Impact of greening on the upgrading of manufacturing subsidiaries' technological capabilities – A Hungarian perspective*

*Andrea Szalavetz***

This paper investigates the relation between greening in global companies and the upgrading of manufacturing subsidiaries' technological capabilities. Drawing on a proprietary database of secondary source information about greening-related product and process upgrading, research and technology development, and functional upgrading at 25 Hungarian manufacturing subsidiaries, we identify two greening related mechanisms that propel the upgrading of subsidiaries' technological capabilities. First, greening enhances the organisational decomposition of innovation, which facilitates manufacturing subsidiary scientists' and technicians' participation in the global R&D team of their owners. Second, greening related changes in corporate routines prompt the delegation of new, sophisticated business functions and activities to subsidiaries. Some of the new tasks require subsidiaries' indigenous technology efforts.[1]

Keywords: greening, upgrading, environmental sustainability, Hungarian subsidiaries, technological capabilities, organisational decomposition of innovation

Introduction

Escaping from a low-wage specialisation trap and enhancing the upgrading of local technological capabilities represent ongoing, major challenges for countries that operate behind the technology frontier and depend on foreign direct investment (FDI) inflows that push their actors ahead, along a modernisation trajectory.

As illustrated by the economic history of Central and Eastern European (CEE) transforming countries, these inextricably linked tasks are not easy to implement. Kravtsova and Radosevic (2012) pointed out that foreign investors' massive technology transfers and the accompanying knowledge inflows have mainly enhanced production (i.e. technology using) capabilities in CEE. Conversely, local technology development capabilities have not much improved. Despite the well-documented internationalisation of corporate research and development (R&D) (see e.g. Moncada-Paternò-Castello et al. 2011 for recent trends and general explanations, and Kalotay 2005; Rugraff 2014; Sass and Szalavetz 2014 for documentation and analysis of the slowly increasing FDI in CEE's R&D) dominant part of foreign business enterprise-performed R&D can still be charac-

* Received: 21.09.2016, accepted: 06.05.2017, 2 revisions

** Andrea Szalavetz, Institute of World Economics, Budapest, Hungary, E-mail: szalavetz.andrea@krtk.mta.hu. Main research interests: technological change and upgrading in global value chains, industry 4.0, corporate environmental sustainability.

1 This research was supported by the National Scientific Research Fund of Hungary (OTKA K116173).

terised as supporting local subsidiaries' technology absorption rather than as a technology frontier activity (Radosevic and Yoruk 2015).

The purpose of this paper is to explore whether the ongoing integration of environmental aspects in corporate strategy in general, and in manufacturing related activities in particular, can produce any improvement with respect to the upgrading of subsidiary-level technological and R&D capabilities in Central and Eastern Europe.

In line with Radosevic and Yoruk (2015) we define production capability as the capability to produce with given level of technology at world levels of efficiency or productivity. Radosevic and Yoruk (ibid.) connect production capability with a pertinent capability to perform minor improvements in existing products and processes. Conversely, the capability to change (*develop*) products and processes *significantly*, is referred to as technological capability. R&D capability, on the other hand, is necessary either for frontier technology activities, or for using (effectively absorbing) knowledge generated elsewhere.

We depart from the proposition that at corporate level, there is a close association between greening[2] and innovation. The integration of environmental aspects in corporate strategy requires product and process innovations, which further enhances the complexity of corporate R&D activities. Enhanced technological complexity requires greater specialisation within the R&D function. This might open up strategic opportunities also for CEE subsidiaries characterised by a dominantly production-oriented mandate (Majcen et al. 2009). New tasks will be assigned to manufacturing subsidiary engineers and scientists in connection with addressing greening related challenges. Greening prompts the delegation of new, sophisticated business functions and activities to subsidiaries. New tasks involve additional transfer of technology and of intangible resources by parent companies. More importantly, undertaking some of the new tasks requires subsidiaries' indigenous technology efforts. Subsidiary engineers' mandates regarding greening related process improvement will deepen. Demonstrated indigenous process innovation capabilities might prompt parent companies to involve subsidiary scientists also in parent-company-coordinated global R&D activities.

Altogether, greening-driven changes in corporate routines propel subsidiary-level technological capability accumulation.

To assess these propositions, we use the empirical experience of the Hungarian manufacturing subsidiaries of global companies. Information is drawn from the content analysis of subsidiaries' corporate announcements, annual reports (notes to the financial statement), sustainability reports (if available) and from business press articles on these subsidiaries' greening and upgrading achievements.

2 This paper uses the term 'greening' as a synonym for the integration of environmental aspects in corporate strategy, routines and practices.

We focus on subsidiary-level environmental initiatives and use the umbrella term of ‘greening’ to refer to their outcome. Greening-oriented initiatives represent the environmental component of overall corporate sustainability-oriented initiatives. We are concerned with initiatives that are strongly linked to companies’ core business activities, involving new or modified products, processes and practices that reduce the impact of the given companies on the environment, since these initiatives and practices are expected to be directly related to subsidiaries’ upgrading and technological capability accumulation. Accordingly, we consider neither host-country-level, legitimacy-oriented (corporate citizenship-type) sustainability initiatives, such as philanthropic support targeting environmental improvement in the region (or settlement) where the manufacturing subsidiary is located, nor the greening of subsidiaries’ facility infrastructure, or activities related to the social dimension of corporate sustainability.

Our aim is not to *measure* the intensification of subsidiaries’ greening related R&D activities, rather to identify the diversity and the scope of the relations between global companies’ efforts to integrate environmental aspects in corporate practices and the technology upgrading opportunities of their subsidiaries.

The remainder of this paper is organised in four sections. We first provide an overview of the related literature. Next, we outline the research method and introduce the sample of the companies surveyed. This is followed by the presentation of the results. The final section provides some conclusive remarks and elaborates on the limitations of our research.

