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Servitization: Disentangling the impact of service business model innovation on the performance of manufacturing firms

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Abstract

As manufacturing businesses compete in an ever more competitive and global economy where products get easily commoditized, innovating by adding services to the core product offering has become a highly popular strategy. Contrary to the expected strategic and economic benefits, recent findings warn of implementation hurdles that lead to a potential performance decline, the so-called ‘service paradox’. In this paper, we analyze this paradox by disentangling the value creation and value appropriation processes of 44 subsidiaries of a multinational manufacturing firm that has been successfully developing an after-sales service business. Empirical analysis reveals that products and services act as revenue complements, thereby managing to transcend the inherent substitution of products by services. In addition, more labor-intensive services, which imply higher levels of customer proximity, further enhance product sales. Finally, our findings reveal a positive yet non-linear relationship between profitability and the scale of service activities: while initial levels of servicing result in an increase in profitability, a period of relative decline is observed before the positive relationship between the scale of service activities and profitability unfolds again. While these findings suggest the presence of initial short-term gains, they also indicate the presence of a ‘profitability’ hurdle; sustainable (profitable) growth seems feasible only to the extent that investments in service capabilities are translated into economies of scale. In helping to clarify the performance implications of service innovations, our findings suggest pathways to sustainable growth for manufacturing firms.

Keywords: Servitization, Open service innovation, Business model, Service paradox
1. Introduction

Increasingly, durable goods manufacturers are opting to innovate their offerings by providing services that accompany their existing products throughout the life cycle. A well-known representative of this innovation trend, typically known under the label of open service innovation (Chesbrough, 2011) and servitization (Neely, 2008), is Rolls-Royce Aerospace. Rolls Royce has evolved from a pure manufacturer of aero engines to a product-service provider of aerospace solutions. Their service innovations began with the provision of spare parts, developed into maintenance and overhaul services, and then evolved into the ‘power by the hour’ business model where customers, through the TotalCare package, purchase the capability the engines deliver whilst Rolls Royce retains responsibility for maintenance and risk. Other examples of manufacturing firms engaged in diverse forms of service innovation include ABB, Caterpillar, GE, IBM, and Xerox (Cohen et al., 2006). Indeed, recent figures suggest that, globally, over a third of large manufacturing firms offer services, with the proportion increasing to almost 60% in Western economies (Neely, 2008). In addition, for an average ‘servitizing’ manufacturer, the share of service sales has reached 31% (Fang et al., 2008), suggesting that service innovation is not only prevalent but has become an important factor in performance.

While management, operations and innovation of service providers have been recognized as emerging areas of operations management research (Heineke and Davis, 2007; Machuca et al., 2007) the phenomenon of product firms diversifying into services has received relatively less attention in highly reputed operations management journals. Indeed, while studies (Cohen and Whang, 1997; Guajardo et al., 2011; Kim et al., 2007; Kim et al., 2010) demonstrate the benefits of servicing for product performance and customer value, while the impact of service innovation on the performance of a manufacturer turned product-service provider is less well understood. On the one hand, anecdotal evidence suggests strategic and economic potential (Agrawal et al., 2012; Chesbrough, 2011; Wise and Baumgartner, 1999), while available case study evidence e.g. Gebauer et al. (2005) and Oliva and Kallenberg (2003) indicates that manufacturers face some
worrisome challenges in formulating and implementing a service-oriented business model. These hurdles seem to result from a strong product-oriented cultural and cognitive heritage of manufacturing firms and from intrinsic differences in managing product and service activities. Firms optimized to deliver products efficiently find it hard to adopt ‘service values’, such as heterogeneity, which are needed for managing services (Bowen et al., 1989; Gebauer, 2009; Gebauer et al., 2005; Tuli et al., 2007). Furthermore, recent quantitative studies analyzing the impact of servitization on financial performance also show mixed results (Fang et al., 2008; Neely, 2008), underscoring the need for a better understanding of service innovation and, in particular, its value creation and appropriation.

Our study aims to contribute by disentangling the processes of value creation and appropriation that product-service firms face; translating them into a set of hypotheses and testing them on 44 subsidiaries of a servitizing manufacturer, Atlas Copco Compressor Technique, the largest business of Atlas Copco Group\(^1\), over the 2001-2007 period. Atlas Copco Compressor Technique, which we will onwards refer to as Atlas Copco, is a global manufacturer of durable industrial equipment, with 2007 revenues exceeding $4.4 billion and a global presence accomplished through a network of country sales-and-service subsidiaries. Its industrial equipment offering, in effect, provides investment products for its clients and, hence, offers significant potential for the provision of related services. With more than 130 years of experience in product innovation, Atlas Copco has, in recent decades, extended its innovation trajectory into services. Starting from the provision of spare parts, it gradually expanded its offering into a service portfolio that encompasses various maintenance services as well as total solution service contracts. Consequently, its innovation into services has led to the development of a business model (Amit and Zott, 2001; Spring and Araujo, 2009) characterized by a variety of services related to the product offering.

