Bringing it all back home? Backshoring of manufacturing activities and the adoption of Industry 4.0 technologies

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Bringing it all back home? Backshoring of manufacturing activities and the adoption of Industry 4.0 technologies

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Abstract: We investigate the relationship between backshoring of production activities and digital manufacturing technologies, also known as Industry 4.0 (I4.0). We argue that I4.0 supports backshoring because it provides a higher productivity and flexibility which offers an incentive for firms to locate production close to their European customers.

The empirical test is based on a large dataset of more than 2,000 manufacturing firms. Backshoring is still a rare event with a share of no more than 4% of all firms. Descriptive statistics as well as regression results indicate a positive correlation between the adoption of I4.0 technologies and companies' backshoring propensity.

Keywords: Backshoring, offshoring; Industry 4.0; technology

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1. Introduction

International business (IB) theory regards information and communication technologies (ICTs) as tools to extend the geographical boundaries of the firm. ICTs help firms to extend control and reduce co-ordination costs in a large network of geographically dispersed subsidiaries, suppliers and customers (Alcácer et al. 2016; Chen und Kamal 2016). Thus, ICTs foster international expansion of firms, and the creation of global value chains.

New technologies, however, may also have the opposite effect, allow firms to re-concentrate manufacturing activities and may lead to de-globalisation. An example is the case of a producer of metal parts with about 150 workers at locations in Austria and Hungary[1]. Smoothening and polishing of large metal parts is one of the core production processes of this firm. This work is time-consuming (100 – 150 h for one part) and dirty, but nevertheless requires experienced staff. Wage advantages were the main motive of the firm to offshore production and locate this production step in Hungary.

Recently, the firm automated this production step, and installed a robot for smoothening and polishing. The robot is faster (20 h for one part, works 24/7) which increased productivity. This investment allowed the firm to move the production step back to Austria, and re-concentrate production at the main premises. This gives the firm more flexibility and responsiveness, because transport between Hungary and Austria is not needed anymore. The firm now can take orders that were not possible before because of the time needed for transport between the production facilities.

This paper asks if this example is just an exception, or part of a new trend where new digital production technologies, or Industry 4.0 (I4.0), may provide incentives to move production back to the home country of the firm, and therefore slow down the further evolution of global value chains (GVC). Backshoring (or 'reshoring') has recently received broad attention in the academic literature (De Backer et al., 2016; Fratocchi et. al., 2014; George et al., 2014; PwC, 2014; Kinkel, 2012; BCG, 2011; Kinkel & Maloca, 2009), and even more attention in public debates. The paper contributes to

[1] Information gathered from an interview with the manager of the firm. We are happy to disclose the identity of the firm on request.

these debates and to the IB literature in two ways: fist, by presenting evidence on backshoring from three European countries; second, by investigating how new technologies relate to backshoring decisions of firms.

We argue that Industry 4.0 may relate to backshoring in two ways: first, increased productivity provided by I4.0 production technologies may neutralize the factor cost advantages of offshoring locations and make labour arbitrage less appealing. Second, the promise of more flexibility by I4.0 technologies may provide an incentive for firms to re-locate production close to their European customers and regain some of the flexibility lost in fine-sliced global production networks. As the pressure for more customized products, greater flexibility and more responsiveness in the supply chain is likely to grow into the future – and Industry 4.0 technologies bear the potential to develop such smart and agile systems – this may lead to more localized production activities including eventual reshoring and near-shoring options.

The empirical test of the paper is based on a large dataset of more than 2,000 German, Austrian and Swiss manufacturing companies. This dataset includes variables on both, backshoring and investments in modern production technologies, and a number of additional control variables.

The paper is structured as follows: in section 2 we discuss backshoring and Industry 4.0; section 3 presents the research question; section 4 describes the data, methodology and the construction of the main indicator; section 5 provides descriptive results, while sections 6 report and discuss the multivariate results. The paper closes with a discussion of conclusions in section 7.

2. Related literature

2.1 Backshoring and offshoring

Backshoring is the decision to relocate manufacturing activities back to the home country of the parent company (Kinkel & Maloca, 2009; Arlbjørn & Mikkelsen, 2014; Fratocchi et al., 2014;Foerstl et al., 2016). Backshoring can origin from wholly owned production sites of the company (captive backshoring) as well as from foreign suppliers (outsource backshoring), thus covering different ownership modes of manufacturing in the offshore country.

There is no explicit theory of backshoring in the IB literature. The literature explains backshoring in the framework of existing theories of the multinational firm, as a reverse or subsequent decision of a previous offshoring decision (Bals, *et al.,* 2013; Ellram *et al.*, 2013; Gray *et al.*, 2013; Tate, 2014; Foerstl et al., 2016). To put it simply, backshoring takes place when the trade-offs between cost advantages, market and knowledge seeking, transaction costs and maintaining control become too large for the firm.