Insights from the related literature

The focus of this paper is closely related to three strands in international business literature discussing: (a) the relation between corporate environmental performance and business performance; (b) subsidiary upgrading; (c) the organisational decomposition of innovation and the internationalisation of corporate R&D.

One of the classical references concerning the interdependence of corporate sustainability strategy and business performance is Elkington’s (1997) triple bottom line approach that argues for a balanced consideration and simultaneous management of economic, social and environmental dimensions of sustainability. These dimensions are not necessarily contradictory, as argued by Porter and Van der Linde (1995). In contrast to the traditional approaches that posit a trade-off between firms’ environmental and business performance (e.g. Palmer et al. 1995; Walley and Whitehead 1994), Porter and Van der Linde (ibid.) postulate that firms might gain competitive advantage (e.g. cost advantages through reduced resources use and advantages from product differentiation, which facilitates access to new markets and contributes to enhanced revenues) by adopting environmental practices and investing in greening related resources. This is referred to as the *Porter-hypothesis* in the literature.[3]

Nidumolu et al. (2009) emphasize the close association between environmental sustainability and innovation. These authors maintain that environmental sustainability has become the key driver of corporate innovations: of both science-based, technological and non-science-based innovations.

Indeed, over time, the focus of academic investigations has gradually shifted away from the costs of compliance towards the profit opportunities offered by the integration of environmental sustainability into business practices (Orsato 2009). A series of quantitative investigations presented evidence of a positive relation between firms' environmental and business performance (e.g. Albertini 2013; López-Gamero and Molina-Azorín 2015). Although it is recognised that substantial variations exist in this positive relation, and not all firms can benefit equally from shifting to a proactive environmental strategy (Albertini 2013; Clarkson et al. 2011), it is safe to argue that the more the green initiatives are integrated in companies' overall business strategy (i.e. if they are interconnected with multiple dimensions of corporate strategy: with both core and support functions), the stronger this positive relation is (Michelon et al. 2013).[4]

Undoubtedly, according to a consensus thesis in the literature, green strategies need to be integrated in and aligned with a number of business functions – this thesis is closely related to the focus of our investigations.

Considered in a 'dynamic capabilities' perspective (Eisenhardt and Martin 2000; Teece et al. 1997), as a response to the increased relevance of environmental issues for business, firms need to adjust the way they conduct business: to reorganise practically each of their business functions. They need to adopt or develop new technologies, redesign the manufacturing and logistics processes, adjust their organisation and corporate governance, and reconsider, among others, the supply chain management strategy, the quality management and procurement strategy, the brand management and marketing strategy, and the distribution and after-sales strategy.

Changing business practices may, among others, boost the upgrading of manufacturing subsidiaries in global companies. Subsidiary upgrading is an evergreen issue of interest for international business research (classical references include

3 See also Hart (1995) for a thorough discussion of competitive advantages resulting from companies' adoption of green practices.

4 The degree of integration of sustainability strategy in overall business strategy is only one of the multiple moderating factors that influence the strength of the relation between environmental and business performance. Other moderators include the industrial context (i.e. whether the surveyed firms operate in a rapidly growing industry), organisational capabilities, R&D capabilities, the specifics of environmental practices, the variables used for the measurement of the correlation (Albertini 2013).

Bartlett and Ghoshal 1989; Birkinshaw and Hood 1998; Jarillo and Martínez 1990). Co-evolving with their parent companies, subsidiaries absorb parent companies' transfers and accumulate specialised capabilities, which allows them to increase the range and the sophistication of their mandates and move towards higher-than-before value adding activities (see Majcen et al. 2009 for a discussion of subsidiary upgrading in a CEE perspective).

The increased value added of subsidiary activities may be manifested in the field of the products manufactured by the given company (product upgrading), or in the improved performance indicators (efficiency, reliability, speed, quality, etc.) of the production processes (process upgrading). A further dimension of subsidiary upgrading is the take-up of additional (more knowledge-intensive and higher value generating) business functions by companies specialised previously only in production, referred to as functional upgrading (Humphrey and Schmitz 2002).[5]

One important research question within the literature on subsidiary upgrading concerns subsidiary participation in its owner's global innovative activities, which would suggest the upgrading of subsidiary-level innovative or technological capabilities (see survey by Sass and Szalavetz 2014). Prior literature indicates that technological learning in CEE manufacturing subsidiaries has mainly been confined to technical and engineering skill accumulation aimed at mastering and improving existing technology, rather than to developing R&D competencies aimed at new product or process innovation – despite some ad hoc anecdotal evidence of the contrary (Havas et al. 2015; Kravtsova and Radosevic 2012; Stephan 2013).[6]

Nevertheless, since the internationalisation of R&D activities orchestrated by global companies has been gaining momentum (Dunning and Lundan 2009; Lema et al. 2015; Moncada-Paternò-Castello et al. 2011; UNCTAD 2005), the disjunction between technology use and technology generation that characterised the transformation and integration decades of CEE may become less tenacious than before. One of the main drivers of the intensification of R&D offshoring and of external technology sourcing is the growing technological complexity of products and of manufacturing processes. For successful new product

5 In Humphrey and Schmitz's (2002) taxonomy there is an additional upgrading category, that of 'intersectoral upgrading'. This refers to the cases where the accumulated competencies are applied in new sectors that promise larger rents and beneficial externalities. This paper does not consider this upgrading category, since it is rarely related to corporate greening.

