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The effects of production offshoring on R&D and innovation in the home country

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Abstract We investigate the effects of production offshoring on the innovation activities of manufacturing firms in the home country. The analysis is based on a dataset of more than 3,000 manufacturing firms from seven European countries. We find that offshoring firms on average employ a higher share of R&D and design personnel, introduce new products more frequently to the market, and invest more frequently in advanced process technologies compared to non-offshoring firms. Concerns that offshoring may hurt innovation because of the lost links between production and product development are not supported by the evidence.

Keywords Offshoring · R&D · Home country effects · Investment · Product innovation · Process innovation

JEL Classification F230 · F610 · O310 · O330

1 Introduction

Offshoring has been a topic of economic policy debates for—at least—the last decade. Most debates focussed on the economic effects of offshoring on firms in the

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home country. Critics of globalisation blame offshoring for job losses, a weakening of the manufacturing base and see it as a potential threat to the innovative capacities and long-term competitiveness of countries. Pisano and Shih (2012a, p. 94) for example, come to the conclusion that 'mass migration (of manufacturing) has seriously eroded the domestic capabilities needed to turn inventions into high-quality, cost-competitive products …'.

This paper contributes to this discussion by investigating the effects of offshoring on innovation. The existing literature on home country effects of foreign direct investment (Lipsey 2002; Barba Navaretti and Falzoni 2004; Crinò 2009) tells only little about this relationship; the vast majority of contributions deal with the effects of offshoring on employment, production and exports. In particular, our contribution provides firm-level evidence on the relationship between offshoring and innovation input, product innovation and process innovation, which are major drivers for productivity growth in European manufacturing industries.

We use a propensity score matching estimator to analyse the causal effect of offshoring on the innovation capabilities of firms. This approach allows us to identify a control group of non-offshoring firms with characteristics similar to those of offshoring firms. Data is provided by the European Manufacturing Survey (EMS), a firm-level data set on product, process, and organisational innovation in manufacturing firms.

The paper is structured as followed: Sect. 2 reviews the relevant literature and presents hypotheses on the relationship between offshoring and innovation activities at home. Section 3 presents the dataset and some descriptive results while Sect. 4 lays out the econometric approach of the analysis. Empirical results are presented in Sect. 5. Finally, Sect. 6 discusses conclusions from the analysis.

2 Related literature and hypotheses

In the context of this paper, offshoring is defined as the transfer of production activities to a location abroad (see Table 1). Related terms are 'international outsourcing', 'international insourcing', the 'fragmentation of global value chains', 'slicing up the value chain', 'global production sharing', or 'trade in tasks' which all describe the location of different stages of the production process at different sites (Stehrer et al. 2012). The most frequent motive for offshoring in European manufacturing are reductions in labour costs, followed by vicinity to customers, and the wish for expansion (Dachs et al. 2012, p. 11).

A vast literature has examined the effects of offshoring and foreign direct investment in general on the home country with early contributions going back as far as the 1930s (see the surveys of Lipsey 2002; Barba Navaretti and Falzoni 2004; Olsen 2006; Crinò 2009). Most studies focussed on output, employment or skills and find a complementary relationship between foreign and domestic economic activity, at least in the long run (Lipsey 2002; Barba Navaretti and Falzoni 2004). Overall effects, however, seem relatively small.

The literature has identified several mechanisms how offshoring affects economic activity in the home country: First, offshoring changes the nature of

Table 1 Insourcing, outsourcing and offshoring

	National	International	
Between firms (outsourcing)	Domestic outsourcing	International outsourcing	Offshoring
Within firms (insourcing)	Domestic supply	International insourcing	
	Within countries	Between countries	

Source: Olsen (2006), p. 7

tasks performed and types of inputs used in the home country (Markusen 2002; Grossman and Rossi-Hansberg 2006). Offshoring firms will focus on technology-, and skills-intensive types of economic activity in the home country, including headquarter services such as supervising, coordinating and other value adding auxiliary activities. As a consequence, activities in the home country may become more innovation-intensive. This effect may be reinforced if offshoring is not just a zero-sum game, but creates additional demand at the level of the multinational company which also benefits the stages of production located at home (Barba Navaretti and Falzoni 2004).

Second, offshoring may augment innovation in the home country because activities in the home country benefit from transfers of knowledge and technology from foreign affiliates back to the home country (Mihalache et al. 2012; Castellani and Pieri 2013; D'Agostino et al. 2013). Reverse technology transfer from foreign affiliates to the parent company can become a source of competitive advantage for firms and home countries in particular when complementarities between the home region and offshore R&D exist (D'Agostino et al. 2013).

Empirical evidence for effects of offshoring on innovation is scarce so far (see Olsen 2006), although there is a large literature on the offshoring *of* R&D and innovation. The existing contributions show mixed results, which may be explained by the different measurements of innovation employed. Mihalache et al. (2012) reveal an inverted U-shaped relationship between offshoring and firm innovativeness which indicates that innovativeness is highest among firms with medium levels of offshoring. However, beyond a certain threshold, benefits of offshoring for innovativeness diminish and can even hinder innovation. Crinò (2012) investigates the effects of imported inputs (a proxy for offshoring) on firms in Central and Eastern Europe and Central Asia. He finds that importing inputs is associated with a specialization in high-skill intensive activities such as the production of new goods, improvements of product quality and, to a lesser extent, R&D and technology adoption. Fritsch and Görg (2013) find a positive relationship between outsourcing and innovation in a sample of firms from 20 emerging economies. Karpaty and Tingvall (2011) reveal for Swedish multinational firms that offshoring has a negative effect on R&D intensity at home. This effect is most robust for offshoring to other European countries and North America. Offshoring to emerging economies has no or even a positive effect on R&D intensity. Egger and Pfaffermayr (2009) find that investing abroad is positively related to higher investments in R&D and intangible assets at home for the case of Austrian firms. Mazzanti et al. (2009) find that outsourcing is positively associated with variables that describe technological innovation in their model.

