al. 2016). This implies significant challenges for cooperating partners.

THREATS AND OPPORTUNITIES OF INDUSTRY 4.0

Industry 4.0 implies intelligent smart fusion of processes and products along the value chain (Industrie 4.0, 2014). Expected real benefits of Industry 4.0 come through new smart products, new services, new business models and new efficient processes. However, this potential profits can have materialised once standards and data protection as well as adequate rules and legal provisions are in place. Furthermore, the understanding of Industry 4.0 cannot be limited to the digitalisation of production. It covers the whole ecosystems including humans, machines, and organisations. Industry 4.0 is believed to be able to address various challenges faced by modern societies in advanced economies. It is expected to help to find ways to balance customization with mass production, to alleviate resource scarcity, to improve energy efficiency; to enable urban production and cushion the consequences of demographic change – shrinking population and aging society. Industry 4.0 brings productivity gains and efficiency increases along the value chains (Rüßmann et al, 2015).

The diagnosed challenges of the fourth industrial revolution encompass various aspects and at this moment it is almost impossible to assess them or evaluate properly their likeliness or full impact on economies or societies. Often quoted challenges include technical issues – quality and availability of advanced infrastructure – machines, devices capable of handling large quantities of data, storage facilities, broadband, legal standards and law safeguarding the rights and obligations under Industry 4.0., as well as labour market solutions – right education, training, or provision of skills. Higher complexity of work would mean for employers more flexibility and at the same time greater instability. Sociologists warn of the hourglass society with thin and getting thinner middle-income class, the disappearing of medium-salary earners, and the growing disparities. Such unequal distribution would obviously affect societies within each country but it may also play out among countries, where some of them would unfortunately find themselves in this hollowing-out middle. They would be neither cheap enough to remain attractive as production places, nor the leaders to benefit from the first-mover surpluses. In other words, hourglass society and hollowing-out might play out also along the global value chains not only within one nation society. The risk, we may be facing soon, is mass unemployment for some categories of workers, combined with lack of skills in other categories and the political and social implications of such imbalances (Mesnard 2016). Rising unemployment due to robotisation may in time evolve into the situation when human workforce becomes

dispensable. This would create additional pressure to rethink the idea to introduce the universal basic wage (*Grundeinkommen*). Hence, there is a need to invent a systemic and sustainable model which accommodates social needs and provide more certainty for workers.

The fourth industrial revolution implies almost exponential increase of complexity due to continuous build-up of new data and the necessity to analyse and store them, and to secure the connections between them. Such situation requires from companies the continuous flexible adaptations. It can be also the source of tensions between short term adjustments and long term strategic goals, capital and production possibilities and employees' interests. Meeting these challenges require transforming production and logistic systems into networked systems working in real times, decentralised, and self-optimising (Spath et al, 2013).

Available studies provide mixed results on the consequences of technological progress on the labour market. Estimation of labour demand effects of routine-replacing technological change (RRTC) for Europe as a whole, and at the level of 238 European regions showed that it has positive labour demand effects over 1999-2010 (Terry et al, 2016). This implies rather the tendency of „labour is racing with the machine and not against". Based on a task framework of regional labour demand in tradable and non-tradable industries, two channels have been distinguished through which technological change affects labour demand - the direct substitution of capital for labour in task production, and compensating effects operating through product demand and local demand spillovers. Positive consequences are interpreted mainly as overcompensation of sizable (negative) substitution effects by product demand and its associated spillovers. In other words, when considering the labour market consequences of Industry 4.0 two effects need to be weighed against each other: positive productivity gains boosting consumer demand so called compensation effect, contra technological unemployment i.e. destroying jobs due to technology replacement so called redundancy effect (Hungerland et al, 2015).

Study of Roland Berger, commissioned by the German Industry Association BDI, shows that Germany may benefit to the tune of 425 billion euro by 2025 thanks to the increase of the value added, which is nearly 5.300 euro per citizen. Europe can in the same time generate 1,25 trillion euro (*Bunderverband der Deutschen Industrie*, 2016). Though, failed the digital transformation, Germany would have to bear the losses of some 220 billion euro and Europe even 600 billion euro within next ten years.