6 Looking beyond CEE, however, a rapidly expanding literature (surveyed by Lema et al. 2015) documents that local subsidiaries in selected rising-power countries have indeed surmounted the decoupling of production and innovation capabilities, and have made advances in building innovation capabilities. This contributed to a shifting global distribution of innovation power.

development and also, for the continuous upgrading of manufacturing processes, a growing number of specialised fields of knowledge need to be accessed and coordinated (Chesbrough 2003), which opens up new opportunities also for peripheral subsidiaries that seek to host offshored R&D (Castellani and Pieri 2013).

Schmitz and Strambach (2009) advance a new concept to describe the changes in global companies' organisation of their innovation activities: the *organisational decomposition of innovation.* Although these authors underscore that the seemingly spectacular geographical dispersal of innovation activities is confined to *problem solving*, while *problem framing* is kept centralised by the headquarters of global companies, it needs to be acknowledged that peripheral actors' increasingly intensive participation in problem solving certainly contributes to the accumulation of their technological and innovation capabilities.

This paper attempts to bring these streams of the literature together through documenting and analysing the technological upgrading opportunities that open up for manufacturing subsidiaries as a result of their owners' integrating environmental aspects in their business practices, across the whole corporation.

Based on the surveyed literature, we make the following propositions. The increasing importance of environmental performance necessitates the transformation of global companies' practices and routines. This enhances the magnitude and the scope of their geographically dispersed innovation efforts – where innovation is understood in accordance with its broad conceptualisation (Mytelka and Smith 2002). These developments open up new opportunities for peripheral manufacturing subsidiaries seeking to upgrade their technological and R&D capabilities.

Research method and sample

Since the purpose of this paper is to explore a complex and multifaceted issue – how greening is associated with the upgrading of technological capabilities in manufacturing subsidiaries, and analyse actors' efforts and initiatives in real settings, grounded theory seemed an appropriate choice for research methodology (Glaeser and Strauss 1967; Suddaby 2006; Yin 2003).

Our investigation involved three procedures: (a) selection of a sample of firms, (b) development of a database of qualitative information on these firms' greening related technology upgrading, technology development activities and functional upgrading, and (c) review and content analysis of the database of qualitative information.

The empirical context of our study is the experience of manufacturing subsidiaries in Hungary. We selected two medium-high environmental-impact industries: automotive and machinery. These industries were selected on the basis of their importance to the Hungarian economy (machinery and automotive industries accounted for 7.5% and 29.8 % of total manufacturing sales respectively, in 2015 – source: Central Statistical Office Hungary). An additional factor that motivated our selection was to take advantage of the author's familiarity with these industries (and prior interviews with selected companies in this sample).

Applying a purposeful sampling method (Patton 1990), we first selected a sample of nine companies. According to Patton (1990) the aim of purposeful sampling is the selection of information-rich cases, i.e. companies whose cases promise insightful observations about issues related to our research. These companies are members of Követ Association for Sustainable Economies, a Hungarian platform for promoting sustainable business management, and are recognised as sustainability leaders within their industries. The environmental initiatives of these companies are summarised in the Association's database of case studies.

This initial sample was extended with information gathered from focussed searches of companies' environmental sustainability-oriented initiatives published in the Hungarian business press. Six journals and six web portals[7] have been reviewed, from January 2014 to August 2016.

Performing focussed searches required first the development of a list of corporate environmental initiatives related keywords. Drawing on our review of the literature (part of which was) summarised in the previous section, we used the following search queries: green(ing), eco-innovation, eco-design, energy & material efficiency, green logistics, energy-saving technology, environmental sustainability, environmental management system, ISO 14001, ISO 50001, EMAS certification, circular economy related innovation, remanufacturing, waste reduction, recycling.

These keywords were individually entered as search queries in the surveyed web portals and journal websites. The returned titles were screened and the titles indicating a corporate case in the content were opened for first check, and saved if they proved relevant. This 'hand-picked' survey produced a list of 23 additional companies. This list was filtered to include only foreign-owned companies, operating in the two selected industries. As a result, 16 additional companies have been added to the sample. Altogether, our database consists of 25 companies operating in the automotive (15) and machinery (10) industries (sample companies are listed in the Annex). Table 1 provides some data on the characteristics of the surveyed companies.

7 The surveyed journals and web portals were as follows: Gyártástrend, Supply Chain Monitor, HVG, Logisztikai Hiradó, A jövő járműve; Piac & Profit; www.innoteka.hu; www.kovet.hu; www.ablakonbedobottpenz.hu; www.autopro.hu; www.leanforum.hu; www.techmonitor.hu.

Table 1: Characteristics of the companies in the sample

Sample size	25
Automotive companies	15
Machinery companies	10
Average employment (2015)	2,184
Average turnover (€ million, 2015)	781.25*
Local subsidiaries with formal R&D departments	18
Local subsidiaries that have published sustainability reports	6[8]
Stylised facts from the analysis of qualitative evidence** Companies with	
■ Greener-than-before products	23
■ Increased process sustainability	21
■ Functional upgrading: greening related new tasks/responsibilities	17
■ Remanufacturing	5
■ Circular innovation (redesigned products)	2
■ Greener-than-before (plant) logistics	14

* n = 24
** Note that the lack of information about selected greening related developments does not necessarily mean the lack of such developments.
Source: Author's calculations

We complemented the initial stock of qualitative evidence (gained from Követ's database and case studies) with the documents gained as a results of our focussed searches (business press information on greening related developments at and on the upgrading performance of the companies in the sample. Additionally we reviewed sample companies' corporate websites, notes to the financial statement and sustainability reports (if available). Our focussed searches have produced altogether 117 written documents about greening related developments and upgrading at the companies in the sample. These documents were read and their content analysed 'manually' in three rounds.