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\(^1\) Atlas Copco is an industrial group with world-leading positions in compressors, expanders and air treatment systems, construction and mining equipment, power tools and assembly systems. With innovative products and services, Atlas Copco delivers solutions for sustainable productivity. The company was founded in 1873, is based in Stockholm, Sweden, and has a global reach spanning more than 170 countries. In 2011, Atlas Copco had 37 500 employees and revenues of BSEK 81 (BEUR 9). Learn more at [www.atlascopco.com](http://www.atlascopco.com).
Our study reveals the nature of the value creation and value appropriation processes and, hence, illustrates how firms can achieve revenue growth and profitability. First, we find that Atlas Copco was able to promote product and service activities that acted as revenue complements, resulting in an overall spiral of revenue growth. Not only do product revenues positively affect service revenue, service revenues positively impact product revenues despite inherent substitution effects (services prolong the lifetime of existing products, thereby postponing product replacement). Moreover, the impact of services on product sales is even more pronounced when deploying labor-intensive services, which imply customer proximity. In terms of profitability, our findings underscore an overall positive effect of servitizing while, at the same time, signaling a decrease in profitability for medium-scale levels. More specifically, while initial levels of servicing result in an increase in profitability, scaling up service activities results in a temporary decrease in profitability. Only when a certain critical mass in terms of service activities is obtained, does a positive relationship with profitability re-emerge.

The remainder of the paper is structured as follows. First, we provide an overview of the relevant literature and then present the theoretical development of the research model. After describing the research context, the data and the empirical models, we present the results obtained from empirical tests of the research model. We end with a conclusion and a discussion of the managerial implications, the shortcomings of the study, and fruitful directions for future research.

2. Literature review

2.1 Research evolution: towards a relational perspective on service innovation

Service research has been a growing area of operations management research (Chase and Apte, 2007; Heineke and Davis, 2007). Researchers have been particularly interested in the ‘pure’ service sectors such as retail and e-retail (Boyer and Hult, 2005; Davis-Sramek et al., 2008; Rabinovich et al., 2008; Rosenzweig et al., 2011), healthcare (Hyer et al., 2009), professional services (Goodale et al.,
Servitization: Disentangling the impact of service business model innovation on the performance of manufacturing firms

2008) and hospitality (Kimes and Thompson, 2005). Most of the studies addressed research questions on the intersection of operations and marketing management, including customer loyalty, service quality and productivity, service supply chain strategies, service operations design, planning, and the impact of these characteristics on firm performance (Machuca et al., 2007).

The importance of the trend among manufacturing firms to move into services has been recognized in the marketing literature in recent decades. ‘Servitization’ was first coined by (Vandermerwe and Rada, 1988) to delineate the tendency of manufacturing firms to “offer fuller market packages or ‘bundles’ of customer-focused combinations of goods, services, support, self-service, and knowledge”. More recently, (Neely, 2008) defined servitization as the innovation of an organization’s capabilities and processes so that it can better create mutual value through a shift from selling product to selling product–service systems. In line with Neely (2008), Chesbrough, (2011) suggests that companies pursue open service innovation in order to extend their innovative efforts into services, thereby better satisfying customer needs and escaping the commoditization trap.

The first underpinnings of research on servitization come from an understanding of the characteristics of effective warranty provision (Balachander, 2001; Balachandran and Radhakrishnan, 2005; Jack and Murthy, 2001, 2007; Patankar and Mitra, 1995). Of particular interest are the studies that examine effective ways to (commercially) engage in extended warranty and after-sales service. For example, Cohen et al. (2006) develop a product life-cycle model that studies a set of strategic choices manufacturers face as they design the joint product/service bundle for a product, which may require maintenance and repair support after its sale. More recent operations literature moves from a provider’s perspective on warranties to examine the nature of the relationship between the provider and the customer. In particular, the implications for contracting, the incentives on product performance, and the effectiveness of the contract (Toffel, 2008). Kim et al. (2007) study the effectiveness of performance-based contracting versus traditional cost-based or fixed-price contracts in terms of equipment availability. In a
subsequent study by Kim et al. (2010), additional differentiations between two types of performance-based contracts are analyzed. Further, Guajardo et al. (2011) empirically investigate the impact of different forms of servitization on product reliability, revealing a positive and significant effect of performance incentives on product reliability, created by performance-based contracts. Finally, Roels et al. (2010) relate the effectiveness of a contract to the degree of customer involvement.

Service innovation has also received considerable attention in studies of environmental economics alongside related phenomena such as leasing (Agrawal et al., 2012). The World Business Council for Sustainable Development identified ‘service extension’ as one of the four important elements in eco-efficiency (Mont, 2004a; WBCSD, 1996). The addition of services such as maintenance, upgrading and remanufacturing prolongs product life and so reduces product turnover (Mont, 2004b). For example, White et al. (1999) cite the case of Electrolux A.B, which conducted a life-cycle analysis of a servitized floor cleaning machine; it found that life-cycle services (maintenance and optimal utilization) reduced in-use (environmental) impacts as well as material and energy consumption in the product system via life extension, part reuse and recycling. Furthermore, a simulation model developed by Brouillat (2009) demonstrates that services such as maintenance, repair, reconditioning, and technological upgrading result in an extension of the product life cycle and, hence, reduce the overall ecological impact of product use.

2.2 Recognizing the gap: a manufacturer’s performance implications of servitization

Warranty literature revealed the interdependencies between products and services, environmental economics explained the over-the-life process of value creation of the products, while literature on contracts began to map out the organizational factors (e.g. adequate incentive schemes) necessary to manage the value appropriation process and avoid the conflicts of interest between service
provider and customer. While this literature has been very instructive in providing a dyadic perspective on value creation and appropriation, the implications for the servitizing manufacturer remain poorly understood.