Additional, indirect evidence on a positive relationship between offshoring and innovation is provided by studies that evaluate the effects of offshoring on skills and employment in the home country. Early studies include Head and Ries (2002) and Hansson (2005), who find that overseas production has a positive impact on domestic skill intensity. This effect is more pronounced when offshoring goes to low-income countries. Egger and Egger (2003) investigate changes in skill intensity from offshoring to Eastern Europe in Austria during the 1990s at the industry level and confirm the aforementioned results. Slaughter (2000), in contrast, finds no significant effect for US firms in the 1980s and 1990s.

More recent studies include the contributions of Morrison Paul and Yasar (2009), Harrison and McMillan (2010), or Neureiter and Nunnenkamp (2010), who show that high-skilled jobs in European firms benefit from offshoring. Simpson (2012a) confirms this result for the UK. She finds that relocating low-skill activities to low-wage countries has potential positive effects on complementary high-skill activities at home. Simpson (2012b) reveals a similar effect for plant exits in low-skill industries. The research of Becker et al. (2013) indicates that offshoring of German multinational firms is associated with a shift towards more non-routine and more interactive tasks in jobs characteristics, and with a shift towards highly-skilled employees.

However, the literature also provides arguments why offshoring may have negative effects on innovation in the home country. Interactive models of the innovation processes of firms (Kline and Rosenberg 1986; Rothwell 1992) imply that technological learning from production activities can be an important input for product and process innovation. The factory can indeed serve 'as a laboratory' (Leonard-Barton 1992). Empirical evidence for the importance of such linkages is provided by Ketokivi and Ali-Yrkkö (2009) or Pisano and Shih (2012a). The offshoring of production activities may cut many of these links, reduce technological learning from production and therefore leads to less innovation in the home country. Naghavi and Ottaviano (2009) propose a model where offshoring leads to reduced feedback from offshored manufacturing plants to domestic innovation and, as a consequence, to a lower domestic product innovation.

The majority of arguments found in the literature as well as empirical evidence point to a positive association between offshoring and innovation. We therefore state an "optimistic" hypothesis to be tested below:

H1: Production offshoring is associated with a higher innovation input of the firm.

We now turn to product innovation. A higher rate of product innovation seems to be a logic conclusion from H1; however, successful innovation needs market acceptance, which is not related to the size of innovation input. Offshoring firms may nevertheless be more successful with product innovation, because they have a more direct access to foreign markets, and can learn from success and failures with product innovation in other markets. Higher overall sales of the firm from international operations and growth expectations might result in a higher demand for R&D and innovation located in the home country. Being a multinational firm also enhances the range of possible markets for an innovation. Moreover, there is empirical evidence that multinational firms have better management capabilities than pure domestic firms (Bloom and Van Reenen 2010). We therefore state H2:

H2: Production offshoring is associated with more product innovation of the firm.

An important part of innovation activity is process innovation—investment in advanced production technologies. At first sight, it seems obvious that process innovation in the home country suffers from offshoring when firms reduce production in the home country. Process innovation in the home country may also be lower after offshoring if capital-intensive production processes are substituted by labour-intensive production abroad.

However, there may also be incentives for firms to invest more in process innovation after offshoring. We have mentioned above that firms can benefit from a co-location of production and innovation activities because this may give way for technological learning from production. These links between production and innovation activities may be most beneficial when the most advanced production equipment such as highly automated production or flexible, 'customized' manufacturing is employed and concentrated at the domestic location. Moreover, firms may find it easier to restrict involuntary spillovers to competitors if advanced production technologies are located close to the head office of the firm. In addition, offshoring and the fragmentation of production may increase the demand for specific process technologies that facilitate communication and a seamless integration between activities in the home country, foreign manufacturing plants, suppliers, customers and other parts of the value chain. This may trigger investments by offshoring firms in electronic network technologies such as enterprise resource planning, supply chain management systems or warehouse management systems.

Existing empirical studies give no conclusive answer on the relationship between offshoring and domestic investments, either. Feldstein (1994) finds a negative relationship, while Desai et al. (2009) report a positive relationship between outward FDI and domestic investment for the US. Braunerhjelm and Oxelheim (2000) find no general tendency that foreign investment would replace or augment domestic investment of Swedish multinationals.

To sum up, the relationship between offshoring and process innovation is ambiguous and needs further empirical research. As a starting point for this research, we assume a positive relationship between offshoring and process innovation:

H3: Production offshoring is associated with moreprocess innovation of the firm.

3 Data

The paper employs data from the European Manufacturing Survey (EMS).[1] The EMS 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).

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

The EMS includes detailed information on the degree of utilization of a number of advanced 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 offshoring on R&D, innovation and investment in production technologies in detail. Other popular data sources, such as the AMADEUS data base only provide a fraction of the variables needed for this analysis.

Offshoring is operationalized in the EMS by a question which asks if the firm has moved production activities to own or foreign firms abroad during a certain period of time. In the case of EMS 2009, this period is between 1999 and 2006. This allows estimating a causal relationship between production offshoring between 1999 and 2006, and innovation input, product and process innovation in the period 2007–2009. Firms which have moved all their production activities abroad, however, are not covered by the survey.

Tables 2 and 3 provide some descriptive statistics on the sample distribution across sectors and countries. We will exploit data from the EMS 2009, which includes 3,106 observations from seven countries. Offshoring in the definition of the EMS is the movement of production activities to own or foreign firms abroad.