First, when building the database and compiling information, we simultaneously reviewed the accumulating qualitative evidence to identify common patterns and features that characterise these companies' greening related developments and upgrading results. This helped us refine the research questions. Our initial question,

8 This refers to the number of formal sustainability reports published in Hungarian. As a matter of fact, most of the companies in the sample published information on their sustainability strategies, values, goals and achievements. Some of them provide links to the corporate-level sustainability report, but only few publish a formal report in Hungarian.

RQ0: Do the greening related initiatives feature any common patterns across the surveyed subsidiaries?

– was thus complemented with two other questions, prompting a re-reading of the documents and a second round of analysis.

RQ1: Can greening be directly associated with the upgrading of the sample companies?

RQ2: Which of the upgrading categories, as detailed in Humphrey and Schmitz's (2002) above-listed taxonomy of upgrading, can be associated with the observed greening related developments?

These questions have guided our interpretation of the "daily realities" (Glaeser and Strauss 1967: 239) of the surveyed actors' greening and of the upgrading of their technological capabilities. Thus, in the second round of the review, we formed ideas about the identified phenomena and generated propositions about the relationships among them. Combining the individual themes that emerged in the course of the two rounds of analysis, we have formulated the main research question to be answered following a third, final round of reviewing the database and clustering the evidence into the cited taxonomy of upgrading.

RQ3: How is manufacturing subsidiaries' shifting to greener products and cleaner practices related to the upgrading of their technological capabilities?

Results

Despite the apparent heterogeneity of the surveyed rich qualitative evidence, two conspicuous commonalities can be identified. The first one is that greening related developments are closely related to upgrading, more specifically, to each of the upgrading categories detailed in Humphrey and Schmitz's (2002) taxonomy: product upgrading, process upgrading and functional upgrading (see footnote 4). Second, that greening related developments required subsidiaries' non-negligible indigenous technology development efforts.

Greening and product upgrading

Some of the most conspicuous greening related developments at sample companies concerned their take-up of the production responsibility for new, greener-than-before products. Indeed, the 'greening' of products is widely communicated by practically all companies in the sample.

Our survey identified four types of greening related product innovation:

(a) General improvements in product quality parameters, such as longevity, reliability, durability. These parameters were considered environmental sustainability related since they extend the lifespan of the products;

(b) 'Greening' of the components or the materials used: replacing inputs that are pollution-intensive. Examples include companies' switching to green adhesives or to other materials with a lower-than-before environmental impact, for example, to recycled material;
(c) Improved environmental sustainability related to product use: for example improved energy efficiency, fuel efficiency,[9] reduced noise level, reduced maintenance costs;
(d) Circular innovation: products have been redesigned for easier disassembly and reuse.

According to the surveyed corporate information, over the past couple of years, the relevance of the above product development initiatives for the upgrading of subsidiary technological and R&D capabilities has become more straightforward than before. While subsidiary-level product upgrading previously referred to taking up the production tasks of the new or upgraded products that had been developed outside Hungary (by scientists and engineers in one of the global R&D centres of the global owners), nowadays subsidiary contribution goes beyond taking up the production tasks of new (greener-than-before) products that had been developed elsewhere.

As detailed in several interviews published in the surveyed business press, new products have been developed by *global teams* that include also Hungarian experts. While new product concepts are usually advanced by the experts of the headquarters, the intellectual input of subsidiary scientists and engineers is also incorporated in the new products.

Our database contains information also about the specifics of subsidiary-level contribution to product development. Besides types of expertise that can be considered a usual contribution by upgraded manufacturing subsidiaries, such as analysis of manufacturability, prototype development and tooling, we identified several cases, where subsidiary scientists participated in new product development-related fundamental, close-to-basic-research activities. (Note that our sample consists of flagship R&D-intensive companies. 18 subsidiaries, i.e. more than 70% of the sample, have formal R&D departments). Examples include

(a) tribology-related research;[10]

9 Example of product innovation leading to improved fuel efficiency is automotive companies' replacing traditional cast iron components with lightweight materials. This reduces the mass of the final product, and thus, results in reduced fuel consumption.

10 Tribology is a research field at the intersection of mechanical engineering and materials science, its results are applied in the engineering of interacting surfaces in relative motion. Tribology is closely related to sustainability since this research aims at reducing the inefficiencies in mechanical systems (e.g. vehicles, industrial machinery) caused by friction. These inefficiencies reduce the performance of the given system and increase its energy- or fuel intensity.

(b) research of the modifier elements in aluminium foundry alloys (that improve tensile strength and other mechanical properties of automotive components);
(c) research on integration of advanced materials (e.g. non-ferrous, light metals and multi-material solutions) in vehicles;
(d) research on combustion and emission characteristics of ignition engines
(e) research to improve the operational efficiency of hybrid and electrical vehicles;
(f) research on autonomous driving.

The above list of R&D activities suggests that subsidiary scientists are specialised in narrow and highly specific segments of the complex product development process.

Additional subsidiary-level R&D activities included modelling and simulation. These activities envisaged either the testing of vehicle components and subsystems in a virtual reality environment, or the design and scale-up of production lines for new products. The increased use of modelling and simulation represents a shift to eco-practices in product innovation, since virtual simulations allow for saving material and energy.

While the aforementioned examples reflect subsidiary scientists' participation in basic and applied research envisaging green product development, our survey has also identified examples of local engineers' participation in circular innovation projects concerned with the redesign of products to facilitate their disassembly and remanufacturing.

To summarise this cluster of evidence, a meaningful number of developments suggests a growing and deepening participation by manufacturing subsidiary engineers and scientists in the complex product development initiatives of their global owners. An increasingly important part of these initiatives concerns the greening of products. However, greening drove the accumulation of subsidiary R&D capabilities only indirectly, by adding to the complexity of product development efforts. The main direct driver of the delegation of R&D activities to subsidiaries was global companies' recognition that the increased technological complexity of products necessitates access to and assembly of globally dispersed knowledge. Global companies have thus become more inclined to offshoring also some relatively advanced R&D activities.

