Paper to be presented at: DRUID17
NYU Stern School of Business, New York, June 12-14, 2017

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

Bernhard Dachs
AIT - Austrian Institute of Technology
Innovation Systems
Bernhard.Dachs@ait.ac.at

Angela Jäger
Fraunhofer Society
Institute for Systems and Innovation Research ISI
Angela.Jaeger@isi.fraunhofer.de

Steffen Kinkel
Karlsruhe University of Applied Sciences
Institute for Learning and Innovation in Networks
steffen.kinkel@hs-karlsruhe.de

Abstract
The paper investigates the relationship between backshoring of production activities and investments in digital manufacturing technologies also known as Industrie 4.0 (I4.0). We argue that I4.0 will have disruptive effects on global value chains and may support backshoring of manufacturing activities. First, because productivity increases by I4.0 technologies can neutralize cost advantages of offshoring locations and make labour arbitrage less appealing. Second, because increased quality and flexibility provided by I4.0 technologies offers an incentive for firms to locate production close to their European customers to regain some of the flexibility lost in fine-sliced global production networks. The empirical test is based on a large dataset of more than 2,000 manufacturing firms from Austria, Germany and Switzerland. 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 I4.0 technologies and backshoring. This confirms the hypothesis that I4.0 technologies with their potential for increased productivity, customization and flexibility support backshoring and strengthen the attractiveness of industrial locations in Western Europe and the US.

Jelcodes:O33,F21
Abstract: The paper investigates the relationship between backshoring of production activities and investments in digital manufacturing technologies also known as Industrie 4.0 (I4.0).

We argue that I4.0 will have disruptive effects on global value chains and may support backshoring of manufacturing activities: First, because productivity increases by I4.0 technologies can neutralize cost advantages of offshoring locations and make labour arbitrage less appealing. Second, because increased quality and flexibility provided by I4.0 technologies offers an incentive for firms to locate production close to their European customers to regain some of the flexibility lost in fine-sliced global production networks.

The empirical test is based on a large dataset of more than 2,000 manufacturing firms from Austria, Germany and Switzerland. 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 I4.0 technologies and backshoring. This confirms the hypothesis that I4.0 technologies with their potential for increased productivity, customization and flexibility support backshoring and strengthen the attractiveness of industrial locations in Western Europe and the US.
1. Introduction

The rise of global value chains has transformed the global manufacturing landscape dramatically in recent decades (Timmer et al., 2014, Brennan et al., 2015). Globally fragmented production processes often result in products consisting of components from a variety of countries, which can be best described as “made in the world” (Ferdows, 1997; WTO, 2011).

Highly fragmented supply chains however, come, at a price. Disadvantages include higher co-ordination efforts, a longer time-to-market, quality issues, a loss of flexibility and a loss of the ability to react quickly to changes in market demand. Moreover, the rise of global value chains and the offshoring of production activities have been blamed for job losses in manufacturing sectors of the US and European countries.

As a result, ‘backshoring’ (or ‘reshoring’) – i.e., bringing production back to the company’s home country – has received broad attention recently in the academic literature (De Backer et al. 2016, Fratocchi et al., 2014, George et al., 2014; PwC, 2014, Kinkel, 2012; Sirkin et al., 2011, Kinkel and Maloca, 2009), and even much more in public debates during the last US presidential election campaign.

This paper investigates the relationship between backshoring and technological change. In particular, we are interested in how investments in new digital production technologies are related to backshoring decisions. These technologies are currently discussed under headings such as “Internet of Things” or “Industrie 4.0” (I4.0). This German term describes a group of production technologies where components and machines communicate and coordinate their operations in factories and (global) value chains (Brennan et al., 2015, Bauernhansl, 2014, Kagermann et al. 2013, Spath et al. 2013, OECD 2017). Industrie 4.0 means that these digital production technologies may have a similar impact on manufacturing like automated production (Industrie 3.0), or electricity (Industrie 2.0 – see figure below).