The sample includes only firms from these countries with 20 or more employees. The average firm size is 228 employees, and there are 80 firms with more than 1,000 employees in the sample. Firms which have offshored production activities between 1999 and 2006 are considerably larger (mean 677 employees) than non-offshoring firms (mean 155 employees), which may give offshorers some advantages in comparisons of innovation performance with a non-matched control group. Employment in the whole sample grew by 11 % between 2006 and 2008. Offshoring firms grew slightly slower (10 vs. 11.3 %) than non-offshoring firms during this period.

German firms have the largest share in the dataset. The most frequent sectors are producers of finished metal products and machinery. The highest share of offshoring firms can be found in textiles, clothing and leather and among the manufacturers of

Table 2 Offshoring of production activities between 1999 and 2006 by source country

Country	Non-offshoring	Offshoring	Share on total (%)	Total sample
Germany	1,282	200	13.5	1,482
Austria	256	50	16.3	306
Switzerland	583	95	14.0	678
Netherlands	289	33	10.2	322
Finland	113	18	13.7	131
Spain	100	16	13.8	116
Slovenia	61	10	14.1	71
Total	2,684	422	13.6	3,106

Source: EMS

Table 3 Offshoring of production activities between 1999 and 2006 by sector

Sector	Non-offshoring	Offshoring	Share on total (%)	Total sample
Man. of food products and beverages, tobacco	246	10	3.9	256
Man. of textiles, clothing and leather	58	30	34.1	88
Man. of wood and of products of wood, etc.	100	5	4.8	105
Man. of pulp, paper and paper products	54	9	14.3	63
Publishing, printing and reproduction of recorded media	115	3	2.5	118
Man. of coke, petroleum, chemicals and chemical products	145	21	12.7	166
Man. of rubber and plastic products	216	26	10.7	242
Man. of other non-metallic mineral products	151	7	4.4	158
Man. of basic metals	75	14	15.7	89
Man. of fabricated metal products (excluding machinery)	528	44	7.7	572
Man. of machinery and equipment n.e.c.	450	93	17.1	543
Man. of office equipment, electrical machinery and apparatus	91	51	35.9	142
Man. of radio, television and communication equipment and apparatus	73	25	25.5	98
Man. of medical, precision and optical equipment	185	35	15.9	220
Man. of motor vehicles and other transport equipment	66	26	28.3	92
Man. of furniture; manufacturing n.e.c.	131	23	14.9	154
Total	2,684	422	13.6	3,106

Source: EMS

office equipment, electrical machinery and apparatus. Production processes and the characteristics of the final product in these sectors allow a high degree of division of labour between various stages of production and therefore a high degree of offshoring. The data reveals that 13.6 % of all firms have offshored production to affiliated or non-affiliated firms abroad between 1999 and 2006. Offshoring firms are surprisingly equally distributed between the countries. The relative shares range between 10.2 % in the Netherlands and 16.3 % in Austria.

Innovation in firms can be described as the accumulation of competencies—knowledge and information—in a complex, cumulative, path-dependent process (Dosi 1988; Patel and Pavitt 1997; Pavitt 2005). Innovation activity is not only R&D, but also includes a range of other non-R&D activities, from the acquisition of external knowledge, to design, testing, the development of prototypes to production preparation and adaptations in the production process (OECD 2005).

We consider this broad approach to innovation and include various indicators that measure innovation input, product and process innovation. The main input into research, development and innovation activities of firms is personnel employed in these areas. In order to capture innovation input we consider R&D, but also non-R&D activities such as design, product adaptation, etc. We measure innovation input by the share of personnel of the firm employed in R&D and the share of personnel employed in design and product development.

Table 4 Operationalization of product innovation output

	Introduction of new products	Economic relevance of new products
New to the firm	Dichotomous variable	Share on turnover
New to the market	Dichotomous variable	Share on turnover

Source: EMS

The operationalization of product innovation in the EMS survey follows the suggestions laid out in the OECD's Oslo manual (OECD 2005). Product innovation output is captured by a dichotomous variable indicating that the respondent firm introduced a new product to the market between 2006 and 2009. In addition, product innovation output is also captured by its economic relevance measured by the share of turnover generated by the new products in the year 2008. In accordance with the OECD (2005) the operationalization of the product innovation output distinguishes between two degrees of novelty: products that are new to the firm and products that are new to the market.

Overall this generates four variables capturing product innovation output. Table 4 summarizes the operationalization and provides immediate reference to the tables reporting the corresponding analysis.

A unique feature of the EMS dataset is the richness of information on process innovation. Unlike the Community Innovation Survey (CIS), which only indicates if a firm has introduced a process innovation or not, EMS gives very detailed information on the implementation of 13 different production technologies (dichotomous variable) including the first year of installation (Kirner et al. 2009). A complete list of the technologies is given in Table 5 below. In addition, Table 14 in the Appendix provides information on the diffusion of these technologies at sectoral level.

To measure process innovation we generate an indicator that captures the involvement of the firm in these 13 production technologies on a detailed basis. Stronger involvement indicated by a higher involvement index reveals more intensive process innovation as more of these advanced production technologies have been implemented to achieve a higher level of technology involvement.

We construct an additive involvement index that resembles the index used in Ebersberger and Herstad (2012), in Bozeman and Gaughan (2007, 2011 and in Gaughan and Corley (2010). It is constructed by first identifying the technologies that a firm currently utilizes. Each of these instances of technology usage is then weighted with the inverse of their relative frequency in the respective NACE 2-digit industry group, and the sum is computed. This procedure weights up (relatively) rare utilization of technologies, and weight down (relatively) common ones. The relative frequency of technology utilization in the sectors in the data set is reported in the Appendix.