Greening the manufacturing processes and upgrading

One of the most frequent greening related developments identified by our review, was the implementation of formal programmes that address process efficiency 'from a carbon perspective'. Several companies set up formal medium and long-term targets for reducing and/or recycling selected material inputs, reducing CO_2 emission and saving energy. The implementation of these strategic plans was usually related to acquiring environmental management (ISO 14001) and/or energy management (ISO 50001)[11] certification. They were often accompanied by the surveyed companies' shifting to total productive maintenance and implementing smart and energy/resource efficient technologies.

In these cases sustainability was the explicit purpose of the announced initiatives, and process development, i.e. the formal review, measurement and improvement of processes were *ways to achieve this purpose*. Process development activities were performed by subsidiary engineers, which enhanced the development of local technological capabilities.

In other cases the direction of causality was reversed: process optimisation was the purpose, and greening was the outcome.

Investment in process optimisation was an across-sample commonality. These efforts were communicated as 'greening the manufacturing process'. Over and above 'greenwashing', the continuous development of the production process can, indeed, be related to greening, since process development usually leads to increased eco-efficiency.[12] Process efficiency improvement e.g. in the form of better process scheduling and reduction of idle time is directly related to environmental sustainability improvement, since for most advanced manufacturing technologies, for example, in the case of CNC machines, the power consumption during idle (stand-by) state is almost as much as in production (Dornfeld 2014).

Process efficiency improvement was often the result of implementation of industry 4.0 technologies in the surveyed companies. The continuous reorganisation of the production system and the introduction of cyber-physical solutions have brought about sizeable productivity improvement, and contributed to achieving considerable resource efficiency gains and reductions in energy use. Smart production monitoring and production control solutions, for example, allowed to detect leaks in the compressed air system and thus, save energy.

Consequently, linking process optimisation to greening is far from being arbitrary reasoning.[13] It can be asserted that most investments in process upgrading can be considered as serving also the purpose of greening, even if only part of them have been made with the explicit purpose of environmental sustainability.

By the beginning of the surveyed period, some companies had just completed their transition to radio-frequency identification (RFID)-based e-kanban system:

11 If the energy management of a plant or industrial company is certified as sustainable (ISO 50001), it means the given unit has completed a comprehensive survey of its energy use, has made a commitment to improve its energy performance (energy use and energy procurement) continuously, and documents its progress.

12 One self-evident example is investment in new production equipment. As new equipment embodies technology that is usually more energy efficient than older vintages, investment improves environmental sustainability.

13 Consider the vast amount of the literature about 'lean' being the new 'green' (surveyed by Dües et al. 2013).

an important milestone in both process automation and transition to paperless operation management. RFID technology implementation has beneficial impact on companies' environmental sustainability performance through improved tracking of material and inventories, and through facilitating green supply chain management (Sower et al. 2013). Furthermore, optimised plant logistics, i.e. the reduction of unnecessary material flows reduced overall energy consumption.

The expansion of production often necessitated the construction of new production sites, which permitted manufacturing subsidiaries to shift to new (greener-than-before) technology and to leapfrog to the best available technology solutions.

Examples of leapfrogging

One example is the implementation of a smart coolant management technology at one of the surveyed companies, an automotive original equipment manufacturer. The company uses coolants in machining to reduce heat caused by fast machining and reduce friction by washing away grinding abrasion and metal chips. Until recently, the plant was running central emulsion systems installed in 1996 to supply the machining lines with coolants. The pumps ran continuously, with excess emulsion recirculated back to the central system via a bypass line. At the new plant of the company, inaugurated in 2011, "the bypass line was dismantled and a self-teaching control system was implemented. With the new approach, the plant is able to provide intelligent emulsion supply by taking into account a significant number of operation parameters. For instance, incorporated measurement devices follow the variation of the emulsion pressure in the different systems, while an algorithm adjusts the necessary level of intervention. The system is now able to maintain energy-efficient working processes using the adaptive power control of the emulsion supply pumps. As a result of the project, one of the existing central coolant system pumps could be disabled, allowing power demand to decrease by 270kWh. This allowed the plant to achieve a reduction in electricity consumption of 1,760MWh a year, equal to a cost saving of €184,000, which in turn corresponds to an annual 595-tonne reduction in CO_2 emissions."[14]

Another example (at two other companies) is the implementation of driverless transport systems (instead of continuously running conveyors) that supply assembly line workers with prepared 'shopping baskets' containing the parts and components to be assembled, arriving at the line in sequence with the tasks to be performed.

Altogether, greening and process upgrading have proved to be strongly interwoven. Moreover, we found that upgrading was not confined to production capabilities: greening-driven process development was accompanied also by the accumulation of local technological capabilities, since it necessitated indigenous research and technology development by the subsidiaries in question.

14 Source: Fluid thinking in machining. *Automotive Manufacturing Solutions,* 03 June, 2015. Available at: http://www.automotivemanufacturingsolutions.com/technology/fluid-thinking.

For example, subsidiary engineers have optimised processes through virtual engineering, relying on smart visualisation solutions (on the digital representation of factory layout). Virtual technologies facilitated the optimisation of logistics flows and engineers could experiment with alternative technological solutions. Absorbing and mastering virtualisation and other advanced manufacturing and decision support technologies necessitated, however, substantial technological learning. Conversely, these solutions opened up new opportunities for subsidiaries to take up sophisticated research assignments.