Through the lens of *internalisation theory* (Buckley and Casson, 1976; Casson, 2013; Rugman, 2010) and Dunning's "eclectic paradigm" (Dunning, 1980, 1998) backshoring is a result of changes in the ownership, location and/or internalization advantages from international production, or a consequence of a wrong assessment of these advantages (Ellram et al., 2013, Fratocchi et al., 2016). International expansion of multinational firms was fueled by labor arbitrage, a substantial lowering of import barriers for intermediate goods, lower cost of cargo transport, and the rapid development of ICTs which supported transborder communication and coordination (Dicken, 2014). Factors that contributed to a wrong assessment of location, internalization or ownership advantages include rising labor costs in foreign locations and narrowing wage differentials, transport costs and long lead-times in transport, currency fluctuations, the cost for obsolete materials ordered according to a long-term and incorrect forecast, unforeseen coordination cost such as additional travelling expenses, or a loss of intellectual property to foreign competitors or suppliers (Handfield, 1994; Kinkel & Maloca, 2009; Holweg at al., 2011; Nassimbeni, 2006). Case studies have shown that some managers have offshored manufacturing activities based on simple comparisons of easily measurable costs, in particular labor costs (Kinkel & Maloca, 2009).

The *resource-based view* (RBV) of the firm (Wernerfelt, 1984; Prahalad & Hamel, 1990) can also be applied to explain backshoring strategies. Firms can develop organisational processes and routines that cannot be acquired over markets, enabling them to use resources and develop capabilities more efficiently and effectively (Barney, 1991; Teece et al., 1997, 2002). Backshoring decisions thus may result from the limited abilities of companies to sufficiently develop and maintain such critical capabilities in foreign locations, or to exploit the host country's resources in order to create competitive advantage for the multinational company as a whole (Canham & Hamilton, 2013). Here again, advanced production technologies come into play. Some organisations are able to adopt manufacturing processes to develop unique and barely imitable competences at specific locations and to exploit these resources in a specific and more effective way (Broedner et al., 2009; Grant, 1991).

Transaction cost theory (TCT) can also help to understand backshoring. High and growing transaction and coordination costs can be strong arguments for re-concentrating manufacturing activities via backshoring. TCT points to various reasons for a wrong assessment of the 'hidden' costs of offshoring. *Bounded rationality* and possible contingencies in transactions across companies and countries may lead to inaccuracy of the projected cost and performance of manufacturing offshoring decisions (Pisano, 1990; Pisano & Shih, 2009; Lewin *et al.*, 2009; Cabral *et al.*, 2013) to higher than expected costs, poorer than expected quality, and higher than expected efforts for the management of transborder activities (Fredriksson & Jonsson, 2009; Tate *et al.*, 2009). Biases in decision making such as the "bandwagon effect" (Abrahamson & Rosenkopf, 1993), aiming at imitating competitor behavior and 'following the herd', can also be explained by bounded rationality (Barthélemy, 2003).

The *level of uncertainty* is also influencing companies' offshoring and backshoring decisions. Foerstl et al. (2016) differentiate between environmental uncertainty, supply chain complexity, and task uncertainty as possible drivers for backshoring decisions. *Environmental uncertainty* encompasses the perceived degree of volatility and unpredictability of a foreign market, including unforeseen cost increases, quality and flexibility issues, raw material shortages, or currency fluctuations (Ellram *et al.*, 2013; Gray *et al.*, 2013; Tate *et al.*, 2014). *Supply chain complexity* includes vertical complexity, horizontal complexity, geographic dispersion and length of the supply chain (Choi & Hong, 2002). It can lead to excessive coordination and monitoring efforts, rising transportation cost or high amounts of working capital in safety stock (Lewin *et al.*, 2009; Tate, 2011; Ritter & Sternfels, 2004). *Task uncertainty* is another factor influencing offshoring and backshoring decisions. Here, to some extent uncertain potentials of technological innovations in manufacturing processes, e.g. by an intensified use of Industry 4.0, come into play. A higher Industry 4.0 adoption might enable more flexible, autonomous and less labor intensive production modes, giving advantages to backshoring decisions over low-wage manufacturing activities (Handley & Benton Jr., 2013; Lasi *et al.*, 2014). *Asset specificity* is also closely linked to the implementation of new product or production technologies, e.g. Industry 4.0 technologies. It involves specific durable investments such as technology or knowledge and skills that are required to realise efficient processes and transactions. A high degree of asset specificity appears to be most critical for the integration of manufacturing activities and their control under unified governance (Williamson, 1985), in particular in cases of high product or process complexity (McIvor, 2009). The higher and more specific investments in advanced production technology are, the higher the possibility to integrate the specific manufacturing operations at one focal plant, favoring rather backshoring than additional offshoring activities.

2.2 Industry 4.0

Many observers today agree that we are witnessing a technological revolution in manufacturing (Brynjolfsson & McAfee, 2014; Ford, 2015; OECD, 2016, 2017). This revolution is based on a variety of digital production technologies (e.g. sensors, actuators, advanced robotics, networked production), new materials, but also new, IT-enabled management processes (e.g. real-time enterprise resource planning and production control, data analytics, applications of artificial intelligence), and new business models.