We compute a total involvement index (all technologies) and separate indexes for production technologies, value chain technologies and product development technologies. The utilisation of production technologies is related to increases in productivity and quality of the manufacture. Value chain technologies, in contrast,

Table 5 Description of the technologies

Description of the technology	Abbreviation
Production technologies	
Industrial robots/handling systems in manufacturing and assembly	ROB
(Process)integrated quality control (e.g., by laser, ultrasonic waves, machine vision systems)	QUC
Laser as a tool (e.g., cutting, welding, forming, micro-structuring)	LAS
Dry processing/minimum quantity lubrication system	DRY
Value chain technologies	
Seamless integration of digital product design/engineering with machine programming (CAD/CAM)	CAD
Radio Frequency Identification (RFID)-utilization in on-site/external logistics	RFID
Automated Warehouse Management Systems (WHS) for on-site logistics and order-picking	WHS
Digital exchange of operation data with supply chain management systems of suppliers/customers	SCM
Processing of novel materials (e.g., composite materials, renewable raw materials)	MAT
Product development technologies	
Rapid Prototyping or tooling (e.g., laser sintering, stereo lithography, 3D printing)	RAP
Manufacturing Execution System (MES) (i.e., integration of PPS/ERP with production data, CAM)	MES
Virtual Reality and/or simulation in product development and/or manufacturing	VIR
Application of bio- and gene-technology in manufacturing processes (e.g., catalysts, bio reactors)	GEN

Source: EMS

aim at a better integration of the firm with suppliers and customers in global value chains. Product development technologies help the firm to facilitate product development, in particular speed up product development.

The computation of the involvement index of this firm is reported as an illustration in Table 6. Consider a firm initially utilizing only CAD/CAM technologies (an automation technology) and virtual reality/simulation in product development (a digital factory technology). In the NACE 2-digit sector of this very firm, CAD/CAM usage is common as 53 % of the firms employ CAD/CAM systems. Virtual reality/simulation in product development is relatively rare as 14 % in the sector employ this technology.

4 Econometric set-up

The econometric analysis will proceed in two steps. First, we model the offshoring decision. We assume that a firms' decision whether or not to offshore production activities is related to firm-specific characteristics X. The influence of these firm

Table 6 Example computation of an involvement index

For employing CAD/CAM	1*(1–0.53) +
For employing virtual reality	1*(1–0.14) +
For all other not employed technologies	0*(1–…)
Involvement index	1.33

Source: EMS

level characteristics is estimated with a probit model, where the offshoring decision *OFFS* is the dependent variable:

$$\mathrm{P}(OFFS_i = 1) = \Phi(X_i) \tag{1}$$

Φ is the cumulative normal density function. X contains firm specific characteristics such as size, age, experience with various production technologies, sector and country.

Second, we use the estimated propensity of the first step for a propensity score matching to construct the counterfactual for the offshoring (for the methodology see for example Heckman et al. 1998; Blundell and Costa Dias 2000; Czarnitzki 2005). This allows us to control for the selection bias and estimate the offshoring effect on the investment in R&D, the implementation of advanced production technologies and on innovation activities.

The temporal structure of the dataset also allows us to address potential endogeneity. Offshoring of production activities between 1999 and 2006 will be modelled using information about the firm characteristics in the year 1999. The information to assess the effects of this offshoring between 1999 and 2006 relate to the years 2007–2009.

The effect of offshoring is the difference between the innovation behaviour I_T of offshoring firms ($OFFS = 1$) and the innovation behaviour of the offshoring firms in the unobserved case where they had not offshored I_C.

$$E(\theta) = E(I_T|OFFS = 1) - E(I_C|OFFS = 1) \tag{2}$$

As the second part of (2) cannot be observed, $E(I_C|OFFS = 1)$ has to be estimated. Matching methods solve this missing data problem by estimating the counterfactual. For each of the offshoring firms the matching approximates the counterfactual behaviour through the behaviour of a non-offshoring firm that is similar to the offshoring firm in terms of exogenous characteristics X. The effect of offshoring is

$$E(\theta) = E(I_T|OFFS = 1, X = x) - E(I_C|OFFS = 0, X = x) \tag{3}$$

As a matching procedure we use the kernel based matching approach. It constructs a convex combination of all non-offshoring firms to be each offshoring firm. The higher the similarity of the non-offshoring firm to the offshoring firm in the characteristics space (X) the higher its weight is in the convex combination. We use a Gaussian kernel with a bandwidth of 0.034. The composition of the conditional sample is such that between the group of offshoring firms and the group of non-offshoring firms no systematic differences exist which influence the offshoring decision. Rosenbaum and Rubin (1983) show that using the propensity score is an appropriate way to solve the problem of finding identical pairs in all dimensions of *X*. The probit model in (1) does not only supply evidence to analyse the determinants of offshoring. It also supplies the propensity score for the matching analysis.

5 Empirical results

5.1 Determinants of offshoring

In this first step of the empirical analysis we investigate the determinants of production offshoring. The offshoring of production activities is captured by a dichotomous variable indicating that production activities have been offshored in the years 1999–2006. The independent variables in the subsequent regressions are measured for the year 1999. The subsequent regressions include a summary indicator for the use of modern organizational concepts in management in the year 1999 (ORG_{99}). It also contains the 1999 usage of eleven different production technologies (Use_xx_{99}). Additionally we include country dummies, sector dummies, firm age dummies and two size indicators which control for the broad size class of the firm (small, medium, large firm) in the period 2007–2009. The affiliation of each firm to these size classes should be fairly stable between 1999 and 2009.

The regression that supplies the propensity score for the subsequent matching analysis also includes interaction terms for country and sector. The results for some base line regressions (Model I–Model III) are reported in Table 7. The regression used for the propensity score is reported in Model IV of Table 7.

To generate the counterfactual for the offshoring firms we use the matching algorithm introduced above. There we argued that the group of non-offshoring enterprises does not represent an unbiased approximation for the counterfactual situation. We argued that there are certain firm specific characteristics that affect the offshoring decision. These characteristics are summarized by the propensity score derived from the probit regression IV in Table 7.