Greening and functional upgrading

As pointed out earlier, when global companies engage into a greening-oriented transformation of their business practices, they need to reorganise corporate routines in a variety of business functions. Environmental strategies are successful, where success is defined, in line with the approach of Porter-hypothesis, as a win-win situation, if they are integrated in the broader context of firms' competitive strategies. *Integrated* environmental sustainability strategies will thus influence the mix and the content of activities across the whole corporation. Accordingly, they are expected to contribute to manufacturing subsidiaries' functional upgrading, to their take-up of additional, more knowledge-intensive and higher value generating business functions.

When reviewing the information collected in our database, we paid special attention to allusions to subsidiaries' environmental sustainability related functional upgrading, on the assumption that this kind of functional upgrading is strongly related to the upgrading of their technological capabilities. We hypothesised that the delegation of new tasks and activities to manufacturing subsidiaries in the framework of a greening related reorganisation of business processes will enhance subsidiaries' indigenous technology efforts.

Indeed, our results indicate that greening related new assignments have contributed to the technological learning and capability accumulation in the surveyed subsidiaries.

Our survey identified a number of greening-related new tasks and activities that qualify as functional upgrading, and necessitate new skills and capabilities. Examples include

(a) Monitoring a number of environmental indicators related to the production activity: gathering and analysing environment related data;
(b) Performing environmental and energy audits to identify potential for waste reduction and energy saving. Defining and implementing the consequent actions for improvement;

(c) Planning and implementing energy and resource efficient infrastructure upgrading projects at the production site[15];
(d) Shifting to (computer supported) total productive maintenance to improve resource efficiency and reduce waste;
(e) Providing environmental training to employees;
(f) Providing environmental training and consultancy services to users / customers;[16]
(g) Implementing green supplier development programmes, auditing local (regional) suppliers' environmental performance;
(h) Setting up an environmental management system;
(i) Undertaking environmental sustainability related product and process development activities;
(j) Developing green packaging solutions;
(k) Designing for disassembly and reuse or recycling;
(l) Taking up remanufacturing, reconditioning and repair activities;
(m) Greening and upgrading plant logistics.

While the activities listed before (h) could, in principle, all be included under this item, they were listed separately, because environmentally conscious activities have been taken up gradually by the surveyed companies (obviously, not always in the order listed here). Conversely, the last four bundles of activities (i - m) are not directly related to environmental management practices but rather to corporate routines and business functions[17] that have been reorganised as a result of the global companies' adoption of an integrated sustainability strategy. At the same time, they can best exemplify the greening related upgrading of subsidiaries' technological capabilities.

Besides traditional production activities, five companies in the sample are specialised also in remanufacturing, i.e. in restoring used products to a 'like-new' functional state by disassembling, cleaning and rebuilding it, and replacing defective components to ensure it meets or exceeds newly manufactured product standards (Sundin and Brass 2005). According to interviews (Szalavetz 2016),

15 Investment in the greening of the factory infrastructure was a common sustainability-oriented initiative at the surveyed subsidiaries. Examples include the installation of renewable energy solutions, such as solar panels, or heat pumps to recover waste heat. One subsidiary opted for switching the heating system to geothermal energy. Others implemented energy-saving lighting systems, and/or upgraded the insulation of production facilities and of offices. Others, again, implemented smart air-conditioning and lighting systems that save energy.

16 The sales channel of dominant majority of the sample companies was intra-firm. There were a couple of companies, however, specialised in designing and implementing complex systems, and delivering them to domestic or global customers. The activity mix of these companies included also provision of environmental consultancy services to customers.

17 Activities (i, j and k) also qualify as product development and product upgrading.

the incorporation of remanufacturing in the business models of global companies has also contributed to the functional upgrading of their Hungarian subsidiaries. Remanufacturing activities are often located to low-cost production facilities, because of their relatively high labour-intensity, and also because remanufactured products are lower-cost alternatives to traditional new products.[18] However, since the knowledge-intensity of remanufacturing – an activity at the intersection of production and services activities (Opresnik and Taisch 2015) that is characterised by relatively low level of automation, higher uncertainties about quality, lack of established standards and small batch sizes – is higher than that of average production activities, specialisation in this activity requires the accumulation of the related problem-solving, testing and technological innovation capabilities by the subsidiaries in question.

Turning our attention now to plant logistics, our survey results indicate that the quest for optimisation prompted significant research and development efforts by the surveyed subsidiaries.

Logistics related R&D was carried out in collaboration with researchers of local universities and of specialised services providers. The surveyed companies have mostly sponsored R&D undertakings envisaging solution provision to their specific production logistics problems (e.g. modelling material flows, optimising plant layout to reduce energy use; implementing simulation-based evaluation and optimisation of production logistics systems). Sometimes they also supported close-to-basic-research undertakings (e.g. use of artificial intelligence methods for controlling warehouse management issues, developing path planning and navigation algorithms for coordinating the fleet of automated guided vehicles in automated warehouses).

Conclusions

Drawing on a database of observations on greening related technology upgrading, technology development and functional upgrading at Hungarian manufacturing subsidiaries, this paper investigated whether greening in global companies can enhance the upgrading of manufacturing subsidiaries' technological and R&D capabilities.

A variety of mechanisms and channels was identified through which greening in global companies entails the upgrading of manufacturing subsidiaries in general, and of their technological and R&D capabilities, in particular.

18 Chen and Chang (2012) show that hybrid business models that include both production and the remanufacturing of end-of-use products can outperform their manufacturing-only counterparts if non-negligible part of the overall demand is characterised by relatively high price sensitivity and/or if remanufacturing cost is low (this latter factor is important from the perspective of the surveyed subsidiaries).

Greening was found to be closely related to each of the upgrading categories, detailed in Humphrey and Schmitz's (2002) taxonomy of upgrading. Greening was closely associated also with subsidiary-level research, development and innovation activities: with product and process development related basic and applied research.