In the manufacturing context, the diffusion of this group of technologies is often labelled as the Fourth Industrial revolution – after mechanization, electrification, and automation – or Industry 4.0, a German term that is widely used in the debate in the European Union (Kagermann et al., 2013; Spath et al., 2013; Bauernhansl, 2014). The most striking feature of Industry 4.0 is that components and machines communicate and co-ordinate their operations in factories and (global) value chains (Brennan et al., 2015, Bauernhansl, 2014; Kagermann et al., 2013; Spath et al., 2013; OECD 2017; UNCTAD 2017). A main component of Industry 4.0 are Cyber Physical Systems (CPS). CPS comprise "smart machines, warehousing systems and production facilities that have been developed digitally and feature end-to-end ICT-based integration, from inbound logistics to production, marketing, outbound logistics and service" (Kagermann et. al., 2013, p. 14). This is done by embedding technology that can take on tasks like sensing or automation into physical objects and connecting them via the Internet. In other words, CPS integrate all stages of the physical production process over the Internet, in order to create a seamless exchange of information between these two worlds. This allows for intelligent, real-time, horizontal and vertical integration of value-added processes and business models (Kagermann et al., 2013).

Additive manufacturing (3D printing) is another new manufacturing technology with disruptive potential for the global organisation of industries (Laplume et al., 2016). However, additive manufacturing today is mainly used for prototyping and small batch operations, and is not yet competitive for high volume production.

3. Research question development

Experts expect that Industry 4.0 will allow a highly flexible and at the same time highly efficient production which makes it possible to produce individualized products under the economic conditions of a mass producer (Lichtblau et al., 2015). Thus, manufacturing firms can expect two main benefits from Industry 4.0:

- First, I4.0 technologies increase productivity, improve capacity utilisation, and make firms more competitive in terms of production costs (Kagermann et al., 2013; Spath et al., 2013; Brynjolfsson & McAfee, 2014; Bauernhansel et al., 2014; Jäger et al., 2015). Moreover, I4.0 may reduce the necessary labour input and therefore shift the ratio between capital and labour inputs in favour of capital. Thus, I4.0 may weaken or even compensate locational advantages of low-wage countries, making labour arbitrage in low-wage countries less appealing and economies of scale of factory sites in developed countries more important. Given that labour cost differentials are a main reason for offshoring (Dachs et al., 2012), we can expect more backshoring due to smaller labour cost differentials.
- Second, the adoption of I4.0 technologies can increase flexibility in manufacturing processes, enabling customized production in small batches with very low marginal cost (Lichtblau et al., 2015). In other words, I4.0 can provide cost advantages of mass production with the flexibility of a small-batch producer. This may open new market segments to firms, particularly in developed

countries. These new market segments can only be successfully approached if the customized goods can also be quickly delivered to the client, calling for a minimum total time between order and delivery. In times of Amazon, no customer is willing to wait for a product order longer than some days. Such flexible short-term delivery is only feasible if the manufacturing site of the customized product is located closely to the customer – which in most cases of customized products is situated in developed countries – favouring backshoring of manufacturing activities from low-wage to high-wage countries.

We argue that I4.0 – via the productivity and flexibility effects – can influence the trade-offs described in the previous chapter in favour of backshoring, and gives an incentive to firms to relocate production back to the home country. A higher productivity from I4.0 may offset the labour cost advantages firms enjoy in offshoring locations. A higher degree of flexibility helps the firm to reduce lead-time, improve market orientation and allows to reach clients which could not have served before. Proximity to the customer is increasingly competing with the long-time dominating global value chains, resulting in high complexity and flexibility disadvantages, especially in the case of short-term and individual customer requests (Kinkel et al., 2016).

One could also argue that historical experience demonstrates that new technologies rather favor production fragmentation in GVCs; ICTs have a stronger effect on economic geography than any other technology before, as they allow for remote coordination and thus render local agglomeration futile (Leamer & Storper, 2001). This argument would also be in line with Buckley's concept of the 'global factory (Buckley & Ghauri, 2004; Buckley, 2011), claiming that new technologies allow firms to 'fine slice' value-adding activities and locate them in their optimal place, as these technologies support sufficient coordination and control at a distance, even when not owning all of the supply chain. However, local agglomerations and clusters of companies' activities still exist. Local agglomerations and global integration via ICTs does not seem to be an 'either/or', rather a 'both/and' phenomenon (Alcacer et al., 2016). ICTs is not able to substitute face-to-face interaction for stimulating competence-creating capabilities – it rather complements it (Alcacer et al., 2016). As the adoption of new I4.0 technologies in manufacturing operations is also a competence-creating activity, the role of local communication and coordination as an important prerequisite for manufacturing process innovation becomes evident.

Against this background, our *research question* is:

Is there a positive relationship between backshoring and the diffusion of Industry 4.0-technologies, once we correct for other firm characteristics?

4. Data and method

4.1 Sample

We test the association between backshoring and Industry 4.0 with data from the European Manufacturing Survey (EMS) 2015. The EMS is a firm-level survey that investigates product, process, service and organisational innovation in European manufacturing. EMS is organized by a consortium co-ordinated by the Fraunhofer Institute for Systems and Innovation Research (ISI)[2].