Digital transformation makes not only products smarter but reorganises markets into platforms. These are defined as places, where thanks to available data, services would be provided and value added would be anew divided and shared. They shall not be confined within the borders of one country as their performance shall expand across countries and platforms need to be transnational. Such structures are long known in automotive industry, where they enable cost reduction by co-sharing in manufacturing different makes of cars, in computer games and airlines alliances. Platforms, though, imply duality and the existence of the core, i.e. the owner of solutions who manages the whole platform and the periphery, i.e. consumers and users who compete, and who

work on the platform provided by the core / the owner. If drawing the analogy or using such filter for countries' analysis, one may claim that some economies would find themselves rather on the periphery, whereas the others – leaders - in the core. Platform structure relies on certain duality whereas the center / core is characterised by monopoly featuring scale economies, high fixed costs, and network effects, periphery is characterised by hyper-competition. In international markets, countries would have to realign somehow and fit themselves into these platforms. Given the peculiarities of Industry 4.0 and the advancement made by Germany it seems reasonable to argue that this country would most likely take the position of the platform core, taking monopoly gains, whereas Poland along with other catching-up countries might become the periphery applying the core solutions, relying on them but simultaneously harshly competing. From the perspective of platform as the whole, it seems that the dynamic of innovative process is unduly appreciated while the stability of the whole systems tends to be neglected. Hence, what is euphemistically labelled as sharing economy is in fact an aspect of new economic order; of capitalism of platforms. Policy makers as well as the societies do not seem to be ready to embrace this new regime (Lobo, 2016).

Industry 4.0. is undoubtedly posing several challenges. Mixed results of the implementation so far have caused that certain scepticism is creeping in. The newest global survey collecting data from 300 experts in Germany, Japan, and US, show problems with respect to coordination of actions across different organizational units, cyber security standards, data ownership when working with third-party providers, motivation and support of team / staff for a radical transformation, or recruiting the necessary talents (Breunig et al, 2016). Experts aware of difficulties faced while phasing-in this revolution suggest manufacturers among others: to focus on a limited number of Industry 4.0 applications, rather than trying to cover all aspects at once; to build a portfolio of third-party technology providers, as Industry 4.0 is causing a shift from the single-provider model to one that hinges on a set of integrated technology providers; to establish a dedicated cross-functional team that drives innovation based on a culture open to change and experimentation. Currently arguments about the industrial internet mix scientific facts with speculations and emotions. We agree as to the unprecedented scale of the change is but there is little agreement on the likely consequences with expectations ranging from technocratic automatised dystopia (dark world of surveillance, consumer lock-in, violations of privacy), a dream-like techno-utopia (fully-interconnected "smart" world of progress) and a digitally-enhanced business as usual (Porcaro, 2016).

POLISH-GERMAN ECONOMIC TIES AGAINST THE BACKGROUND OF INDUSTRY 4.0

Germany accounted in 2014 for 26% of Poland's export (http://www.polen.diplo.de/Vertretung/polen/pl/09-wirtschaft-verkehr/03-dt-poln-wirtschaftsbeziehungen/0-dt-poln-wirtschaftsbeziehungen.html). The stock of German FDI reached 27,5 bln euros in 2013, whereas the inflow in this year amounted to nearly 2 bln euro. Accord-