We found that greening has further increased the technological complexity of activities and thus, enhanced specialisation within global companies' overall R&D function. Altogether, greening intensified the organisational decomposition of innovation in global companies, prompting strategy realignment. The organisation of corporate R&D in global R&D teams (Von Zedtwitz et al. 2004) and the willingness of corporate headquarters to delegate partial R&D tasks among others to manufacturing subsidiaries have fostered manufacturing subsidiary scientists' and technicians' learning and capability accumulation.

Further, greening related changes in corporate routines opened up opportunities for manufacturing subsidiaries to take up (partial) responsibility for new, sophisticated business functions and activities. Some of the new responsibilities required subsidiaries' indigenous technology efforts.

Our results extend the Porter-hypothesis by putting it in the perspective of headquarter–subsidiary relations. We found that the win-win situation posited by the Porter-hypothesis applies not only to global value chain orchestrators. Lead firms' manufacturing subsidiaries also benefit from their owners' efforts to shift to greener products and to cleaner practices: these developments open up upgrading opportunities for them.

A key managerial implication of our findings is that proactive, entrepreneurial subsidiary behaviour (Birkinshaw 1996; Birkinshaw and Hood 1998) is timelier than ever. The greening related accumulation of specialised capabilities in manufacturing subsidiaries can more effectively influence the headquarters' resource and charter allocation decisions than subsidiaries' previous efforts to gain R&D assignments. Subsidiary managers striving to improve the competitive position of their units within the organisation of their global owners should identify and grab new, greening-driven opportunities for R&D networking both within the global company and externally (establish backward R&D linkages locally).

This research has a number of limitations. One limitation is the biased sample selection, as we have selected companies that had disclosed information about their successful environmental practices. These companies are not representative of the whole population of local manufacturing firms, not even of firms operating in the selected industries. Furthermore, in line with Hart (1995) it needs to be reiterated here that environmental management and innovation in environmental technologies are difficult to separate from firms' other activities. As argued earlier, firms tend to attach a green label to any activity and achievement they consider worth being disclosed. In this vein, in a dominant majority of the cases, subsidiary upgrading is considered as being related at the same time to greening, which might not always be the case.

References

Albertini, E. (2013): Does environmental management improve financial performance? A meta-analytical review. *Organization & Environment*, 26, 4, 431–457.

Bartlett, C.A./Ghoshal, S. (1989): *Managing across borders. The transnational solution.* Boston: Harvard Business School Press

Birkinshaw J. (1996): How multinational subsidiary mandates are gained and lost. *Journal of International Business Studies*, 27, 3, 467–495.

Birkinshaw J./Hood N. (1998): Multinational subsidiary evolution: Capability and charter change in foreign-owned subsidiary companies. *Academy of Management Review*, 23, 4, 773–795.

Castellani, D./Pieri, F. (2013): R&D offshoring and the productivity growth of European regions. *Research Policy*, 42, 9, 1581–1594.

Chen, J. M./Chang, C. I. (2012): The economics of hybrid manufacturing systems in a closed-loop supply chain. *NETNOMICS: Economic Research and Electronic Networking*, 13, 2, 79–91.

Chesbrough, H.W. (2003): *Open innovation: The new imperative for creating and profiting from technology*. Boston: Harvard Business Press.

Clarkson, P.M./Li, Y., Richardson, G.D./Vasvari, F.P. (2011): Does it really pay to be green? Determinants and consequences of proactive environmental strategies. *Journal of Accounting and Public Policy*, 30, 2, 122–144.

Dornfeld, D. A. (2014): Moving towards green and sustainable manufacturing. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 1, 1, 63-66.

Dunning, J. H./Lundan, S. M. (2009): The internationalization of corporate R&D: a review of the evidence and some policy implications for home countries. *Review of Policy Research*, 26, 1-2, 13–33.

Dües, C. M./Tan, K.H./Lim, M. (2013): Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. *Journal of Cleaner Production*, 40, 93-100.

Eisenhardt, K.M./Martin, J.A. (2000): Dynamic capabilities: what are they?. *Strategic Management Journal*, 21, 10-11, 1105–1121.

Elkington, J. (1997): Cannibals with forks: The triple bottom line of 21st century business. Oxford: Capstone Publishing.

Gereffi, G./Fernandez-Stark, K. (2011): *Global value chain analysis: a primer.* Center on Globalization, Governance & Competitiveness (CGGC), Duke University, NC, USA. Available at: http://www.cggc.duke.edu/pdfs/2011-05-31_GVC_analysis_a_primer.pdf

Glaser, B.G./Strauss, A.L. (1967): *Discovery of Grounded Theory*. Mill Valley, CA: Sociology Press

Hart, S. L. (1995): A natural-resource-based view of the firm. *Academy of Management Review*, 20, 4, 986–1014.

Havas, A./Izsak, K./Markianidou, P./Radosevic, S. (2015): Comparative analysis of policy-mixes of research and innovation policies in Central and Eastern European countries. GRINCOH Working Paper Series, Serie 3: Knowledge, Innovation, Technology, Paper No. 3.12. Available at SSRN: http://ssrn.com/abstract=2577569

Humphrey, J./Schmitz, H. (2002): How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies*, 36, 9, 1017-1027.

Jarillo, J.C./Martínez, J.I. (1990): Different roles for subsidiaries: The case of multinational corporations in Spain. *Strategic Management Journal*, 11, 7, 501–512.

Kalotay, K. (2005): Central European Research and Development Platform for Investors. *Journal of World Investment & Trade*, 6, 6, 995–1009.

Kravtsova, V./Radosevic, S. (2012): Are systems of innovation in Eastern Europe efficient? *Economic Systems*, 36, 1, 109-126.

Lema, R./Quadros, R./Schmitz, H. (2015): Reorganising global value chains and building innovation capabilities in Brazil and India. *Research Policy*, 44, 7, 1376–1386.