Before we start with the interpretation of the effects of offshoring on the innovation input, product innovation and on process innovation, two issues have to be clarified. First, we analyse whether the matching algorithm was able to balance the propensity score of the offshoring firms with the propensity score of the control group. Table 8 illustrates that the matching algorithm has succeeded in balancing the sample with respect to the propensity score. We do not find significant differences between the offshoring firms and the matched control group that we use to approximate the counterfactual here.

Second, we investigate whether the offshoring indicator plausibly captures the increased embeddedness of the firm in international value chains. In order to do so we provide an analysis of the effects of offshoring on the firms' production and their

Table 7 Determinants of the offshoring decision

	Dependent variable: offshoring of production activities in 1999–2006							
	Model I		Model II		Model III		Model IV	
	b	se	b	se	b	se	b	se
ORG_{99}					0.385*	0.189	0.529	0.317
Use_CAD_{99}	0.152	0.090	0.061	0.094	0.032	0.095	0.030	0.101
Use_ROB_{99}	0.348***	0.090	0.334***	0.093	0.299**	0.095	0.211*	0.101
Use_QUC_{99}	0.048	0.105	0.06	0.108	0.020	0.11	−0.048	0.116
Use_RFID_{99}	0.297	0.343	0.361	0.363	0.364	0.36	0.412	0.380
Use_WHS_{99}	0.325**	0.115	0.291*	0.118	0.257*	0.12	0.133	0.127
Use_LAS_{99}	0.350**	0.112	0.340**	0.116	0.315**	0.117	0.325**	0.121
Use_DRY_{99}	0.015	0.126	0.075	0.131	0.057	0.131	−0.02	0.137
Use_RAP_{99}	0.583**	0.203	0.569**	0.208	0.540**	0.209	0.539*	0.223
Use_MAT_{99}	−0.463	0.498	−0.364	0.531	−0.360	0.526	−0.467	0.553
Use_SCM_{99}	−0.025	0.128	−0.037	0.133	−0.058	0.133	−0.058	0.143
Size (small)							0.289***	0.087
Size (large)							−0.244***	0.065
$Country^{+}$	No		Yes		Yes		Yes	
$Sector^{+}$	No		Yes		Yes		Yes	
Age^{+}	No		No		No		Yes	
$Country^{+}$ * $sector^{+}$	No		No		No		Yes	
N	3,106		3,106		3,106		3,011	
Log likelihood	−1,492.24		−1,410.75		−1,408.69		−1,314.21	
R2	0.027		0.08		0.081		0.130	
Chi2	81.3***		244.3***		248.5***		392.8***	

+ indicates a set of dummy variables

***, (**,*) indicates significance at the 1 %, (5, 10 %) level of significance

Table 8 Propensity score before and after matching

		Obs	Mean	Std. err.	p
Propensity score (before matching)	Offshoring (TG)	412	−0.468***	0.028	0.000
	No offshoring (CG)	2,590	−1.026	0.010	
Propensity score (before matching)	Offshoring (TG)	358	−0.640	0.024	0.800
	No offshoring (CG)	358	−0.639	0.024	

The group labelled as ‘no offshoring’ are all the companies in the sample that have not offshored production activities in the years 1999–2006

The propensity score is generated from regression IV in Table 7

***, (**,*) indicates significance at the 1 %, (5, 10 %) level of significance

international value chain involvement in Sect. 5.2. This is not to sketch out the effect—which would be all too obvious—but to increase the legitimacy of our indicator.

5.2 Offshoring and the firms’ production and value chain

In the following sections we will compare firms which have offshored production activities in the years 1999–2006 with their non-offshoring counterfactuals identified by propensity score matching in the preceding section. We compare the two groups with *t* tests over a number of variables listed in Table 13 in the Appendix.

All other things equal, we would expect the offshoring firms to reveal a reduced intensity of production activities. The first two rows of Table 9 show that offshoring firms indeed have a significantly ($p = 0.000$) lower share of employees in production (55.8 %) than non-offshoring firms (62.2 %). This confirms one of the central assumptions of this paper: offshoring results in a shift in the internal division of labour of the firm from production to headquarter functions.

In the same manner, we expect that offshoring activities increase the integration of firms in international value chains. In Table 9 the integration in international value chains is captured upstream by the fraction of intermediate goods that are imported and downstream by the share of exports on turnover. For both indicators we find that offshoring firms exhibit a significantly ($p = 0.000$ in both cases) more intensive integration than non-offshoring firms.

In addition to the finding that offshoring firms are more intensively embedded in international value chains we investigate whether this leads to effects, possibly adverse effects, on the firms’ delivery time. We observe that the offshoring firms have a mean delivery time of 45.2 days. The matched controls exhibit a delivery time of 47.7 days, which is decisively longer (see Table 9, last two rows). Yet, the difference is not significant.

Overall, the findings do not indicate a negative effect of production offshoring on the delivery time. The findings from Table 9 add to the plausibility of the offshoring indicator, on which the analyses of the following sections will base.