The two studies that assessed the impact of servitization on the economic performance in a more quantitative manner display mixed results. Fang et al. (2008) analyzed the link between the degree of servitization and firm value, measured by Tobin’s Q. Results indicate that, once a critical level of service scale has been reached, servicing has a positive influence on the overall value of the firm. This effect is, however, highly contingent on the industry; for firms operating in mature and/or turbulent industries, adding services to the core product is effective, whilst firms operating in other conditions may decrease their firm’s value by transitioning to services. In addition, the transition to services is effective for firms that offer services related to their core product business, whilst services that are unrelated to the core product offering seem to decrease firm value. At the same time, Neely (2008) shows that the decision to servitize has a positive impact on profitability, while the extent of servitization has a negative effect on profitability. Furthermore, the findings reveal that considerably more servitized firms have declared bankruptcy than might be expected. This latter observation suggests that product firms may be engaging in service activities too late – i.e. when already in trouble – or in an ineffective way.

Case-study research has identified obstacles including lack of attention from top management, deficiencies in organizational design and information technology, the lack of an appropriate culture, and insufficient capabilities for service management (Gebauer et al., 2008; Neu and Brown, 2008; Oliva and Kallenberg, 2003). In particular, the literature points to a cultural and cognitive bias against services and service-specific values, such as heterogeneity and flexibility, since these values contradict traditional manufacturing goals and practices such as standardization and efficiency (Bowen et al., 1989). This cognitive bias towards product-focused practices is present at all levels of the organization but, especially, in the selling process; salesmen who are accustomed to selling tangible and ‘pricey’ products find it hard to sell intangible services (Gebauer et al.,
2005; Mathieu, 2001; Oliva and Kallenberg, 2003). Some manufacturers seek a solution to these challenges by outsourcing services. Yet this does not come without difficulties, in particular with regard to maintaining customer relationships. “You’re placing one of your most valuable assets – customer relationships – in a stranger’s hands,” points out Ton Heijmen, senior adviser to The Conference Board (New York City) on offshoring and outsourcing [of services] ((Johnson, 2007), p.1).

So, while studies demonstrate that servitization has a positive impact on the product and creates value on the level of the dyad, its impact on the product-service provider is subject to debate. Moreover, the literature points to worrisome challenges with regard to servitization that may result in a decline of the overall performance, the so-called ‘service paradox’. The questions of value creation and value capture are highly complex and remain somewhat obscure, mainly because value creation transcends the boundaries of a single firm. To get past this, we first explicate the process of value dynamics starting from the logic of value creation/appropriation from the customer’s perspective and translating it into the manufacturer’s perspective.

3. Theoretical development of the research model

From a customer’s perspective, servitization represents a ‘make or buy’ decision, where a customer considers whether to continue to service products in-house or to outsource services to either an independent service provider or the product manufacturer who offers relevant services (see Haywood-Farmer et al. (2000) for a case study that illustrates this dilemma). In line with arguments advanced by the theory of the multiproduct firm (Teece, 1980, 1982), a customer will opt to outsource services to the product-service provider if the latter is able to provide them in a more cost-effective way compared to the other two options (self-service and outsourcing to an independent service provider). The manufacturer’s ability to achieve such an advantageous proposition will depend on the presence of
economies of scale in services, and economies of scope in products and services (Akan et al., 2011; Chase, 1981; Panzar and Willig, 1981).

First, economies of scale arise as the manufacturer provides services for its entire installed base, while a single customer would need to invest in service resources and capabilities for a much smaller number of machines. It is worth noting that an independent service provider could benefit from the same advantage. On the other hand, economies of scope achieved by leveraging technological and marketing capabilities across products and services (Gebauer et al., 2008) can only be attained by the product-service provider. For example, manufacturing firms can capitalize on the existing CRM information and sales channel infrastructure developed for traditional product activities (Quinn and Gagnon, 1986), implying that transaction costs are reduced by spreading them over products and services (Williamson, 1975). Finally, going beyond the mere price of the service, sourcing products and services from one and the same supplier can enhance purchasing productivity and reduce the information asymmetries of customers (Nayyar, 1993). Furthermore, customers may experience complementarities in use such as interoperability, which have been studied as an important source of competitive advantage in IT markets (Lee et al., 2010; Nambisan, 2002; Tanriverdi and Lee, 2008; Tanriverdi and Venkatraman, 2005).

Combined, arguments on economies of scale and scope strongly suggest that customers will be inclined to purchase related, life-cycle services from the product manufacturer. The terms ‘related’ and ‘life cycle’ imply that the service offering the manufacturer devises is related to the product offering and, hence, the manufacturer’s competence base. This logic results in the following hypothesis:

**Hypothesis 1a.** An increase in product sales will result in an increase in service sales.

While a thriving product business clearly creates opportunities for service business development, the impact of services on the development of the product business is less clear. Environmental economics literature (Brouillat, 2009; Mont, 2004a;
WBCSD, 1996; White et al., 1999) suggests that the major source of the value gain from servitization from the perspective of customers (and society at large) comes from a lowering of the overall life-cycle costs and the cost of product functioning. Some types of service – such as repair, maintenance, and even complete overhauls – do so by prolonging the lifetime of existing products, thereby postponing sales of replacement products. As the life of an existing product is extended, the replacement – and therefore sale – of a new product is postponed. This means that services may, to a certain extent, substitute products (Siggelkow, 2002).