The data set employed in this paper is a sub-set of the EMS 2015 survey and includes 2,120 manufacturing firms from Austria, Germany and Switzerland with at least 20 employees. We selected these three countries because they are comparable in many indicators, including their manufacturing share on GDP. 1,236 firms are from Germany, another 749 from Switzerland. The most frequent sectors in the sample are manufacturers of fabricated metal products, the machinery industry, manufacturers of electrical equipment, electronic and optical products, and the food industry (see Table 2, first column).

The EMS measures backshoring with a question if the firm has relocated production activities from own affiliates or from suppliers back to the home country during 2013 and 2014. As a consequence, backshoring is not just disinvestment of assets abroad; it also relates to activities which have been contracted out to third parties. In other words, backshoring firms do not necessarily possess affiliates and production activities abroad.

[2] http://www.isi.fhg.de/i/projekte/survey_pi.htm

Production technologies are counted with an array of questions if the firm utilized a specific technology or not. Here, the reference year is 2014. We use this information on the utilization of single technologies to create an index of I4.0 readiness (*iready*) in two steps.

In a first step, we define three different I4.0 technology fields:

Table 1: Technology fields used to construct an index of I4.0 readiness

Digital Management Systems
Product-Lifecycle-Management Systems
Enterprise resource planning software (ERP) for production planning and scheduling
Wireless Human-Machine-Communication
Mobile/wireless devices
Digital Visualisation
Cyber-Physical-systems (CPS)
Digital Exchange of data with suppliers / customers
Systems for automation and management of internal logistics
Near real-time production control systems

Source: EMS 2015

In a second step we assign values to the index (*iready*). It can take six values:

- 0 if the firm has not yet introduced any technology from the three technology fields
- 1 if the has introduced at least one technology from the three different technology fields
- 2 if the firm has introduced technologies from at least two of the three different technology fields.
- 3 if the firm has introduced all three different technology fields.
- 4 if the firm has introduced all three different technology fields and at least two technologies from the field "Cyber-physical systems"
- 5 if the firm has introduced all three different technology fields and at least three technologies from the field "Cyber-physical systems", or in other words, all I4.0 technologies.

We see an advantage of this approach that it assigns a higher weight to the most advanced technologies – CPS. However, we have also tried alternative specifications of the index, for example by simply counting the number of technologies employed. The results reported below are robust with respect to this alternative specification.

4.2 Dependent and independent variables

Table 2 below gives an overview of the dependent and independent variables used in the analysis. The dependent variable is backshoring, a dummy variable which is one if the firm has backshored production activities to the home country in 2013 or 2014, and zero otherwise.

Independent variables include the size of the firm measured by the number of employees, the I4.0 readiness index, the share of exports on turnover, and a dummy that indicates if the firm has production sizes abroad.

Sectoral variables describe the technological regime the firm operates following the taxonomy of Marsili & Verspagen (2002). This sectoral taxonomy is a better mirror of sectoral differences related to production technology than the usual classification of sectors according to their technology intensity. The taxonomy distinguishes five technological regimes: Continuous Process (the base case - Food, beverages, textiles, paper, wood, printing, mineral products, basic metals), Fundamental Process (*reg_fp*: petrol, chemicals), Complex Systems (*reg_cs*: automotive), Science Based (*reg_sb*: pharmaceuticals, electronics), and Product-engineering (*reg_pe*: metal products, machinery, electrical products).

Finally, we include a dummy variable that is one if the firm is a supplier to other firms, country dummies, and two variables that identify firms which produce in single pieces and produce complex products. Finally, a dummy variable indicates if he firms uses additive manufacturing (3D printing).

Table 2: Definitions of the variables

Variable Label	Definition	Variable Type
back	Backshoring; the variable is one if the firm has backshored production in in 2013 or 2014, zero otherwise.	Dummy
lemp	Logarithm of the number of employees in 2014	Metric
iready	I4.0 readiness index described in section 3	Ordinal
exp	Share of exports on turnover of the firm	Metric
aprod	Production activities abroad; the variable is one if the firm has production abroad, zero otherwise.	Dummy
reg_cp, reg_fp, reg_sb, reg_cs, reg_pe	Sectoral variables that describe the technological regime the firm operates following the taxonomy of Marsili & Verspagen (2002). Base case is the continuous process regime (reg_cp).	Dummy
supp	Position in the value chain; the variable is one if the firm is a supplier to other firms, or zero if the firm is a producer of final products.	Dummy
AT, CH, DE	Location of the firm; AT for Austria and CH for Switzerland, with Germany (DE) as the base case.	Dummy
batch	Batch size; the variable is one if the firm produces single pieces and zero if it produces in larger batches .	Dummy
complex	Degree of complexity of the main product; this variable is one if the firm produces predominantly products consisting of many parts, and zero if the products consist of only a few parts or single parts.	Dummy
3Dprint	3D printing or additive manufacturing; the variable is one if the firm utilized 3D printing, zero otherwise.	Dummy