Table 9 Effects of offshoring on production activities and the value chain of the firm

		Obs	Mean	Std. err.	Pr
Share of employees in production	Offshoring (TG)	332	55.765***	1.135	0.000
	No offshoring (CG)	332	62.200	0.631	
Share of imported intermediates	Offshoring (TG)	318	45.903***	1.600	0.000
	No offshoring (CG)	315	31.491	1.003	
Share of exports on turnover	Offshoring (TG)	328	52.664***	1.777	0.000
	No offshoring (CG)	328	41.800	1.227	
Delivery time	Offshoring (TG)	325	45.246	3.783	0.559
	No offshoring (CG)	325	47.660	2.734	

The group labelled as 'no offshoring' includes all companies in the sample that have not offshored production activities in the years 1999–2006

The propensity score is generated from regression IV in Table 7

***, (**,*) indicates significance at the 1 %, (5, 10 %) level of significance

Table 10 Effects of offshoring on innovation input

		Obs	Mean	Std. err.	Pr
Share of personnel in R&D and design	Offshoring (TG)	326	13.668**	0.671	0.011
	No offshoring (CG)	326	11.875	0.380	
Share of personnel in R&D	Offshoring (TG)	326	5.831*	0.376	0.099
	No offshoring (CG)	326	5.152	0.227	
Share of personnel in design	Offshoring (TG)	326	7.837**	0.514	0.037
	No offshoring (CG)	326	6.721	0.265	

The group labelled as 'no offshoring' are all the companies in the sample that have not offshored production activities in the years 1999–2006

The propensity score is generated from regression IV in Table 7

***, (**,*) indicates significance at the 1 %, (5, 10 %) level of significance

5.3 Offshoring and innovation input

Hypothesis 1 stated that offshoring is positively related to innovation input. We measure innovation by the share of R&D personnel, and by the share of design and product development personnel on total staff to capture non-R&D innovation activities as well.

Table 10 provides the result of the analysis. For all three indicators—the share of R&D staff ($p = 0.099$), the share of designers ($p = 0.037$), and the combined share of R&D and design staff ($p = 0.011$)—we identify a significant difference between offshoring firms and the control group of non-offshoring firms.

Comparing the effect of offshoring on R&D employees with the effect of offshoring on designers we find that the difference in R&D employees (0.679) is distinctively smaller than the difference in the share of design and product development personnel (1.116). This may be explained by the fact that multinational firms have a higher need for product adaptations to meet regulations, consumer tastes, environmental conditions, etc. in foreign markets compared to national firms. Comparing the relative effect, we find that offshoring in 1999–2006 is associated with an increase in the share of R&D employees by 13.2 % and with an increase in the share of designers by 16.6 % compared to non-offshoring firms. Here, it is also worth noting that both offshoring and non-offshoring firms have increased employment between 2006 and 2009, although non-offshorer grew faster. A higher innovation input intensity is therefore not a result of less total employment in offshoring firms.

Based on these results, we reject the null-hypothesis claiming no effect of offshoring on innovation input and find support for Hypothesis 1 above.

5.4 Offshoring and product innovation

Hypothesis 2 claims that offshoring exerts a positive effect on product innovation. We measure product innovation by four variables: a dummy variable which is one if the firm has introduced a new product to the market between 2006 and 2009; a dummy variable which is one if the firm has introduced a market novelty between 2006 and 2009; the share of new products on turnover in the year 2008; and the share of market novelties on turnover in the year 2008.

The data reveal that about 76 % of the offshoring firms introduced new products, whereas about 62 % of the matched non-offshoring firms, which proxy the counterfactual to the offshoring, report the introduction of new products. The significant effect ($p = 0.000$) of offshoring amounts to about 14 % (see Table 11 first two rows).

In contrast to the increased likelihood of introducing new products, offshoring firms do not realize a higher turnover share from product innovation. Products that are new to the firm generate about 17 % of sales in offshoring firms. The matched non-offshoring firms generate a share of 16 % by sales of new products. The difference is not significant at any conventional level of significance (see Table 11, third and fourth row). This finding suggests that, although offshoring firms have the

Table 11 Effects of offshoring on product innovation

		Obs	Mean	Std. err.	Pr
New products	Offshoring (TG)	352	0.760***	0.023	0.000
	No offshoring (CG)	352	0.621	0.016	
Share of new products on turnover	Offshoring (TG)	230	16.900	1.091	0.463
	No offshoring (CG)	230	15.990	0.064	
Market novelties	Offshoring (TG)	247	0.587*	0.031	0.050
	No offshoring (CG)	247	0.517	0.021	
Share of market novelties on turnover	Offshoring (TG)	113	9.000	1.016	0.767
	No offshoring (CG)	113	9.342	0.674	

The group labelled as 'no offshoring' are all the companies in the sample that have not offshored production activities in the years 1999–2006

The propensity score is generated from regression IV in Table 7

***, (**,*) significance at the 1 %, (5, 10 %) level of significance capability to develop and introduce new products more frequently, they are not able to generate a higher fraction of sales through these products when compared with their matched non-offshoring firms.

Analogous to the interpretation of Table 11, the effect of offshoring on the introduction of market novelties—products which are new to the market—is positive and significant (see Table 11, fifth and sixth row). Here again, analogous to the findings for the economic relevance of new products (see Table 11, fifth and sixth row) firms do not realize a higher economic relevance from market novelties. Market novelties generate 9 % of the sales of offshoring firms. The matched non-offshoring firms generate a share of about 9.3 % by sales of market novelties. The difference is not significant at any conventional level of significance. This finding suggests that, although offshoring firms have the capability to conceptualize, develop and commercialize market novelties on a higher frequency, they cannot generate a higher fraction of sales through these products when compared with their matched non-offshoring companies.

To sum up, offshoring has a significant effect on the probability to introduce new products. It does not, however, exert a positive effect on the generation of sales from these new products. Overall, we find support for Hypothesis 2.

5.5 Offshoring and process innovation

Finally, we look at process innovation. In Sect. 2 we found that the relationship between offshoring and process innovation is ambiguous and needs further empirical research. As a starting point, we assumed a positive association between the two variables. In Sect. 3 we described how we constructed three indexes of involvement in specific process technologies and one index for overall technology involvement. These three indexes describe the involvement of the firm in technologies to increase the productivity and quality of production processes; technologies to improve the integration of the firm in global value chains; and technologies that facilitate and speed up the development of new products.