On the other hand, services may have a number of positive effects on product sales. To start with, the regular exchange of disposable parts will prevent breaking and malfunction of the product, leaving the customer with a more positive experience of product quality and brand loyalty. Customers who are satisfied with the services delivered will be more likely to purchase product replacements from the same manufacturer, thereby increasing the product renewal rate (Heskett et al., 2008). Additional product sales may accrue from replacing products previously provided by competitors with the product-service provider’s products. Furthermore, by engaging in service activities, the manufacturer becomes much better informed about the customer’s broader needs: this information can be instrumental in enlarging the scope of the product offering, resulting in additional product sales. This set of arguments points to potential for services to act as a complement to products, offsetting the substitution effect; subsequently, higher service revenues will result in higher product revenues.

**Hypothesis 1b.** An increase in service sales will result in an increase in product sales.

While, overall, service sales could have a positive effect on product sales, practice suggests that labor-intensive service activities, such as maintenance and repairs, imply greater face-to-face customer interaction and, hence, lead to customer intimacy and more detailed information about customer needs. Product-service providers, who shift their service mix to services characterized by higher
engagement in customer operations and higher responsibility for overall customer performance, are likely to learn more about customers (e.g. regular customer encounters) and the product (e.g. harvesting information on product functioning), which may intensify the positive feedback from services to products. Hence, the greater the service contact through labor-intensive services or ‘customer proximity’, the more knowledge is generated and the greater the opportunities created to strengthen customer relationships. In addition, field service activities provide valuable information feedback on product development and engineering work. These arguments lead us to the following proposition:

**Hypothesis 1c.** An increase in ‘customer proximity’, measured by the share of labor-intensive services, results in an increase in product sales.

To summarize, Hypotheses 1a and b suggest a reciprocal, positive relationship between products and service activities: an increase in product revenues results in the increase in service revenues and vice versa. In addition, Hypothesis 1c argues that an increase in the share of labor-intensive services of the overall service sales mix will result in additional growth of product sales.

Nevertheless, the question remains whether firms can manage to appropriate value in terms of the overall profitability (the overall profit margin) of the product-service business. This question is particularly apposite given that recent findings signal a ‘service paradox’, or an inability of manufacturers to retain value from service business (Bowen et al., 1989; Gebauer et al., 2005; Oliva and Kallenberg, 2003). As the literature suggests, a manufacturer needs to invest in service-specific resources and capabilities in order to create a sustainable competitive advantage in services. The necessary investments range from ‘operational’ service capabilities and resources such as service delivery, service sales skills (Barney, 1991; Peteraf, 1993), and service information systems and tools (Penttinen and Palmer, 2007), to more dynamic capabilities enabling service deployment (Teece et al., 1997) such as service management and top management capabilities to reorganize a manufacturing firm from pure product provider to product-service provider. Sizeable investments in services could
initially result in lower profit margins (Gebauer et al., 2005; Quinn and Gagnon, 1986).

On the other hand, the accumulation of service activities will lead to economies of scale in services, which may prompt more cost-efficient service delivery. Moreover, to the extent that service sales lead to an increase in product sales, additional economies of scale on the product side may occur as well. Thus, one can expect that higher margins for the product-service business are feasible (Quinn and Gagnon, 1986), in particular, when a certain scale in terms of service activities is being realized. The curvilinear relationship between the size of service activities and performance has been already probed by Fang et al. (2008). Their study shows a curvilinear relationship between the extent of service provision and Tobin’s Q, where lower levels of servicing result in a value decrease, higher levels of servicing result in a value increase. In line with extant literature and theorizing on the impact of investments and economies of scale, we advance the following hypothesis:

**Hypothesis 2:** The relationship between the scale of service activities and profit margin is curvilinear: while initial, modest, levels of service activity will affect the level of profitability negatively, obtaining scale in terms of service activities will positively affect profitability.

4. Research methodology

4.1 Research design

To test the hypotheses, we collected data from the national sales-and-service subsidiaries of a large multinational equipment manufacturer, Atlas Copco. The firm under study achieved consolidated annual revenues in excess of €3.2 billion ($4.4 billion), with the service business amounting to approximately 40% of the revenues in 2007. The firm’s product offering encompasses an assortment of equipment types used for powering a diverse set of factory machines in a variety
of industrial applications. For example, a compressor produced by Atlas Copco or its competitors is necessary to power machines used to produce plastic bottles, textile or automobiles. For the majority of customers – mostly industrial manufacturers themselves – these products represent investment goods priced in excess of €50,000 and even €100,000 that will form part of their production unit for years to come. Over time, a given country subsidiary may have sold tens of thousands of equipment units to thousands of clients. Service portfolio opportunities range from spare parts and ad-hoc repairs to maintenance agreements with varying degrees of coverage (e.g. from preventative maintenance to maintenance plans with wide coverage of operational and financial risks). In recent years, Atlas Copco has concentrated on promoting a service offering that also covers related machinery, aiming to improve reliability and reduce energy costs for the entire functional group of products.