Source: EMS 2015

4.3 Method

To test the hypothesis of a positive relationship between I4.0 production technologies and backshoring we employ descriptive statistics and a probit regression that relates backshoring to the index of I4.0 readiness described above and a number of control variables. We estimate the following model:

$$Y^* = X'\beta + \varepsilon$$

where Y^* can be viewed as an indicator for whether the latent dependent variable Y – the probability to backshore - is positive or not:

$$Y = 1_{\{Y^*>0\}} = \begin{cases} 1 \text{ if } Y^* > 0 \text{ i.e. } X'\beta + \varepsilon > 0 \\ 0 \qquad\qquad\qquad \text{otherwise} \end{cases}$$

with *X'* denoting the vector of explanatory variables from Table 2 and β being the parameter reflecting the marginal effect of a discrete change in the probability to backshore for the explanatory variables. ε is the error term, which is assumed to be of zero mean and with a standard deviation of σ^2.

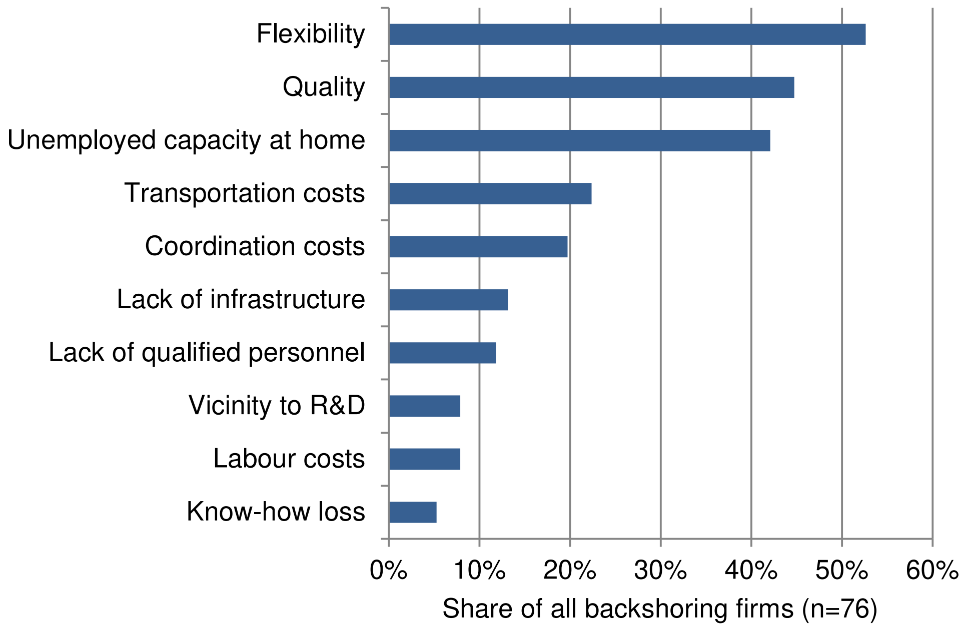
5. Descriptive results

This section presents the distribution of the backshoring and the iready variables across firms. Overall, we see a very small share of manufacturing firms which have backshored production activities. In total, the share of backshoring firms is only 3.8% of all firms in the sample. The share increases to around 10% if we only consider firms with production activities abroad. This low share is certainly an obstacle for the analysis of backshoring.

Backshoring increases with size up to a certain level; the highest shares of backshoring firms are found among firms with 250-499 employees (see Table 1). The likelihood to find a backshoring firm is highest in the automotive industry (Table 2).

The most important reasons for backshoring are the lack of flexibility at the offshoring location and a low quality of the goods produced (Figure 1). Both reasons are relevant in around half of all backshoring decisions. A lack of flexibility and low quality points to issues related to high and unexpected co-ordination and control costs, and principal-agent problems described by transaction cost theory. The problem of low product quality may also result from the challenge of transferring assets and resources within the company, and develop such assets in or adapt them to foreign environments. A third important reason are unemployed capacities in the home country. Too high labour costs, or a perceived loss of know-how due to involuntary spillovers, are the least relevant reasons for backshoring. However, as the low number of backshoring firms in the sample indicates, such misjudgements of shifts in the locational factors that lead to backshoring do not happen very often.

Figure 1: Reasons for backshoring



Source: EMS 2015, own calculations

Moreover, firms with production activities abroad do not seem to suffer from a separation of production and R&D activities; vicinity of R&D to production and the co-location of both activities does not seem to be an important reason for backshoring and thus not a pressing challenge for firms.

Quality and flexibility as the most important reasons for backshoring show a high consistency over time. They have also been the most frequent answers in the surveys of 2010/12 and 2007/09 (see Dachs & Zanker 2014). Hence, the most frequent reasons for backshoring clearly link to the advantages of Industry 4.0 technologies, which – as discussed above – can provide a higher degree of flexibility and may also improve the quality of the products because of a higher degree of control over the production process.

In a second step, we look at I4.0 readiness and the frequency of backshoring in different size classes (see Table 1) and sectors (Table 2). In the tables, I4.0 readiness is the mean of the firm values of the I4.0 readiness indicator described above for each size class and each sector. Backshoring indicates the share of firms which have backshored production activities between 2013 and 2015 in their size class or sector.