The effect of offshoring on the overall technology involvement and the three subcategories is reported in Table 12. After matching, which accounts for the fact that offshoring is not a random event but affected by certain firm specific characteristics that in turn also affect the utilization of technologies, we observe a significant ($p = 0.003$) difference in the involvement of all technologies. As those matched non-offshoring firms are considered a proxy for the counterfactual to offshoring, the effect of offshoring on the overall technological utilization of advanced technologies in the production process is significant and positive. Thus, offshoring firms show a stronger involvement in production technologies than they would have in the counterfactual situation of being a non-offshoring firm. This supports H3.

As noted above the overall technological involvement is the aggregate index of three involvement indexes covering more detailed sub-groups of advanced technologies in the production process. Investigating the effects on these sub-indices can reveal from which technologies this significant overall effect originates.

Production technologies, such as industrial robots and handling systems, laser as a tool for cutting, welding, forming, or integrated quality control systems have

Table 12 Effects of offshoring on process innovation

		Obs	Mean	Std. err.	Pr
Overall involvement in process technologies	Offshoring (TG)	353	2.483***	0.097	0.003
	No offshoring (CG)	353	2.156	0.062	
Production technologies	Offshoring (TG)	353	0.895***	0.043	0.005
	No offshoring (CG)	353	0.764	0.027	
Value chain technologies	Offshoring (TG)	353	1.152***	0.049	0.003
	No offshoring (CG)	353	0.988	0.027	
Product development technologies	Offshoring (TG)	353	0.435	0.033	0.407
	No offshoring (CG)	353	0.403	0.021	

The group labelled as 'no offshoring' are all the companies in the sample that have not offshored production activities in the years 1999–2006

The propensity score is generated from regression IV in Table 7

***, (**,*) significance at the 1 %, (5, 10 %) level of significance

considerable labour-saving and quality-increasing potentials, because they speed up production and reduce scrap. According to EMS results, the main reason for their introduction is to increase productivity. The results on the effect of offshoring on the involvement in automation technologies can be found in the third and fourth row of Table 12. Despite the labour-saving character of many of these technologies, we find that offshoring is associated with a subsequently higher involvement in production technologies. The difference between 0.895 of the offshoring companies and 0.764 of the matched not-offshoring companies is highly significant ($p = 0.003$). Hence, offshoring is not a strategy to substitute capital-intensive process technologies in the home country by investments in low-wage countries. However, offshoring firms invest more in technologies to increase productivity at home than non-offshoring firms.

The second sub-group of **value chain technologies** include supply chain management systems of suppliers/customers, manufacturing execution systems which allow the integration of production steps, the seamless integration of digital product design/engineering with machine programming (CAD/CAM), applications of radio frequency identification (RFID) in logistics, or automated warehouse management systems. These technologies are a means to facilitate the integration of production processes between suppliers and clients across firm boundaries and therefore promote the 'Great Unbundling' of production tasks in global value chains (Baldwin 2006). The fifth and sixth row of Table 12 summarizes the findings for the involvement in value chain technologies. Again, we find a significant difference between the index value for offshoring firms (1.152) and the matched non-offshoring firms (0.988). This is in line with the results of Rasel (2012) who finds that firms which use software to manage the supply chain are more likely to offshore than firms which do not use such technologies.

Finally, **product development technologies** such as rapid prototyping or virtual reality can increase the flexibility and shorten time-to-market in product development. Moreover, biotechnologies or new material may allow new products not possible before, and can therefore open new opportunities for product development. The results indicate a non-significant difference ($p = 0.4086$) between offshoring and non-offshoring firms (last two rows of Table 12). The offshoring firms show a higher involvement index of 0.435, whereas the non-offshoring companies, as the counterfactual, show an involvement index of 0.403. We interpret this as a sign that offshoring firms have not yet discovered the advantages of these technologies.

6 Conclusions and policy issues

The consequences of production offshoring for the home countries are a much-discussed topic in economic policy. We investigated the effects of offshoring on innovation inputs, product and process innovation of manufacturing firms in the home country.

Overall, we see no negative effect of production offshoring on innovation activities of firms in the home country. On contrary, most indicators reveal that offshoring is associated with a higher innovation performance at the firm level. We explain this result by the changing specialisation patterns of offshoring firms towards R&D, design and innovation in their home countries. Moreover, innovation activities in the home countries may also benefit from additional demand generated abroad and reverse knowledge spillovers from foreign affiliates to the home county. Fears that offshoring may lead to lower innovation are not supported by the analysis.

The effects on innovation input, including R&D and design, are univocally positive. Offshoring of production activities is associated with a significant higher input in R&D and non-R&D innovation activities. The analysis of product innovation gives a more differentiated picture of the effects of offshoring: production offshoring is associated with a higher likelihood of product innovation, regardless of the degree of novelty of the product innovation. However, product innovation does not show any relationship with the share of sales from new products. Yet, it can be argued that this particular indicator rather captures the product lifecycle of the firm, than the firm specific relevance of product innovation. Our findings can hence also be interpreted that offshoring does not affect the lifecycle of the product of the offshoring firm.

Finally, the analysis reveals a positive effect of production offshoring on process innovation, which can be traced back to a stronger investment in production technologies and in technologies that facilitate the management and integration of global value chains. The index for technologies for product development shows no significant difference between offshoring and non-offshoring firms, despite possible losses of domestic production activity due to offshoring. An explanation is that offshoring firms want to concentrate the most advanced, most productive equipment—which can compete with low wages at locations abroad—in the home country to increase flexibility.

The results support a view that regards offshoring as an strategy of international expansion, and not a passive reaction of firms to a loss of their competitiveness. This view is in line with the international business literature (Dunning 2001; Dunning and Lundan 2008) and the international economics literature (Helpman et al. 2004;

Helpman 2006) where internationalisation is explained by the wish of the firm to exploit superior firm-specific assets at international markets. We show that this expansion goes hand in hand with process modernization and increased innovation efforts at home.