ing to AHK report, the stock of German investment in the end of 2013 accounted in Poland 114 bln PLN, as much as 17% of all FDI accumulated in Poland with nearly 31% directed to manufacturing (*Perspektywiczne* … 2014). According to the figures published by Polish Investment and Trade Agency, Germany belongs to major investors in Poland with more than 27.3 billion euro invested so far (https://www.paih.gov.pl/poland_in_figures/foreign_direct_investment). Latest NBP statistics from 2015 show that the inflow of German FDI to Poland accounted in this year 2.350 mln euro whereas the stock totalled 27.356 mln euro (http://www.nbp.pl/home.aspx?f=/statystyka/bilans_platniczy.html). On the other hand, Polish direct investments flowing to Germany accounted in 2015 137,3 mln euro and accumulated investments (stock) totalled 1193 mln euro (http://www.nbp.pl/home.aspx?f=/publikacje/pib/pib.html). Polish investment in Germany account for less than 1% of German all FDI and the stock totalled in the end of 2013 3,6 bln PLN. Poland as other CEE countries faces a „sandwich position" in global competitive positioning (Schuh, 2016, p: vii). Asian emerging economies pose challenge in terms of cost and efficiency. West European countries or USA are ahead with respect to innovation or quality.

This mutual economic dependence, although asymmetrical, clearly implies that any major transformations taking place in one partner would have an impact on the other one. Ongoing gradual phasing-in of Industry 4.0 in Germany must not be ignored in Poland, particularly as experts foresee Germany as future "factory outfitter of the world" (Heng 2014; Brettel et al, 2014)[3]. Germany is becoming a world leader in digital manufacturing and cutting-edge field of additive manufacturing; in the future market of virtual systems and production systems that are highly complex yet ultra-efficient (Folkerts-Landau et al, 2016). Germany outdo rivals in plant engineering. German companies help entire countries to industrialize or modernize and the sign "Made in Germany" seems slowly being replaced by "Invented in Germany". Experts stress that Poland if anything is in a very early phase of this fourth revolution (Experts, 2016). To advance the evolution towards Industry 4.0 required are not that much funds and top-down support but more involvements and engagements from the bottom. Building new industrial ecosystem needs active participation of firms. It should be hence welcome that the representatives of German firms and industry Chamber AHK are advocating the development of new industrial paradigm in Poland[4]. It is

[3] As M. Brettel et al, 2014 find: „Many companies from the German manufacturing industry adjust their production focusing on customized products and fast time to market. Leveraging the advantages of novel production strategies such as Agile Manufacturing and Mass Customization, they transform into integrated networks. Hereby, virtualization of the process- and supply-chain ensures smooth inter-company operations providing real-time access to relevant product and production information for all participating entities. Boundaries of companies deteriorate, as autonomous systems exchange data, gained by embedded systems throughout the entire value chain."

[4] Representatives of Siemens, Volkswagen, Baluff, Rec Global and Mercedes took part in a discussion panel on Lower Silesia as a place for development of IT sector and Industry 4.0. „Dolny Śląsk – od miejsca produkcji do zagłębia IT i przemysłu 4.0"; A. Golański, *Idziemy w ślady Niemców: polski Przemysł 4.0 zaczyna się we Wrocławiu*, http://www.dobreprogramy.pl/Idziemy-w-slady-Niemcow-polski-Przemysl-4.0-zaczyna-sie-we-Wroclawiu,News,67494.html

obviously in German own interest to assure some continuation of so far rather fruitful cooperation with Polish partners. This would require sharing previously designed and implemented by the leader – in this case Germany – advanced solutions and new business models, also offering best practises and safeguarding necessary infrastructure connections. All this in order to assure certain compatibility between partners.

Enterprises are becoming dependent on the ability to take part in collaborations (Lauras et al, 2015). Hence, it is necessary to get actively involved in emerging, potentially opportunistic collaborative enterprise networks. To assess the readiness of firms to get involved in Industry 4.0 it is not enough to tap into already available measures of technological advancement or innovativeness of national economies. It becomes necessary to gauge the capacities of sectors and firms to plug into GVC transformed by Industry 4.0, and to adapt new business models. Hence, it becomes critical to evaluate factors such as infrastructure, big data cloud computing, net security, IT skills of employees, digital literacy, etc. Some of these elements feature in the newest surveys conducted by the EU bodies. These elements, and not that much classic innovativeness indicators such as the number of patents, student population, tertiary education enrolment, or R&D expenditures, are critical for defining the capability and readiness of firms and sectors which already trade and cooperate to get upgraded to the fourth industrial revolution. It may turn out that existing partners would be replaced not by cheaper suppliers from low-cost countries but more expensive yet more industrially compatible firms, who have already transformed their business models and are ready to conclude advanced cooperation.