Table 3: I4.0 readiness and backshoring in different firm size classes

Size class	No. of firms	I4.0 readiness (mean)	Backshoring (% of firms)
< 30	338	1.139	1.3%
30-49	524	1.339	2.4%
50-99	501	1.641	3.3%
100-249	459	2.282	5.0%
250-499	180	2.525	9.2%
500-999	72	2.819	5.6%
1000	46	2.933	7.1%
Total	**2,122**	**1.775**	**3.8%**

Source: EMS 2015, own calculations

The data shows a clear tendency that increasing firm size is related to both, higher I 4.0 readiness as well as a higher backshoring propensity. I4.0 readiness is highest among the largest firms, which also have the second-highest backshoring propensity. The opposite can be found among the smallest firms with less than 30 employees. Altogether, the correlation between the two variables across different size classes is 0.54.

At the sectoral level, we see very low values of the I4.0 readiness index in low-technology sectors such as food and beverages, textiles and clothing and wood, paper and printing, while highest values can be found in electrical, electronics and among the manufacturers of vehicles. Vehicles is also the sectors with the highest share of backshoring firms, while the sectors with the second-highest share of backshoring firms – pharmaceuticals and chemicals – has only average I4.0 readiness. The correlation coefficient between the two variables at the sectoral level is 0.54, the same value we found for the relationship between I4.0 readiness and different size classes.

Table 4: I4.0 readiness and backshoring in different sectors

Sector	No. of firms	I4.0 readiness	Backshoring (% of firms)
Food, beverages	203	1.193	1.2%
Textiles, clothing	57	1.462	4.0%
Wood, paper, print	217	1.617	2.0%
Pharma, chemicals	134	1.813	9.4%
plastic	145	1.986	4.4%
Mineral products	107	1.540	3.0%
Metal, metal products	491	1.772	2.4%
Electrical, electronics	309	2.124	4.9%
Machinery	358	1.868	3.3%
Vehicles	70	1.985	10.8%
Other manufacturing	125	1.748	4.4%
Total	**2,216**	**1.775**	**3.8%**

Source: EMS 2015, own calculations

The relationship between I4.0 readiness and backshoring is also confirmed by a T-test of the means (see Table 3 below). This test confirms a significantly higher I4.0 readiness value for firms which have backshored production activities compared to firms with have not backshored.

Table 5: Two-sample t test with equal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
no backshoring	1,958	1.737	0.032	1.411	1.675	1.800
backshoring	77	2.519	0.171	1.501	2.179	2.860
combined	2,035	1.767	0.032	1.422	1.705	1.829
diff		-0.782	0.164		-1.104	-0.460
diff = mean(no) - mean(yes)			t = -4.7593			
Ho: diff = 0		degrees of freedom = 2033				
Ha: diff < 0			**Ha: diff != 0**		**Ha: diff > 0**	
Pr(T < t) = 0.0000			**Pr(|T| > |t|) = 0.0000**		**Pr(T > t) = 1.0000**	

Source: EMS 2015, own calculations

6. Results from the multivariate regression

The table below reports results for of the probit regression. We report marginal effects for the coefficients of dummy variables. We employed five different variants of the regression (columns 1-5).

Regression results in columns (1), (2), (3), and (5) first indicate that the coefficient for the I4.0 readiness index (*iready*) is significant and positively related with backshoring. This confirms the results from the descriptive analysis. This result is robust when using a 4-step instead the 6-step (0-5) index, or when *iready* is a count the number of I4.0 technologies adopted. It is also robust in different specifications including sector dummies (column 1), dummies that identify firms which produce complex products which consist of many parts and/or produce in large batch sizes (column 2), or a specification that includes sector, complex and batch size dummies (column 3). Column (5) provides a robustness check and includes only firms with production activities abroad. Remember that backshoring also includes moving back production from contractors to the home country. *iready* also remains significant in column (5),

The equation of column (4) tests the effects of 3D printing or additive manufacturing on backshoring. Here, *iready* is replaced by a dummy (*3Dprint*) that identifies all firms which employ additive manufacturing. The coefficient of *3Dprint* shows no significant association with backshoring. We explain this result by the fact that this technology is still in an early stage and so far predominantly used for developing and prototyping, and not for production. Additive manufacturing is still 'slow, expensive, and can equally be adopted by those low-wage countries where global manufacturing currently dominates' (Brennan et al., 2015, p. 1264). Thus, effects from additive manufacturing may become visible in future studies.