With respect to policy, the analysis clearly rejects fears of a weakening of national competitiveness from offshoring (Pisano and Shih 2012a, b). Activities that add to the technological capabilities of firms and their ability to create competitive advantage—such as R&D, design or process innovation—are positively associated with a firm's decision to relocate production activities to foreign countries. Concerns that offshoring may cut feedback loops between production and innovation find no support from the evidence provided in this paper. On contrary, offshoring firms have higher propensity to invest in advanced production technologies in the home country than the control group. Thus, protective policy measures to prevent production offshoring do not seem to be a suitable approach to strengthen domestic technological capabilities and value-adding competences.

Moreover, our findings point to complementarities between domestic education and innovation policies and internationalisation. Politics should be aware that domestic firms are likely to specialise in more knowledge-intensive activities when they internationalize their production activities. Consequently, policy can help to take full advantage of the benefits from internationalisation by promoting education and qualifying personnel early enough, particularly in countries or regions where talent is short.

The analysis has also some limitations. First, the data set does not include firms which have offshored all their production activities. Second, we have no information on the magnitude of offshoring, which may be helpful to distinguish between effects from various offshoring intensities or levels. Third, it would be wrong to regard the results as valid for the aggregate of the home country, since we cannot asses the indirect effects of offshoring on the home country, like the effects on the suppliers of manufacturing firms. Finally, a discussion of the results of this paper has to consider the global financial crisis, which has reached its climax during the observation period 2007-mid 2009. We have shown that offshoring firms are much stronger embedded in international value chains than non-offshoring firms. Paunov (2012) suggests that export-oriented firms were more severely hit by the crisis and suffered more severe cuts in innovation and R&D expenditure than less export-oriented firms. Thus, we can assume that the crisis has also narrowed down the differences in innovation between offshoring and non-offshoring firms observed in the preceding sections.

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Appendix

See Tables 13 and 14.

Table 13 Description of the dependent variables used in the analysis

Name	Description	Measure
Share of employees in production	Personnel in production divided by total staff	Percentage
Share of imported intermediates	Imported intermediary inputs divided by total inputs	Percentage
Share of exports on turnover	Total exports divided by total turnover of the firm	Percentage
Delivery time	Number of days between receipt of an order and finish of the product	Days
Share of personnel in R&D and design	Personnel in R&D and design divided by total staff	Percentage
Share of personnel in R&D	Personnel in R&D divided by total staff	Percentage
Share of personnel in design	Personnel in design divided by total staff	Percentage
New products	Indicates if the firm has introduced a new or significantly improved product between 2007 and mid-2009	Yes/no
Share of new products on turnover	Turnover with new products as a share of total turnover	Percentage
Market novelties	Indicates if the firm has introduced a new or significantly improved product which was also new tot he market between 2007 and mid-2009	Yes/no
Share of market novelties on turnover	Turnover with market novelties as a share of total turnover	Yes/no
Overall involvement in process technologies	Involvement index of process, see Sect. 3	Index
Production technologies	See Table 5	Index
Value chain technologies	See Table 5	Index
Product development technologies	See Table 5	Index

Table 14 Share of firms which have introduced a particular process technology

Sector (NACE rev. 1.1)	Technologies												
	CAD	ROB	QUC	RFID	WHS	LAS	DRY	RAP	GEN	MAT	SCM	MES	VIR
15–16	0.06	0.20	0.22	0.05	0.19	0.02	0.02	0.00	0.02	0.04	0.24	0.13	0.02
17–19	0.18	0.01	0.06	0.01	0.13	0.05	0.06	0.01	0.00	0.22	0.20	0.14	0.04
20	0.36	0.20	0.15	0.01	0.13	0.03	0.02	0.03	0.00	0.18	0.17	0.13	0.05
21	0.15	0.21	0.29	0.11	0.19	0.04	0.02	0.02	0.00	0.13	0.35	0.22	0.05
22	0.18	0.08	0.30	0.01	0.12	0.07	0.02	0.04	0.01	0.11	0.25	0.26	0.05
23–24	0.10	0.23	0.17	0.08	0.24	0.03	0.01	0.03	0.06	0.15	0.22	0.23	0.09
25	0.31	0.34	0.31	0.05	0.15	0.07	0.04	0.10	0.01	0.26	0.36	0.33	0.11
26	0.24	0.28	0.24	0.04	0.08	0.07	0.05	0.01	0.01	0.14	0.14	0.14	0.04
27	0.41	0.32	0.48	0.08	0.17	0.15	0.23	0.07	0.01	0.05	0.34	0.43	0.19
28	0.43	0.26	0.19	0.03	0.12	0.19	0.16	0.05	0.01	0.09	0.26	0.27	0.12
29	0.42	0.19	0.13	0.03	0.19	0.16	0.12	0.08	0.01	0.10	0.29	0.25	0.18
30–31	0.31	0.18	0.27	0.08	0.19	0.18	0.07	0.09	0.00	0.09	0.37	0.29	0.13
32	0.52	0.39	0.57	0.05	0.27	0.18	0.02	0.14	0.00	0.11	0.51	0.40	0.23
33	0.43	0.23	0.29	0.03	0.16	0.20	0.07	0.17	0.00	0.14	0.29	0.26	0.20
34–35	0.40	0.36	0.38	0.09	0.25	0.11	0.18	0.07	0.00	0.23	0.44	0.31	0.29
36	0.53	0.22	0.07	0.02	0.18	0.07	0.05	0.04	0.01	0.23	0.34	0.26	0.14
Total	0.33	0.23	0.22	0.04	0.16	0.12	0.08	0.06	0.01	0.13	0.28	0.25	0.13

See Tables 3 and 4 for full labels of the technologies

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