Figure 1: Industrial revolutions of the past and Industrie 4.0

OECD (2017)
We argue that Industrie 4.0 may also on global value chains: first, because increased productivity provided by I4.0 production technologies may neutralize the factor cost advantages of offshoring locations and make labour arbitrage less appealing. Second, because increased quality and flexibility provided by I4.0 technologies may provide an incentive for firms to 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 and greater flexibility and responsiveness in the supply chain is likely to grow into the future – and Industrie 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 has the advantage of including variables on both, backshoring and investments in modern production technologies, and a number of additional control variables.

The paper is structured as follows: in the following section 2 we deliver the background of this study and sketch our research question; section 3 describes the data and the construction of the main indicator; section 4 provides descriptive results, while section 5 reports multivariate results. The paper closes with conclusions in section 6.

2. Background

Many observers today agree that we are witnessing a technological revolution in manufacturing (Brynjolfsson and McAfee, 2014; Ford, 2015; OECD, 2016b, a). This revolution is based on a variety of digital production technologies (e.g. 3D printing, sensors, advanced robotics, networked production), new materials, but also new, IT-enabled management processes (e.g. enterprise resource planning and production control, data analytics, applications of artificial intelligence). In the manufacturing context, the sum of these technologies is often labelled as the Fourth Industrial revolution – after mechanization, electrification, and automation - or Industrie 4.0 (Kagermann et al. 2013, Spath et al. 2013, Bauernhansl 2014).

A main ingredient of Industrie 4.0 (or I4.0) 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 integrates all stages of the physical production process over the Internet, in order to create a seamless exchange of information between these two worlds.

This paper argues that I4.0 may have disruptive effects on the global division of labour and global value chains. The reasons for this have been beautifully developed by Laplume et al (2016) in a recent paper for the case of 3D printing and by De Backer et al. (2016, p. 9) for the general case of digital production technologies. Their arguments also apply to the question of this paper: The core of the I4.0 vision is that of a highly flexible and at the same time highly efficient production system, which makes it possible to produce customized products with the scale advantages of a mass producer (Lichtblau et al., 2015). Thus, I4.0 production technologies can provide two types of advantages to firms, which may have an disruptive effect on global value chains:
First, 4.0 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 and McAfee, 2014, Bauernhansel et al. 2014, Jäger et al. 2015). Moreover, 4.0 may reduce necessary labour input and therefore shift the ratio between capital and labour inputs in favour of capital. This implies that locational advantages of low-wage countries – which fuelled the emergence of global value chains in recent decades – may be weakened or even compensated by 4.0. 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, 4.0 technologies allow manufacturing firms a higher degree of customization and more flexibility in their production processes. This means, for example, to adapt colour, size, shape etc. of products to specific needs of customers in a very short time and with very low extra cost. This makes smaller batch sizes economically viable, and may open new market segments to firms. These new market segments, however, can only be approached if the goods can also be delivered quickly to the client, so that the total time between order and delivery can be minimized. Thus, a higher degree of customization and more flexibility favours production close to potential clients, and may favour backshoring.

This paper tests the assumption that 4.0 – via productivity and flexibility effects - affects location decisions of manufacturing activities. If 4.0 really leads to higher productivity, a higher degree of customization and more flexibility to manufacturing firms, this may offset the labour cost advantages firms enjoy in offshoring locations. As a consequence, Western Europe may become again a more attractive location for manufacturing, because firms benefit from geographical proximity to their customers - "in the market and for the market" (Brennan et al., 2015), without suffering from higher production costs. Proximity to the customer is increasingly competing with the long-time dominating global value chains, incorporating a variety of operations from different low-wage countries, resulting in high complexity and increasing flexibility disadvantages, especially in the case of short-term and individual customer requests (Kinkel et al., 2016).