Table 6: Linking backshoring and Industry 4.0: regression results

	(1)	(2)	(3)	(4)	(5)
lemp	0.006	0.031	0.017	0.058	-0.172**
	(0.057)	(0.057)	(0.058)	(0.054)	(0.083)
iready	0.121***	0.109***	0.107**		0.129**
	(0.042)	(0.042)	(0.042)		(0.065)
exp	0.004*	0.005**	0.004**	0.004**	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
aprod	0.626***	0.604***	0.579***	0.579***	
	(0.130)	(0.129)	(0.132)	(0.132)	
reg_fp	0.259		0.253	0.267	0.455
	(0.264)		(0.265)	(0.262)	(0.379)
reg_cs	0.778***		0.808***	0.768***	0.976**
	(0.265)		(0.267)	(0.268)	(0.407)
reg_sb	0.342*		0.355*	0.359*	0.569*
	(0.185)		(0.188)	(0.187)	(0.319)
reg_pe	0.129		0.150	0.143	0.176
	(0.159)		(0.163)	(0.164)	(0.288)
supp	-0.430***	-0.421***	-0.471***	-0.439***	-0.543***
	(0.138)	(0.137)	(0.141)	(0.139)	(0.205)
at	0.183	0.120	0.188	0.188	0.267
	(0.184)	(0.181)	(0.186)	(0.185)	(0.296)
ch	0.106	0.064	0.109	0.119	-0.089
	(0.133)	(0.130)	(0.134)	(0.133)	(0.223)
batch		0.173	0.152	0.162	
		(0.149)	(0.154)	(0.154)	
complex		-0.046	-0.079	-0.089	
		(0.127)	(0.130)	(0.130)	
3Dprint				0.163	
				(0.136)	
Constant	-2.538***	-2.580***	-2.662***	-2.675***	-0.815*
	(0.280)	(0.274)	(0.305)	(0.300)	(0.476)
Pseudo R2	0.1391	0.1239	0.1403	0.1324	0.0785
Observations	1,875	1,843	1,843	1,843	376

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The size of the firm (*lemp*) is not relevant for the explanation of backshoring once we control for all other variables. In the smaller sample of column (5), *lemp* even turns significant with a negative sign which indicates that backshoring rises with *decreasing* firm size, all other factors being equal. So, the positive correlation between backshoring and firm size we saw in descriptive statistics can rather be explained by the I4.0 readiness indicator, which increases with firm size just like backshoring. Larger firms usually do have more production locations abroad and are stronger integrated in global value chains, leading to more opportunities to backshore than smaller companies. Second, smaller companies do not have the necessary tools, experiences, management and financial resources to evaluate offshoring decisions as professionally as large multinationals (Hollenstein, 2005; Kinkel et al., 2007). As a result, their offshoring decisions might be rather error-prone, leading to a higher share of backshoring decisions. Also, small companies are more often strategically dependent on serving their customers very fast and flexible in their specific market niches, so proximity to customers becomes vital (Kinkel et al., 2016), whereas large firms are more often competing via price and image.

The analysis also reveals some differences between sectors. Companies in a complex systems regime (mainly the automotive industry) display a higher backshoring propensity after controlling for independent variables than companies producing in continuous processes. One explaining factor could be the technological intensity of the industry; complex systems producers might be more receptive to adopting advanced manufacturing technologies such as Industry 4.0 (Lasi *et al.*, 2014). Second, companies in a technology-intense environment usually also possess a higher asset specificity (Foerstl et al., 2016). This makes cross-border co-ordination more complex, and may favor local integration and backshoring over global value chains and offshoring strategies.

Being a supplier (*supp*) reduces the likelihood of backshoring in all specifications of the regression. This can be explained by the fact that many suppliers have offshored production to follow their clients. For them, being present at the foreign location of their customers is essential compared to manufacturers of final products, who can also supply foreign markets by exports. In the case of suppliers, the argument of closeness to customers works in favour of staying offshore. So, production has been built up and is kept at the offshore location, as proximity to customers and markets was an essential motive and driver for their offshoring strategies. These customer relations seem to provide an effective 'glue' to keep manufacturing activities at foreign locations, even if external factors like wages or costs of material change.

Product complexity and batch size does not add to the explanatory power of the model. The coefficients are not significant and R^2 remains the same after introducing these variables in columns (2) and (3). Firms which produce mainly single pieces or small batches (compared to larger batch sizes), or complex products (compared to simple products) have no higher backshoring propensity once we control for all other factors. This is surprising, given that backshoring increases the flexibility of production processes in the firm, and flexibility is an important advantage for producers of single pieces or small batches which produce on demand. The production of complex products often requires many interactions with clients, which are facilitated by flexibility. Since complex and batch dummies did not reveal explanatory power in equations (2) to (4), we exclude it in equation (5).

There is no difference between firms with respect to the location of their head office, so Austrian or Swiss firms have no higher or lower backshoring probability than German firms once we control for all other factors in the regression.

7. Discussion and conclusions

We investigated the relationship between backshoring of production activities and investments in Industry 4.0 technologies in European manufacturing firms. Descriptive statistics as well as regression results indicate a positive and significant association between these two variables. We explain this positive association by increased productivity and more flexibility and responsiveness from I4.0 technologies which allow firms to backshore. Backshoring may become also an interesting option for firms when international expansion has overstretched, and unforeseen costs such as a loss of flexibility and lower product quality occur.