This section puts forward some measures helpful for assessing the readiness of a given economy to embrace the concept of Industry 4.0. There is data available in some papers and dossiers or in the EU databases such as DESI[5] which might prove useful in this respect, though, it does not seem sufficient and further work on proper readiness measure should be continued (https://www.zvei.org/en/subjects/industry-4-0/the-reference-architectural-model-rami-40-and-the-industrie-40-component/; Industrie 4.0 maturity index RWTH Aachen; Kuruczleki, et al 2017; DESI - http://digital-agenda-data.eu). This part seeks to identify the gap between Poland and Germany in this respect. Selected indicators might be evaluated to roughly assess the compatibility of German and Polish firms with respect to Industry 4.0. The share of IT workers in total employment differs between Polish and German firms quite significantly (*Information Society Statistics, Eurostat, February 2016*). In 2015, this share in the group of all firms accounted to 21% in Germany and barely 12% in Poland, whereas in manufacturing sector it totals 26% in Germany and 13% in Poland. The benefits from cloud computing – crucial element of fourth industrial revolution, such as the cost reduction, more flexibility or faster application of new solutions, can be already used by Polish companies, though, fully exploited are only in a handful of them (Hermann et al, 2015; Duszczyk 2016). The share of using cloud computing is assessed at some 3%, with exception of IT sector,

[5] DESI overall index is calculated as the weighted average of five dimensions: 1 Connectivity, 2 Human Capital, 3 Use of Internet, 4 Integration of Digital Technology and 5 Digital Public Services.

where it is obviously higher. Variety of factors prevents companies form the use of cloud services. Their meaning is different for companies in Germany and Poland. It also varies depending on the industry. Most widespread barriers include: the risk of security system collapse, uncertainty regarding the location of data, uncertainty with respect to legal solutions or dispute settlements, high costs or lacking knowledge. Some pattern can be, however, detected. Whereas for German firms, regardless the size or industry, the highest risk is associated with security systems collapse (32%, 40% in manufacturing), for Polish companies it results from deficient knowledge, lack of awareness and good understanding as to the functioning of cloud computing (40% in general and in manufacturing). The number of Polish firms using cloud computing is on average, depending on the type of specific service, half of the German share. In Poland, the most widespread is the purchase of cloud computing via internet, less popular is hosting of databases, storage of files or purchase of services for accounting, financial departments or customer relationship management (CRM). Firms use different forms of protection. In Germany, it is usually the backup of data (52%) and security instruments (42%), then strong passwords and encrypted messages (37%). In Poland, most popular are security instruments (53%), next backup of data (51%) and strong password (47%). The share of Polish firms who have formally defined ICT security policy was in 2010 on average twice (20% vs 8% policy addressing the risks of destruction of data, unavailability of ICT services due to attack) or even three times lower than in Germany (27% vs 11% formally defined ICT security policy). The awareness of the need of developing this area is also low. The popularity of ICT solutions is similar among Polish and German manufacturing firms with respect to general use of computers and internet, where the differences amount to some 3-5 pp. It is, however, much higher when it comes to placing and receiving orders online. Whereas in Germany 48% of firms in manufacturing place orders via internet in Poland only 22%. In Germany, the online orders are received by 24% of companies, in Poland by 13%. In the total population of all firms, the differences in using internet and computers reach some 4-5 pp between Polish and German firms. Though, they are higher when it comes to placing and receiving orders. Some 45% of companies do place orders and 25% of them receive orders online in Germany. In Poland orders are placed online only by 23% of firms and received by 11%.