One of the first who argued along these lines is the Boston Consulting Group (BCG, 2011). Moreover, the argument is also brought forward recently by UNCTAD 2017 and, most prominently, by Laplume et al. (2016) for the case of additive manufacturing (AM), or 3D printing. AM has disruptive potential due to its ability to offer individualization advantages 'virtually for free'. According to Taylor et al. (2013), AM has the potential to trigger backshoring. The motivation for backshoring would be particularly strong for the production of items that are 'high value, customized, complex in design, high quality, advanced technology, specialized and produced in low volumes' (Brennan et al., 2015, p. 1264).

However, as AM is mainly used in prototyping and small batch operations so far, it is not yet competitive for high volume production when compared to mass production in low-cost countries. Thus, an alternative hypothesis is that AM is not likely to lead to significant changes in the location of manufacturing, as it is 'slow, expensive, and can equally be adopted by those low-wage countries where global manufacturing currently dominates' (Brennan et al., 2015, p. 1264). Here, similarities between AM and 4.0 technologies end. The latter offer explicit potential for 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).
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 Europe. Offshoring is indeed not only labour arbitrage and a reaction to cost pressures, but often also a step to enter new markets. So, the argument developed above is only valid if foreign production serves domestic or European markets. This is not the case for many suppliers to other manufacturing firms, which have followed their industrial customers to locations abroad.

Against this background, our research question is:

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

The answer to this question has a considerable policy relevance. It will decide if firms will maintain production and innovation activities in European high-wage countries and expand their activities here. Thus, it is an eminently important issue for securing future value added and attractive employment at these locations.

### 3. Data

We test the association between backshoring and Industrie 4.0 technologies 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).

The EMS includes detailed information on the degree of utilization of a number of production technologies, on innovation input including R&D expenditure, innovation output such as the introduction of new products to the market, the qualification structure of the employees, and a number of control variables such as firm size, exports, the position of the firm in the value chain, or characteristics of the main product and of the production process. This allows studying the effects of backshoring and investment in production technologies in detail. Other popular data sources, such as the AMADEUS database only provide a fraction of the variables needed for this analysis.

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. The three countries are comparable in terms of 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 also Table 2).

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.

---

1 [http://www.isi.fhg.de/i/projekte/survey_pi.htm](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 of the utilization of single technologies to create an index of I4.0 readiness (iready). This index can take six values:

- 0 if the firm has not yet introduced any of the I4.0 technologies
- 1 if the has introduced at least one technology from 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.

The three different I4.0 technology fields are:

- **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

4. 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, both reasons are relevant for around half of all backshoring decisions (Figure 2). 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.

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 and Zenker 2014).

Figure 2: Reasons for backshoring

![Graph showing reasons for backshoring]

Hence, the most frequent reasons for backshoring clearly link to the advantages of Industrie 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.

Table 1: 4.0 readiness and backshoring in different firm size classes

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

Source: EMS 2015, own calculations

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.
sector. Backshoring indicates the share of firms which have backshored production activities between 2013 and 2015 in their size class or sector.

The data shows a clear tendency that increasing firm size is related to both, higher 4.0 readiness as well as a higher backshoring propensity. 4.0 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 4.0 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 – pharma and chemicals – has only average 4.0 readiness. The correlation coefficient between the two variables at the sectoral level is 0.54, the same value we found for the relationship between 4.0 readiness and different size classes.

Table 2: 4.0 readiness and backshoring in different sectors

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

Source: EMS 2015, own calculations

The relationship between 4.0 readiness and backshoring is also confirmed by a T-test of the means (see Table 3 below). This test confirms a significantly higher 4.0 readiness value for firms which have backshored production activities compared to firms with have not backshored.
Table 3: Two-sample t test with equal variances

<table>
<thead>
<tr>
<th>Group</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>Std. Dev.</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>no backshoring</td>
<td>1,958</td>
<td>1.737</td>
<td>0.032</td>
<td>1.411</td>
<td>1.675 - 1.800</td>
</tr>
<tr>
<td>backshoring</td>
<td>77</td>
<td>2.519</td>
<td>0.171</td>
<td>1.501</td>
<td>2.179 - 2.860</td>
</tr>
<tr>
<td>combined</td>
<td>2,035</td>
<td>1.767</td>
<td>0.032</td>
<td>1.422</td>
<td>1.705 - 1.829</td>
</tr>
<tr>
<td>diff</td>
<td>-0.782</td>
<td>0.164</td>
<td>-1.104</td>
<td>-0.460</td>
<td></td>
</tr>
</tbody>
</table>

\[ \text{diff} = \text{mean(n)} - \text{mean(y)} \]
\[ t = -4.7593 \]