Atlas Copco’s product sales and provision of services are effectuated through the network of country subsidiaries. Each subsidiary is charged with establishing and maintaining market presence with a full spectrum of product and service offerings in a given country. Atlas Copco’s globally diffused network of highly skilled technicians assures high levels of intimacy with its customer base. When it comes to the level of decentralization and subsequent diversity of subsidiaries, it is important to note that, on the one hand, subsidiaries offer homogeneity with respect to the product and service portfolio, brands and pricing while, on the other hand, each subsidiary differs significantly in terms of its organizational structure, local practices, management style, and deployment of its business model. Offering the same product portfolio with a similar price base enables Atlas Copco to achieve a global footprint and maintain fair competition in different markets (a Atlas Copco subsidiary from one country can sell in another subsidiary’s country market) while, at the same time, the diversity of managerial practices with respect to service business model implementation makes it possible to adjust to different country market environments.
In the Atlas Copco study that took three years to complete, we compiled a dataset on 44 individual country subsidiaries over the 2001-2007 period, which allowed us to test the outlined hypotheses on scarcely understood value creation and appropriation processes of servitization. Each of the 44 subsidiaries has operated in countries that ranged from developed Western European and North American countries to most of the large countries of Asia Pacific and Latin America, as well as some African and Middle Eastern countries. Each of the subsidiaries was present in the country for at least 15 years, well beyond our seven-year observation period. In addition to the fine-grained quantitative data obtained from internal sources, we have also benefited from numerous discussions – at the level of headquarters and sales-and-service subsidiaries – that helped us interpret and give meaning to the collected data (Jick, 1979). “The ability to get closer to theoretical constructs is particularly important in the context of longitudinal research that tries to unravel the underlying dynamics of phenomena that play out over time” (Siggelkow, 2007).

Opting for a longitudinal econometric study on the level of country subsidiaries did pose its challenges, in particular with respect to generalizability. Indeed, the study is based on the variability in managerial practices with respect to service business model implementation and environmental factors while the industry, product portfolio, brand and governance practices of the mother company are shared. At the same time, these disadvantages facilitate testing since they decrease the need for a number of control variables (further discussion on this follows). Also, priority has been given to a longitudinal econometric approach over a survey study set-up as the former can generate inferences on over-time causality that a survey study cannot. Finally, to construct particular servitization variables, we needed to construct measures specific to the product and service portfolio of the given mother company; performing the study across different companies would mean substantially compromising the precision of the measures and the internal validity.
4.2. Models 1 and 2

Hypotheses 1a and 1b argue for a reciprocal relationship between products and services. The installed product base enables the sale of service contracts and additional services in the following year, after the expiry of the obligatory warranty. As soon as servicing starts, services are expected to foster stronger relations with customer and to result in additional purchases and the eventual replacement of the existing products (e.g. a technician comes to the factory and immediately sees opportunities to replace other product units). As Hypothesis 1c argues, this feedback loop is expected to be stronger when the service mix includes more labor-intensive services that require service visits and, hence, result in customer proximity.

The reciprocal relationship between products and services, expressed in Hypotheses 1a and 1b, represents a system of equations with simultaneous causality. The presence of ‘simultaneous’ causality is a common cause of violation of the standard regression analysis assumption pertaining to the absence of correlation between the error terms and the independent variables. This ‘endogenous’ phenomenon can produce biased estimates and may lead to incorrect conclusions (Stock, 2001; Stock and Watson, 2003; Wooldridge, 2002). To treat the endogeneity problem that arises in the case of simultaneous causality, econometricians recommend the use of instrumental variables (Sargan, 1958). In addition to the direct simultaneous causality between Hypotheses 1a and 1b, customer proximity in Hypothesis 1c is also likely to be endogenous to product sales (dependent variable). Customer proximity is measured as a ratio of labor-intensive and total-service sales and, therefore, participates in the simultaneous causality loop between products and services.

An instrumental variables (IVs) approach consists of a system of equations where the (endogenous) independent variable is first ‘regressed’ on another dependent variable – called the ‘instrument’ – which, in large measure, explains the independent variable but is unrelated to the dependent variable of interest (for a detailed overview of the instrumental variable approach and its application in
management research see (Bascle, 2008). An instrument is said to be ‘strong’ or ‘relevant’ when it explains well the independent variable, and it is said to be ‘independent’ or ‘exogenous’ when it is unrelated to the error term and the dependent variable of interest (Staiger and Stock, 1997; Stock et al., 2002; Stock and Yogo, 2004). The search for a strong instrument represents an important study-specific task because the idiosyncratic nature of independent variables implies the absence of an exhaustive theory on appropriate instruments (Levitt, 1997; Wooldridge, 2006).

As product sales and service sales represent endogenous independent variables in the first and second models respectively, they both need instruments that are strong and independent from each other. Having understood that Atlas Copco has a policy that allows cross-border sales of products but not services (e.g. the German subsidiary can sell products in France despite the presence of a French subsidiary), we identified the macroeconomic indicator of country exports as an adequate product-sales instrument. More specifically, country exports indicate the climate in a given country for exports, which will positively influence the subsidiary’s product sales (strength). The climate for export will result in more products being sold and located abroad and, as these products will not be serviced by the same subsidiary, the export climate will have no influence on service sales (independence). In addition, absolute growth of GDP will likely stimulate one-time investment in new products with no visible impact on service activities; hence, we chose this as an additional instrument.