López-Gamero, M.D./Molina-Azorín, J.F. (2015): Environmental Management and Firm Competitiveness: The Joint Analysis of External and Internal Elements. *Long Range Planning*, in press, doi:10.1016/j.lrp.2015.12.002

Majcen, B./Radosevic, S./Rojec, M. (2009): Nature and determinants of productivity growth of foreign subsidiaries in Central and East European countries. *Economic Systems*, 33, 2, 168–184.

Michelon, G./Boesso, G./Kumar, K. (2013): Examining the link between strategic corporate social responsibility and company performance: an analysis of the best corporate citizens. *Corporate Social Responsibility and Environmental Management*, 20, 2, 81–94.

Moncada-Paternò-Castello, P./Vivarelli, M./Voigt, P. (2011): Drivers and impacts in the globalization of corporate R&D: an introduction based on the European experience. *Industrial and Corporate Change*, 20, 2, 585–603.

Mytelka, L.K./Smith, K. (2002): Policy learning and innovation theory: an interactive and co-evolving process. *Research Policy*, 31, 8, 1467–1479.

Nidumolu, R., Prahalad, C. K., & Rangaswami, M. R. (2009): Why sustainability is now the key driver of innovation. *Harvard Business Review*, 87, 9, 56-64.

Opresnik, D./Taisch, M. (2015): The manufacturer's value chain as a service-the case of remanufacturing. *Journal of Remanufacturing*, 5, 1, 1-23.

Orsato, R.J. (2009): *Sustainability strategies.* Palgrave Macmillan

Palmer, K./Oates, W.E./Portney, P.R. (1995): Tightening environmental standards: The benefit-cost or the no-cost paradigm? *Journal of Economic Perspectives*, 9, 4, 119–132.

Patton M.Q. (1990): Qualitative evaluation and research methods. Newbury Park, CA: SAGE Publications.

Porter, M.E./Van der Linde, C. (1995): Toward a new conception of the environment–competitiveness relationship. *Journal of Economic Perspectives*, 9, 4, 97–118.

Radosevic, S./Yoruk, E. (2015): A New Metrics of Technology Upgrading: The Central and East European Countries in a Comparative Perspective. Mimeo, Available at: https://www.researchgate.net/profile/Slavo_Radosevic/publication/284423397_A_NEW_METRICS_OF_TECHNOLOGY_UPGRADING_THE_CENTRAL_AND_EAST_EUROPEAN_COUNTRIES_IN_A_COMPARATIVE_PERSPECTIVE/links/5652f73908aefe619b18e676.pdf

Rugraff, E. (2014): *Foreign direct R&D investment in Central Europe: where do we stand?* Bureau d'Economie Théorique et Appliquée, Documents de Travail No. 2014-22, Strasbourg. Available at: http://www.beta-umr7522.fr/productions/publications/2014/2014-22.pdf

Sass, M./Szalavetz, A. (2014): R&D-based integration and upgrading in Hungary. *Acta Oeconomica*, 64, Supplement 1, 153–180.

Schmitz, H./Strambach, S. (2009): The organisational decomposition of innovation and global distribution of innovative activities: insights and research agenda. *International Journal of Technological Learning, Innovation and Development*, 2, 4, 231–249.

Sower, V./Bellah, J./Zelbst, P./Green, K. (2013): RFID and Environmental Sustainability: An Unlikely Partnership. Available at: http://www.rfidjournal.com/articles/view?11008/

Stephan, J. (2013): *The Technological Role of Inward Foreign Direct Investment in Central East Europe*. New York: Palgrave Macmillan.

Suddaby, R. (2006): From the editors: What grounded theory is not. *Academy of Management Journal*, 49, 4, 633–642.

Sundin, E./Bras, B. (2005): Making functional sales environmentally and economically beneficial through product remanufacturing. *Journal of Cleaner Production*, 13, 9, 913-925.

Szalavetz, A. (2016): Global Crisis and Upgrading of MNCs' Manufacturing Subsidiaries: A Case Study of Hungary. *Central European Business Review*, 5, 1, 37–44.

Teece, D.J./Pisano, G./Shuen, A. (1997): Dynamic capabilities and strategic management. *Strategic Management Journal,* 18, 7, 509–533.

UNCTAD (2005): World Investment Report. Transnational corporations and the internationalization of R&D. Geneva: UNCTAD

Von Zedtwitz, M./Gassmann, O./Boutellier, R. (2004): Organizing global R&D: challenges and dilemmas. *Journal of International Management*, 10, 1, 21–49.

Walley, N./Whitehead, B. (1994): It is not easy being green. *Harvard Business Review,* 72, 3, 46–52.

Yin, R.K. (2003): *Case study research: Design and methods,* Sage publications: Thousand Oaks, CA.

Annex: Sample companies

Legrand Zrt.	Grundfos Magyarország Gyártó Kft.	SMR Automotive Mirror Technology Bt.	BPW Hungária Kft.	Delphi Hungary Kft.
Audi Hungária Motor Kft.	Linamar Hungary Nyrt.	Nemak Győr Kft.	Knorr Bremse Hungária Kft.	ThyssenKrupp Presta Kft.
Mercedes-Benz Manufacturing Hungary	GE Hungary (GE Power and Water)	Robert Bosch Power Tools Kft.	Siemens Zrt.	BorgWarner Oroszlány Kft.
Schaeffler Group Luk Savaria Kft.	Valeo Auto-Electric Magyarország Kft.	Opel Szentgotthárd Kft.	Remy Automotive Hungary Kft.	Phoenix Mecano Kecskemét Kft.
Electrolux Lehel Kft.	Claas Hungária Kft.	Denso Kft.	Continental Automotive Hungary Kft.	Kuka Robotics Hungária Kft.