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# The expected contribution of Industry 4.0 technologies for industrial performance

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ABSTRACT

Industry 4.0 is considered a new industrial stage in which vertical and horizontal manufacturing processes integration and product connectivity can help companies to achieve higher industrial performance. However, little is known about how industries see the potential contribution of the Industry 4.0 related technologies for industrial performance, especially in emerging countries. Based on the use of secondary data from a large-scale survey of 27 industrial sectors representing 2225 companies of the Brazilian industry, we studied how the adoption of different Industry 4.0 technologies is associated with expected benefits for product, operations and side-effects aspects. Using regression analysis, we show that some of the Industry 4.0 technologies are seen as promising for industrial performance while some of the emerging technologies are not, which contraries the conventional wisdom. We discuss the contextual conditions of the Brazilian industry that may require a partial implementation of the Industry 4.0 concepts created in developed countries. We summarize our findings in a framework, that shows the perception of Brazilian industries of Industry 4.0 technologies and their relations with the expected benefits. Thus, this work contributes by discussing the real expectations on the future performance of the industry when implementing new technologies, providing a background to advance in the research on real benefits of the Industry 4.0.

## 1. Introduction

Industry 4.0 is understood as a new industrial stage in which there is an integration between manufacturing operations systems and information and communication technologies (ICT) – especially the Internet of Things (IoT) – forming the so-called Cyber-Physical Systems (CPS) (Wang et al., 2015; Jeschke et al., 2017). This new industrial stage is affecting competition rules, the structure of industry and customers' demands (Gilchrist, 2016; Bartodziej, 2017). It is changing competition rules because companies business models are being reframed by the adoption of IoT concepts and digitization of factories (Dregger et al., 2016; Lasi et al., 2014; Wang et al., 2015). From the market point of view, digital technologies allow companies to offer new digital solutions for customers, such as internet-based services embedded in products (Ayala et al., 2017; Coreynen et al., 2017). From the operational perspective, digital technologies, such as CPS, are proposed to reduce set-up times, labor and material costs and processing times, resulting in higher productivity of production processes (Brettel et al., 2014; Jeschke et al., 2017).

Several countries have recently created local programs to enhance the development and adoption of Industry 4.0 technologies. In Germany – where this concept was born – this program was called "High-Tech Strategy 2020", in the United States was established the "Advanced Manufacturing Partnership", in China the "Made in China 2025" and in France the "*La Nouvelle France Industrielle*" (Kagermann et al., 2013; Rafael et al., 2014; Wahlster, 2013; Zhou, 2017; CNI, 2013; Liao et al., 2017). In Brazil, the program called "Towards Industry 4.0" (*Rumo à Indústria 4.0*) was created by the Brazilian Agency for Industrial Development (ABDI – *Agência Brasileira de Desenvolvimento Industrial*) together with other initiatives of the Ministry of Industry, Foreign Trade and Services (MDIC – *Ministério da Indústria, Comércio Exterior e Serviços*) (ABDI, 2017). All these programs, in both developed and emerging countries aim to disseminate the Industry 4.0 concepts and technologies in local firms.

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Nevertheless, it is well-known that the adoption of advanced technologies can be more challenging for emerging countries (Hall and Maffioli, 2008; Kumar and Siddharthan, 2013). Since the economies of emerging countries have been historically more focused on the extraction and commercialization of commodities, companies in these countries are frequently behind in terms of technology adoption, when compared to their counterparts in developed countries (Castellacci, 2008). Other factors such as ICT infrastructure, culture, level of education and economic and political instability can also interfere in the value perception and in the consequent level of investments in advanced technologies (Frank et al., 2016). Thus, even when the Industry 4.0 related technologies are presented by the literature as beneficial for firms, given the particular characteristics of emerging economies, an important question emerges: *what is the perception of industries in emerging countries about the benefits of Industry 4.0 related-technologies for industrial performance*?.

We aim to answer this question by analyzing the potential benefits for product development, operations and side-effects aspects expected by the Brazilian industry when implementing the Industry 4.0 related technologies. We analyze secondary data from a large survey recently applied in Brazil by the National Confederation of the Industries (*Confederação Nacional das Indústrias* – CNI), which comprises a sample of 2225 companies from different industrial segments of this emerging country. Our findings indicate that only some of the Industry 4.0 related technologies are expected as beneficial by the Brazilian industry and that it depends on the focus of the industrial sectors, i.e. focus in differentiation or cost. We also discuss some unanticipated findings regarding advance technologies with negative expected results on industrial performance.

The remaining sections of this paper are structured as follows. In Section 2, we provide the theoretical background for Industry 4.0 technologies and the expected benefits of their implementation, as well as their usefulness in emerging countries. Section 3 introduces the research method where we discuss the secondary data source and our methodological procedures for the data treatment and analysis. The results are presented in Section 4, followed by the discussions of the findings in Section 5 and the conclusions in Section 6.