For the same reasons, the macroeconomic indicator of a country’s imports was identified as an adequate instrument of service sales. A subsidiary that is located in a country where there are substantial imports of Atlas Copco products may have the opportunity to service these products and, hence, generate higher service sales (instrument strength), which do not stem from national product sales (in the previous case, the French subsidiary would have greater opportunity to sell services on the products sold by the German subsidiary). In addition, the number of service staff, comprising service technicians, dispatchers, administrators, salesmen and managers, would be a good predictor of service sales, independent
of product sales, considering the labor intensity and the dedicated nature of service activities.

Finally, customer proximity would depend on proximity in the previous year, given that a large proportion of the service contracts will be renewed annually. In addition, the density of the country will be a good predictor of customer proximity as low density reduces the profitability of service contracts (technicians need to be dispersed over a vast area and held in a state of underutilization). For example, to offer servicing of products located in certain areas of Siberia, a technician from the Russian subsidiary in Moscow would be required to spend no less than three days travelling. The shipping of spare parts to be used by local technicians, in addition to the shipping of products, makes more economic sense (independence).

Due to the scarce amount of data and complex nature of interdependencies between products and services, the choice of controls represents a particularly important part of the model design. As all subsidiaries have been operating for 15 years or more prior to the observation period, the subsidiary age was deemed irrelevant. Subsidiaries have also exhibited homogeneity with respect to the product portfolio, brand and high-level pricing strategy (allowing a modest degree of discretion for individual client negotiations). This homogeneity allowed us to perform an analysis controlling with fixed effects for the country-specific and time-invariant factors, such as culture and propensity to pay for services, while relying on a limited number of control variables for time variant factors. In Models 1 and 2, in order to control for the fine differences in product-mix, we constructed an indicator of the product mix that represents the share of small versus large products used in different applications. Furthermore, we captured differences in market development by GDP per capita (e.g. subsidiaries operate in countries ranging from China to Switzerland), while a year dummy variable was used to capture the expected yearly effects of price increases. Table 1 provides an overview of the included variables, while the discussion on the use of fixed effects and year-trend variables will be presented in the following sections.
Model 1 (Hypothesis 1a) and Model 2 (Hypotheses 1b and 1c) are formally represented below, each followed by the instrument models. In all models presented below, \( v_i \) and \( \epsilon_{i,t} \) represent the country dummies and specific residuals, respectively.

\[
M1. \text{service sales}_{i,t} = a_1 + b_1 \times \text{product sales}_{i,t} + c_1 \times \text{gnppercapita}_{i,t} + d_1 \times \text{product portfolio}_{i,t} + f_1 \times \text{year trend}_{i,t} + v_1 + \epsilon_{1,i,t}
\]

\[
a. \text{where product sales}_{i,t} = f(\text{exports}_{i,t-1}, \text{gnppercapita increase}_{i,t-1})
\]

\[
M2. \text{product sales}_{i,t} = a_2 + b_2 \times \text{service sales}_{i,t} + c_2 \times \text{gnppercapita}_{i,t} + d_2 \times \text{product portfolio}_{i,t} + f_2 \times \text{year trend}_{i,t} + g_2 \times \text{customer proximity}_{i,t} + v_2 + \epsilon_{2,i,t}
\]

\[
a. \text{service sales}_{i,t} = f(\text{imports}_{i,t}, \text{service staff}_{i,t}),
\]

\[
b. \text{customer proximity}_{i,t} = f(\text{density}_{i,(t-1)}, \text{customer proximity}_{i,(t-1)})
\]

### 4.3. Models 3 and 4

Hypothesis 2 argues that the relationship between service scale and the overall profitability of the product-service business is curvilinear, with low levels of servicing resulting in profitability decrease and higher levels of servicing resulting in profitability increase. Nevertheless, after consultation, the top management of firms pointed out that our reasoning did not take into account ‘economies of scope’ between products and services that might result in ‘low hanging fruits that can be reaped very early on’. Stated differently, it can be conceived that the profit margin will exhibit an *increase* at low levels of service scale, capitalizing on the economies of scope with products, a decrease at the medium scale level due to investments, and finally an increase as the economies of scale effect (together with the economy of scope) unfolds. Thus, our models account for the possibility of a curvilinear relationship between service scale and profitability characterized by two saddles or a cubic relationship.

We define Model 3 that simply tests linear relationship between service scale and profitability, Model 4 that tests the quadratic relationship as stipulated in Hypothesis 2, and Model 5 that tests the cubic relationship. Similar to Models 1 and 2, we control for *customer proximity*, *product portfolio*, *GNP/capita* in Models 3, 4 and 5, and we use *fixed effects* to control for time-invariant country
characteristics, while we use a year dummy variable to capture the expected yearly effects of price increases. In addition, we deploy service coverage to control for service sales over the installed base of products so that country differences are accounted for to the extent that they provide services for a given installed base. Increases in service staff and in non-service staff are expected to capture the negative effect of labor increases on profit margins, in particular in the case of (labor-intensive) services. Table 1 contains further information on the variables, while Models 3 and 4 are formally represented below.