Ho: diff = 0
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

5. Multivariate results

To test the hypothesis of a positive relationship between I4.0 production technologies and backshoring, we employ 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:

\[ Y = I_{Y^* > 0} = \begin{cases} 1 & \text{if } Y^* > 0 \text{ i.e. } X' \beta + \varepsilon > 0 \\ 0 & \text{otherwise} \end{cases} \]

with \( X^* \) denoting the vector of explanatory variables and \( \beta \) being the parameter reflecting the marginal effect of a discrete change in the probability to backshore for the explanatory variables. \( \varepsilon \) is the error term, which is assumed to be of zero mean and with a standard deviation of \( \sigma^2 \).

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. We include the following explanatory variables in vector \( X^* \):

- the logarithm of the number of employees in 2014 to account for the size of the firm (lemp)
- the I4.0 readiness index (iready) described in section 3
- two variables that control for the international activities of firms: the share of exports on turnover (exp) and a dummy variable which is one if the firm has production activities abroad (international production)
Sectoral dummies that describe the technological regime the firm operates following the taxonomy of Marsili and Verspagen 2002. These sectoral variables are a better mirror of sectoral differences related to production technology than the usual classification of sectors according to their technology intensity. The regimes include: Continuous Process (Food, beverages, textiles, paper, wood, printing, mineral products, basic metals), Fundamental Process (petrol, chemicals), Complex Systems (automotive), Science Based (pharma, electronics), and Product-engineering (metal products, machinery, electrical products). Continuous process is the base case.

The typical batch size of the firm, this variable is one if the firm produces single pieces and zero if it produces in larger batches than single pieces.

The degree of complexity (complex products) of the main product, this variable is one if the firm produces mainly products consisting of many parts, and zero if the firm produces products consisting of only a few parts, or single parts.

A dummy variable (supplier) that is one if the firm is a supplier to other firms, or zero if the firm is a producer of final products.

Dummy variables for the location of the firm (Austria and Switzerland, with Germany as base case)

The table below reports results for five variants of this probit regression. Coefficients for dummy variables are marginal effects.

We first (1) estimate the equation with sector dummies, but without complex and batch dummies. Column (2) includes no sector dummies, but complex and batch size dummies. In equation (3) we include both, sector and complex and batch size dummies. We estimate these variations because it is possible that batch size, complexity and sector dummies measure the same sectoral characteristics.

Equation (4) tests the claim by Laplume et al. (2016) on the effects of 3D printing on global value chains. Here, we use a dummy that identifies all firms which already employ 3D printing instead of is ready.

Finally, equation (5) provides a robustness check and includes only firms with production activities abroad. Remember that backshoring can also mean that production from contractors is moved back to the home country. Since complex and batch dummies did not reveal explanatory power in the previous estimations, we exclude it in equation (5).

Regression results in (1), (2), (3), and (5) first indicate that the I4.0 readiness index has a significant and positive relationship with backshoring, although the coefficient is small. This confirms the results from the descriptive analysis. However, in contrast to the descriptive results, the size of the firm measured by the number of employees is not relevant for the explanation of backshoring once we control for all other variables. So, the positive correlation between backshoring and firm size can rather be explained by the I4.0 readiness indicator, which increases with firm size just like backshoring.

Sector dummies have only a limited relevance for explaining backshoring. We see a higher probability for backshoring only in the complex systems regime compared to the continuous-process regime.

Product complexity and batch size does not add to the explanatory power of the model, the coefficients are not significant and R2 remains the same. Firms with single pieces production (compared to larger batch sizes), or with 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; this may be an important incentive for producers of single pieces or small batches which produce on demand and producers of complex products with require many interactions with clients.