7.1 Relevance for IB theory

The paper holds two interesting results for IB theory. First, we show that new technologies not necessarily foster the globalisation of enterprise activities, but may also lead to a re-concentration of production activities., This is a new observation - given the tendency of ICTs to lower internal coordination costs extend the potential boundaries of firms - which so far found only little recognition in the IB literature (an exception is Laplume et al. 2016). From today's perspective, however, it is too early to say that I4.0 can lead to de-globalisation. Backshoring is still confined to a small group of manufacturing firms. Thus, compared to policy-driven de-globalisation – examples are the Brexit and US industrial policies – technology-driven de-globalisation from backshoring seems to play only a minor role so far.

Second, the most frequent reasons for backshoring reported in chapter 5 indicate that backshoring can be explained within the existing theoretical framework of IB theory. The most frequent motives for backshoring – a lack of flexibility and a lack of product quality – can be explained with internalisation and transaction cost theory, although we did not elaborate a theoretical discussion of the motives for backshoring in this paper. Such a discussion will follow in different contribution.

7.2 Implications for policy

As a consequence, countries in Western Europe and North America may become more attractive locations for manufacturing of customized products, as companies benefit from the geographical proximity to individual customers – 'in the market and for the market' (Brennan et al., 2015) –, without suffering from significantly higher manufacturing cost. *Local value chains (LVCs)* where firms benefit from the proximity to customers with increasingly diversified demands and needs would thus be competing with dominating global value chains and their inherent characteristic of separating production from consumption. Additive manufacturing, just like I4.0 technologies, seem to pull in the direction of more locally concentrated value chains, enabling co-location of production and consumption (Laplume et al., 2016). However, this technology is still in its early stages and our results do not indicate a significant relationship with backshoring.

More local value chains is good news for policy. The political debate is currently dominated by fears of a large decrease in employment due to ICTs and new industrial process technologies (Frey & Osborne, (2013) 2017; Arntz et al., 2016). Our results show that Industry 4.0 may also trigger developments against this trend, although it is not possible to give an estimation of the employment effect of these relocations. However, we should not expect huge increases in manufacturing jobs; new jobs due to backshoring will be rather high-skilled; it is unlikely that low-skilled jobs will ever return.

7.3 Managerial relevance

The paper shows that backshoring of production can be a viable strategy for firms to cope with the pressure for greater flexibility and responsiveness. Modern production technologies can facilitate backshoring when they increase productivity and flexibility in the home location. We believe – and we find support for this view in the IB literature - that backshoring is not a sign for managerial failure, but a legitimate managerial response to changing economic conditions in the host country. Industry 4.0 not the only factor which may increase attractiveness of backshoring in the future. First, wages in offshoring locations are growing fast, which makes labour arbitrage a less promising strategy (Kinkel 2012; Kinkel et al., 2016; Forfas, 2013; Foresight UK, 2013). Second, the share of labour costs on total production costs is shrinking in many manufacturing firms, due to continuing automation and efficiency improvements. For example, direct labour cost today accounts for only around 10 per cent or less of production output value in German manufacturing (Statistisches Bundesamt, 2014). Third, fragmented global chains are also vulnerable, as the Fukushima disaster has conclusively demonstrated (Brennan et al., 2015; Foresight UK, 2013). Steering and controlling of multi-stage supply chains, which can easily include 30 or more different players and locations, is costly.

However, it is not easy to restore ‘industrial commons’ (Pisano & Shih, 2009), and product and process competences outsourced some years ago. In many cases it might be easier to build up capabilities for the next generation of products or technology, e.g. in the new and vibrant area of I4.0 technologies, as re-learning of once outsourced competences can be a difficult process and provides only catching-up instead of leading positions (Kinkel, 2014a).

7.4 Limitations of the results

An important limitation of our assumption relates to the geographical focus of the company. The advantages of producing in close proximity to the customer, of course, do not favour backshoring if the customer is not located in the home country or region of the company, in our case Central and Western Europe. Offshoring is indeed not only a reaction to cost pressures, but also a step to enter new markets and being closer to the customers in foreign countries. So, the argument developed above is only valid if foreign production serves domestic or European markets. This is not the case for many suppliers which have followed their industrial customers to locations abroad or are serving their foreign customers with production abroad. For them, the argument of closeness to customers works in favour of staying offshore and was already an essential motive for their previous offshoring decision.

Moreover, our results indicate no causal relationship between backshoring and I4.0. It may be that both trends are driven by a third factor, the need for more flexibility, which can be achieved by a re-concentration of production activities via backshoring as well as by investments in Industry 4.0. The causality of the relationship will be addressed by future research. Future research may also yield more insights by examining the role of productivity growth in the home country as an incentive for backshoring in more detail.

Another promising topic of future research is the analysis of backshoring strategies in dependence of the motives of the previous offshoring decision (Gray et al., 2013). One can argue that the backshoring of offshored activities that were predominantly targeted towards labor cost reductions in low-wage countries may show different patterns and timing than offshoring decisions for market entry or proximity to customers. The first type might be much more prone to changes in location factors like rising wages, whereas the latter might display a higher stamina due to the "glue" of customer relations and downstream LVCs in the foreign market. Therefore, motives of the previous offshoring decision need to be integrated in future frameworks explaining backshoring activities.

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