\[ M3. \text{profit margin}_{i,t} = a_3 + b_3 \times \text{sales}_{i,t} + e_3 \times \text{service coverage}_{i,t} + f_3 \times \text{customer proximity}_{i,t} + g_3 \times \text{gnppercapita}_{i,t} + h_3 \times \text{year trend}_{i,t} + i_3 \times \text{product portfolio}_{i,t} + j_3 \times \text{service staff increase}_{i,t} + k_3 \times \text{non-service staff increase}_{i,t} + \epsilon_{3,i,t} \]

\[ M4. \text{profit margin}_{i,t} = a_3 + b_3 \times \text{sales}_{i,t} + b_3 \times \text{sales}_{i,t}^2 + e_3 \times \text{service coverage}_{i,t} + f_3 \times \text{customer proximity}_{i,t} + g_3 \times \text{gnppercapita}_{i,t} + h_3 \times \text{year trend}_{i,t} + i_3 \times \text{product portfolio}_{i,t} + j_3 \times \text{service staff increase}_{i,t} + k_3 \times \text{non-service staff increase}_{i,t} + \epsilon_{3,i,t} \]

\[ M5. \text{profit margin}_{i,t} = a_3 + b_3 \times \text{sales}_{i,t} + c_3 \times \text{sales}_{i,t}^2 + d_3 \times \text{sales}_{i,t}^3 + e_3 \times \text{service coverage}_{i,t} + f_3 \times \text{customer proximity}_{i,t} + g_3 \times \text{gnppercapita}_{i,t} + h_3 \times \text{year trend}_{i,t} + i_3 \times \text{product portfolio}_{i,t} + j_3 \times \text{service staff increase}_{i,t} + k_3 \times \text{non-service staff increase}_{i,t} + \epsilon_{3,i,t} \]

4.4. Estimators, model corrections, diagnostic checks and software

In Models 1 and 2 (H1a, b and c), we use one of the most common approaches to address simultaneous causality (Hahn et al., 2004; Murray, 2006), the two-stage least square estimator with instrumental variables (Wooldridge, 2002). Hence, the first two models represent the systems of equations that are estimated by using two-stage least square generalizations of simple panel-data estimators (Anderson and Hsiao, 1981; Baltagi, 2002). In Models 3, 4 and 5 (Hypothesis 2), we use panel-data estimators directly, given that there is no indication of endogeneity.

In all econometric models, we use panel data analysis with fixed effects. The fixed-effects model includes dummy variables for each subsidiary, thereby ‘specifying an estimable conditional mean’ and addressing biased and inconsistent parameter estimates’ ((Greene, 2003): 285). We introduce fixed effects to control for time-
invariant, unobserved heterogeneity among subsidiaries, given our expectation that time-constant differences may determine the effectiveness of the service strategy (Greene, 2003). For example, discussions with the firm’s management demonstrated that multiple country-specific differences, such as cultural acceptance of charging for service provision or size of the country’s territory, could have a considerable impact on service-related performance.

In the model specification, we also use ‘heteroskedasticity and-autocorrelation-consistent’ (HEC) standard errors (Bascle, 2008) to avoid concern about invalid inferences caused by these two violations of the standard OLS assumptions (Arellano and Bond, 1991). The expected yearly effect of price increases and growth targets is countered by introducing a trend variable in each model. Furthermore, we stationarized all monetary data (e.g. sales, GDP/capita, exports and imports) by transforming the nominal values into real 2000 values, using the World Bank’s GDP deflator. While diagnosis of multicollinearity is difficult in the 2SLS environment, tests on the models using the OLS estimator show that the variance inflation factor scores (VIFs) are well below 10 for the first two models (average VIF for M1 is 1.14 and M2 is 1.23). In Models 3, 4 and 5, all variables have VIFs below 2.28, apart from service sales, service sales$^2$ and service sales$^3$, which have VIFs exceeding 10, as anticipated. Finally, the dataset was considered fairly balanced: all data was present apart from data on profit margins and service coverage for three subsidiaries, on service staff for nine subsidiaries, and on four years in the case of one additional subsidiary. As the data was missing due to IT system issues, we do not expect the introduction of any bias. Table 2 below provides descriptive statistics for all the variables.

----- INSERT TABLE 2 ABOUT HERE -----
4.5 Instrument statistics and alternative instruments used in Models 1 and 2

Each of the models has relevant instruments, since F-statistics for the first-stage regressions exceed the 9.08 threshold and are significant at the 0.001% level (Bascle, 2008; Staiger and Stock, 1997; Stock and Yogo, 2004). In addition, instruments are jointly exogenous for each of the models, given that the P-value of Hansen’s J statistic exceeds 10%, thereby rejecting endogeneity in instruments (Hansen, 1982). Moreover, the results of the ‘Difference-in-Sargan’ test (C-statistics), which separately tests the exogeneity of each of the instruments, confirmed that all our instruments are exogenous (Hayashi, 2000).

Various additional robustness checks were performed. First, different instruments to the retained ones were used (lagged products sales as an IV for products sales, lagged service sales and installed base size as an IV for service sales). Additionally, different controls were used (e.g. service staff and employees in absolute figures, population density instead of service staff). Finally, various IV estimators were used in Models 1, 2, and 3. When instruments are strong, analysts can generally perform limited information maximum likelihood (LIML) or Fuller’s modified LIML (FULL) estimation, in addition to 2SLS (see Bascle (2008) for an overview). Furthermore, Stock et al. (2002), among others (e.g. Stock (2001); Yogo (2004)), recommend that the 2SLS estimation be upgraded to the generalized method of moments procedure (GMM) to allow for more efficient estimation when the model is overidentified (i.e. there are more instruments than endogenous regressors), though this estimator is preferred over 2SLS only when the sample size exceeds 700 observations. All these variants – including LIML, FULL and GMM – generated very similar estimates to those obtained by applying 2SLS. Results of the diagnostic tests and selected alternative specifications can be found in Table 1 in the Appendix.