Table 4: Regression results

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

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

Being a supplier (supp) reduces the likelihood of backshoring, which can be explained by the fact that many suppliers have offshored production to follow their clients. For them, being present at the foreign locations of their customers is essential compared to manufacturers of final products who can also supply foreign markets by exports.

Compared to Germany, Austrian or Swiss firms have no higher probability of backshoring once we control for all other factors in the regression.

iready also remains significant if we only include firms with foreign production in the regression in column (5), similar to supp. However, in the smaller sample, lemp turns
significant, with a negative sign which indicates that backshoring rises with decreasing firm size, all other factors being equal. This is a confusing result, which contradicts the descriptive statistics presented above and needs some further investigation.

6. Conclusions

We investigated the relationship between backshoring of production activities and investments in Industry 4.0 production technologies in European manufacturing firms. Descriptive statistics as well as regression results indicate a positive correlation between investments in I4.0 technologies and the propensity for backshoring.

This result confirms our assumption that I4.0 technologies - with their potential for highly flexible, customized manufacturing operations – are a facilitator for the backshoring of production processes. Providing customized products and services makes it necessary to develop and produce in smart and agile (responsive) modes close to local clients (Forfas, 2013; Foresight UK, 2013, McKinsey Global Institute, 2012). Thus, these technologies may favour a trend to locate production close to the customers to better serve their specific needs. As I4.0 technologies provide the basis for real-time information systems along the value chain, the emergence of new last-mile solutions will develop to meet same-day consumer purchase habits that will be electronically captured. Apps will allow consumers to interact in real-time with their suppliers, driving last-mile distribution strategies that support more customized solutions (Brennan et al., 2015).

An alternative interpretation of our results focuses on flexibility as the driver of both, backshoring and Industrie 4.0 investments. It could be that both trends are driven by the need for more flexibility, which can be achieved by backshoring as well as Industrie 4.0.

Industrie 4.0 technologies are one, but not the only factor that may facilitate backshoring in the future. First, the advantages of cost-based relocation activities to low-wage countries are diminishing which makes labour arbitrage a less promising strategy (Kinkel 2012; Kinkel et al., 2016 Forfas, 2013, Foresight UK, 2013). Companies in high-wage countries have focussed on utilizing the strengths and potentials of their factories in their home base. 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, in German manufacturing industry today direct labour cost account for only around 10 per cent or less of production output value. Third, the steering and controlling of complex, multi-stage supply chains, which can easily include 30 or more different players and locations, is costly. Such fragmented global chains are vulnerable to damage to any one of their links, as the Fukushima disaster has conclusively demonstrated (Brennan et al., 2015; Foresight UK, 2013).

In a longer perspective, we might see the beginning of trend for a more local manufacturing in strategic markets, characterized by either high volumes, dynamic growth potentials or lead customers in specific technological areas. This will call for building the capability to provide ‘complete solutions’ with all the necessary engineering and manufacturing competences in these strategic markets, at least partially reversing the trend to fragmented global supply chains (McKinsey Global Institute, 2012).

More local manufacturing may be also good news for policy. The political debate is currently dominated by fears of a large decrease in employment in manufacturing and services due to new industrial process technologies such as Industrie 4.0 (Frey and Osborne, 2013, 2017,
Our results show that Industrie 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.

Overall, the pressure for greater flexibility and responsiveness is likely to grow into the future, thus suggesting increasing consideration of backshoring options. However, it is not easy to restore product and process competences outsourced some years ago and restore their ‘industrial commons’ (Pisano and Shih, 2009). 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, 2014).

7. References


Forfas (2013), Making it in Ireland: Manufacturing 2020, Dublin. George et al., 2014;


Kagermann, H., Wahlster, W., and Helbig, J. (eds. 2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; Final report of the Industrie 4.0 Working Group. acatech – Deutsche Akademie der Technikwissenschaften e.V.