The differences between two countries persist not only to the actual usage of new advanced solutions. They can be also diagnosed in terms of the awareness of them; the understanding of them and hence the knowledge about the benefits stemming from them, as well as risks attached. In Poland, there are certainly firms of cutting-edge technologies, very advanced front-runners in selected areas capable to compete globally. Though, in population the share of such companies is very low. The awareness of new models necessary for successful transformation towards Industry 4.0 is still very low. The future cooperation might be endangered due to failed catching up of new Industry 4.0 regime. This is the compatibility and similarity of structures, behaviours, models and solutions adopted which is the prerequisite for the fruitful and mutually beneficial cooperation.

It is evident that given the peculiarities of Industry 4.0 comparing the countries is hard as we lack proper indicators adequately measuring related phenomena. The

distinctiveness of fourth industrial revolution and the way it materialises means that for the moment being we do not have indicators which would measure it properly. Hence, even more important becomes the direct first-hand information extracted from companies and firm-level data.

Summing up, any quantitative analysis of Industry 4.0 especially in international settings (cross-country comparison) is hampered by the lack of proper databases. To evaluate this phenomenon, we have either to draw on some substitutes measures which can be proxies of Industry 4.0 (as presented in this paper above) or rely on surveys and experts' assessments.

Germany thanks to the rent of being a leader and enjoying the first-mover advantage, can assure some monopolistic position. By setting the rules and standards in this respect it can promote particular solutions, require certain norms and somehow coerce partners to follow the suit and adjust appropriately if interested in continuing collaboration (Lydon, 2016). For cooperating firms, this means buying some technologies, adopting devised solutions, safeguarding the compatibility of production systems and undertaking necessary adjustments inevitable to be able to further source or trade with German more advanced partners – leaders in Industry 4.0. On the one hand, the scale and history of Polish-German economic trade and investment flows particularly in manufacturing is a good starting point for further developing and augmenting of these ties. On the other hand, low innovativeness of Polish firms and other diagnosed deficiencies might hamper advancing of this cooperation. In such case Poland first would need to acquire necessary technologies and adopt manufacturing solutions before being able to continue cooperation in new realms of Industry 4.0. Hence, sourcing in Germany and acquiring the Industry 4.0 technologies might be *sine qua non* condition to assure the required compatibility. Poland should attempt to shift the economic ties with Germany up, to the higher level. Dynamic development of trade and investment between two neighbours should stimulate the more advanced cooperation in the area of research, development, and innovation processes. But it must not be limited to and seen only as the collaboration of scientific institutions, research labs or academia but rather as technical cooperation among companies, which would enable Polish firms catching up and learning operating in Industry 4.0. Impressive volumes of current economic ties, at least from Poland's perspective and as measured by the Germany's share in Poland's export, import or FDI should not be only preserved but constitute the starting point for much more advanced collaboration and offer Polish firms a chance to climb up in the value chain. The observed fourth industrial revolution is hence for Poland both, the necessity for maintaining the existing scale and intensity of ties and a unique opportunity for upgrading the cooperation.

CONCLUSIONS

The Industry 4.0 is supposed to transform the contemporary business models. It has been so far studied mainly from the perspective of a company or a given sector and in the context of domestic economy. Nevertheless, it will have profound cross-