## 2. Theoretical background

### 2.1. Industry 4.0 and the international technology diffusion-adoption theories

Some scholars and practitioners have considered four main industry changes throughout the history, while the Industry 4.0 is the last one and an ongoing industry transformation (Qin et al., 2016). The steam machine – between 1760 and 1840 – characterized the first industry revolution; the second was defined by the utilization of electricity in industrial processes in the end of the XIX century; the third revolution started in the decade of 1960 with the use of ICT and industrial automation. The fourth industrial revolution – or Industry 4.0 – emerged from several developed countries and it was consolidated in a German public-private initiative to build smart factories by the integration of physical objects with digital technologies (Brettel et al., 2014; Hermann et al., 2016). The key element that characterizes this new industrial stage is the deep change in the manufacturing systems connectivity due to the integration of ICT, IoT and machines in cyber-physical systems (CPS) (Kagermann et al., 2013; Schwab, 2017). As a result, the Industry 4.0 can be considered nowadays as a new industrial age based on the connectivity platforms used in the industry (Lasi et al., 2014; Parlanti, 2017; Reischauer, 2018). It considers the integration of several different dimensions of the business, with a main concern on manufacturing issues, based on advance manufacturing technologies (Saldivar et al., 2015; Fatorachian and Kazemi, 2018). In such a sense, Industry 4.0 can be understood as a result of the growing digitization of companies, especially regarding to manufacturing processes (Kagermann, 2015; Schumacher et al., 2016).

Following this concept, Industry 4.0 can be seen as a matter of technology diffusion and adoption. Emerging technologies of this new industrial age have been conceived in developed countries such as Germany, which is nowadays leading the diffusion of the concept to other countries interested in its adoption (Arbix et al., 2017; Bernat and Karabag, 2018). However, the diffusion-adoption process tends to be slow and it usually flows from developed countries to emerging countries (Phillips et al., 1994; Eaton and Kortum, 1999; Comin and Hobijn, 2004). Therefore, different behavior patterns could be seen when analyzing digital technologies in an emerging country such as Brazil comparing to the leading countries on this issue such as Germany. According to the diffusion-adoption theories, different aspects can produce such gaps between economies. Barriers to the diffusion and adoption are frequently present (Parente and Prescott, 1994) and the competitive environment of both the supplier side and the adopter industry also create differences (Robertson and Gatignon, 1986). As a consequence, emerging countries can have a different value perception of the diffused technologies (Alekseev et al., 2018; Luthra and Mangla, 2018) which may be based on different needs compared to developed countries (Kagermann, 2015).

Our study is based on the fact that the perceived value of technologies can be different in emerging countries, which can also change their adoption of these technologies (Castellacci, 2008; Castellacci and Natera, 2013). Instead of studying the technology diffusion-adoption flow, as previously done by several other scholars (e.g. Phillips et al., 1994; Comin and Hobijn, 2004), we focus on the current adoption and its expected benefits in the Brazilian industry. We first address the general benefits proposed by those enthusiastic on Industry 4.0. Second, we consider the Brazilian industrial context and the possible difficulties for the implementation of Industry 4.0 concepts. Then, we use empirical data to investigate the adoption levels and the expected benefits. We use the diffusion-adoption theory in order to understand better our findings.

### 2.2. Industry 4.0 and its expected benefits

The Industry 4.0 concepts are proposed to enable companies to have flexible manufacturing processes and to analyze large amounts of data in real time, improving strategic and operational decision-making (Kagermann et al., 2013; Porter and Heppelmann, 2014; Schwab, 2017). This new industrial stage has been possible due to the use of ICTs in industrial environments (Kagermann et al., 2013) and due to the cheapening of sensors, increasing their installation in physical objects (Brettel et al., 2014; Porter and Heppelmann, 2014; Bangemann et al., 2016). The advancements in these technologies allowed the development of embedded and connected systems (Jazdi, 2014; Kagermann et al., 2013; Brettel et al., 2014). These systems aim to monitor and control the equipment, conveyors and products through a cycle of feedbacks that collect a great quantity of data (big data) and update the virtual models with the information of the physical processes, resulting in a smart factory (Wang et al., 2015, 2016; Gilchrist, 2016). Therefore, since the development of digital manufacturing in the 1980s, different technologies have emerged and have been applied in production systems, such as cloud computing for on-demand manufacturing services (Yu et al., 2015), simulation for commissioning (Saldivar et al., 2015), additive manufacturing for flexible manufacturing systems (Kagermann et al., 2013; Wang et al., 2016), among others. Table 1 presents a list of ten types of technologies frequently associated to the Industry 4.0 concept (CNI, 2016; Gilchrist, 2016; Jeschke et al., 2017).

The technologies presented in Table 1 support the three main advantages that characterize Industry 4.0: vertical integration, horizontal integration and end-to-end engineering (Kagermann et al., 2013; Wang et al., 2015). The vertical integration refers to the integration of ICT systems in different hierarchical levels of an organization, representing the integration between the production and the management levels in a