border consequences. It may challenge existing economic ties among countries and reshape their trade as well as mutual investments. Current economic ties between Poland and Germany are indeed impressive mainly from the Polish perspective. Germany is Poland's main trading partner accounting for around a quarter of import and export. It is also main direct investor to Poland. These well-founded relationships might be, however, challenged by the ongoing gradual transition towards the Industry 4.0 particularly visible in Germany. Recent studies show that parts and components trade dominates in export-import linkages (Frensch et al., 2016). Whereas for initiating this kind of relations costs play the decisive role, their importance vanishes when it comes to maintaining and further developing existing ties. These findings may offer hence some insight into the future pattern of Polish-German trade by stressing the diminishing role of wage differentials and growing importance of other factors. Industry 4.0 additionally reinforces these developments. As it requires the suppliers and cooperating partners to be equipped to face the challenge of new production systems. Polish partners of German firms must not ignore such findings. Cooperating mainly along the value chain they need to embrace the necessary transformation and stay ready to adapt flexibly to the German counterparts' business models and formula of operating. The future of Polish-German economic ties in the light of Industry 4.0 would very much hinge on the general strategy adopted by the German industry. Whether it would be a strategy of "appropriation/internalization" according to the idea of being the world leader and main supplier of advanced solutions and of maintaining and augmenting the competitive advantage of German firms in dynamic global environment? Or whether it would be a strategy of "sharing", implying broadening the scope of cooperating partners (Brettel at al. 2014; Neugebauer, 2016)? The plans to assist and foster the SMEs in their transformation towards Industry 4.0 or the recognised need to develop the infrastructure not only within but also between countries would indicate the support of such strategy. On the other hand, much in terms of modernising and upgrading remains to be done obviously by Polish firms. As experts argue, unless the catching up of economic, social and technological conditions materialize and certain level of coherence including the right level of infrastructure development is achieved successful transformation towards digital economy in the EU is endangered (Experts, 2016).

Summing up, various broader cross-border, transnational consequences can be expected as far as the existence and functioning of global value chains and production networks is concerned. It will imply certain reshufflings along the chains. Critical would hence become if tested partners are equipped and ready to face the new requirements, to adapt smoothly to new work organisation, if they possess the necessary infrastructure and technology enabling minimal compatibility and safeguarding continuity of cooperation. Classic low cost advantages would undergo further erosion and would be replaced gradually by other competitiveness determining factors such as structures and capabilities (Aiginger et al., 2015). Being cheap and charging lower prices might soon be insufficient to successfully

expand abroad and be part of global value chains. Critical become the swift capability to join existing networks of cooperating companies. The two key instruments for enhanced value creation would be platform-based cooperation and a dual innovation strategy (radical and incremental) (Kagermann, 2014). As it seems, the current hype of Industry 4.0 is hardly touched upon in scholarly papers, representing other domains than engineering. Yet, it poses certain challenges to the whole socio-economic system and might affect the current international relations having an impact on pattern of cross-border trade and composition of global value chains. Available reports drafted by analytical centres and think-tanks offer some predictions and estimations as to this impact. The exact evaluation and hence any meaningful cross-country comparison is not feasible right now. As it seems it is not only because we lack proper indicators measuring this phenomenon (proxies) but also we don't know exactly what factors shall be accounted for. One way to overcome this deficit can be to resort to other available statistics (like it was done in this paper) representing rather the necessary conditions and broader environment for the development of Industry 4.0. Another would be to carry out the expert review and collect first-hand data from involved firms.

The case of Polish-German relations may offer some insight as to the future research areas worth exploration regarding the international aspects of Industry 4.0. The key issues to be addressed are: determinants of readiness and factors critical for competitive advantage in the era of Industry 4.0, obstacles to cross-border economic cooperation, and the potential of Industry 4.0 to reshape existing patterns of GVC. This paper attempts at exploring the fourth-generation industry in the international context. It might be considered as a starting point for further more detailed studies on this topic. Particularly, since there are several research streams in the context of Industry 4.0, which promise to have a considerable impact on the global industry landscape (Brettel et al., 2014).

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ABSTRACT

Industry 4.0 is associated with the Internet of Things, Internet of Services, and Cyber-Physical Systems (CPS). This revolution is profoundly transforming the current business models. There is a growing interest in this phenomenon among scholars, policy makers and representatives of business and industry as it poses several challenges to the national legal systems, labour markets and technical capacities. Yet little is known about the international context of the fourth industrial revolution. This paper aims at bridging the gap in this respect. Drawing on the Polish-German case it identifies the research areas worth considering and advances a hypothesis on economic ties in the context of Industry 4.0. The author outlines the premises of the fourth-generation industry, diagnoses and discusses the main risks and benefits associated with it. The paper might be regarded as a starting point for further, more detailed studies on this topic.