To conduct the analysis, we have used Stata/IC 11.00. Models 1 and 2 have been estimated using the command XTIVREG2, FE (Schaffer, 2010), while Models 3, 4 and 5 have been estimated using XTREG, FE. Table 2 in the Appendix provides each STATA command.
5. Results

Table 3 below summarizes the results obtained in relation to the testing of the hypotheses. Results displayed in Model 1 confirm the arguments posited in Hypothesis 1a: as customers seem to realize higher economic benefits by outsourcing their servicing to the product-service provider, 1% of the increase in product sales leads to an increase of 0.9% in service sales \((b_1=0.91; p=0.000)\). Interestingly, service sales have a higher impact on product sales: as Model 2, confirming Hypothesis 1b, suggests that a 1% increase in service sales results in approximately a 1.6% increase in product sales. Indeed, Atlas Copco’s subsidiaries are able to transcend inherited substitution and enact complementary effects from services to products \((b_2=1.56; p=0.000)\). Furthermore, Model 2 also reveals that customer proximity leads to an additional increase in product sales \((g_2=33.45; p=0.050)\), thereby confirming Hypothesis 1c.

Table 3 shows the empirical results of testing the impact of servitization on the profit margin, as advanced in Hypotheses 2. First, Model 3, which tests the impact of service sales on overall profitability, reveals the absence of a linear relationship \((b_3=0.001, p=0.196)\). Model 4, which directly tests the hypothesized curvilinear relationship, does not confirm the stated relationship; the tests suggest that the stipulated quadratic relationship is not convincingly significant \((b_4=0.004, p=0.102; c_4=-3.46*10^{-5}, p=0.091)\). Finally, Model 4, which assesses the presence of a cubic relationship between service sales and profitability, returns convincing results; suggesting a non-linear relationship with the presence of two inflection points \((b_5=0.011, p=0.000; c_3=-2.6*10^{-4}, p=0.003; d_3=1.85*10^{-6}, p=0.008)\).

The interpretation of the results does indeed require a consideration of both the effects of economies of scale and economies of scope on profitability. When the scale of service activities is low, growth coincides with higher profit margins, suggesting that the product-service provider can indeed harvest the ‘low-hanging fruit’ enabled by economies of scope between products and services. In practice, this phase is marked by a high proportion of spare-parts activity implying attractive
margins without substantial investment in staff and organization. Moderate scale of service activity is associated with diminishing profit margins. A manufacturer that hosts a moderate level of service activity is faced with a need to invest in a service organization that countenances systematic, large-scale service provision. The economies of scope alone seem insufficient to counter the pressure that investments put on the margin. Finally, a higher scale of service operations again results in a positive relationship between scale and profit margin, suggesting that economies of scale (together with economies of scope with products) eventually compensate for investment costs.

Finally, reflecting on extant literature, economies of scope with products may explain why (Neely, 2008) notes a positive impact of the decision to servitize, while investments may cause a negative impact on the extent of servitization. Furthermore, our observation with respect to the second and the third stages (the effects of service investments and economies of scale) seem to be in line with the findings of (Fang et al., 2008).

Models 3, 4 and 5 also indicate that the impact of service coverage on profitability is positive and significant (e5=0.010, p=0.007) while customer proximity is negative and non-significant (f5=-0.9 p=0.166). In discussing the latter observation with the company under study, it emerged that there are two influences working simultaneously on profitability. One is the cost efficiency of service provision and the other relates to the pricing tactics with respect to spare parts. The lack of significance for customer proximity can be attributed to the fact that the prices of less labor-intensive services (parts delivered) in a number of countries denote margins equal to, or even greater than, more sophisticated, labor-intensive service activities.

Finally, statistics presented for all relevant models (M1, M2 and M5) suggest that the relationships are strong since R-squared, which measures the explanatory power of the model, is relatively high for each of the models (R-squared is 44% for Model 1, 79% for Model 2, 33% for Model 5). Furthermore, the adopted
6. Conclusion

6.1. Study results and the contribution to theory and practice

Table 4 summarizes the results of the testing of the hypotheses. First, the results of Model 1 (H1a) and Model 2 (H1b and H1c) indicate that product sales and service sales complement each other and that the customer proximity of service offerings reinforces the positive feedback from services on product sales. While positive effects are anticipated in progressing from products to related service activities, the reverse relationship – whereby service sales positively influence product sales – is far less obvious, since the impact of servicing may be negative when services act as substitutes for products. The firm under study overcomes inherent substitution effects by using services to extend the sales potential of products; moreover, increasing levels of customer proximity achieved by more labor-intensive service offerings further enhances the positive effect of service activities on product activities. The firm under study manages to enact these positive revenue dynamics between products and services by relying on an integrated product-service business model and managerial practices that support positive feedback from services to products. These findings attempt to contribute to the literature (Brouilat, 2009; Kim et al., 2007; Mont, 2004a) by illuminating the process of value creation through servitization from the perspective of the manufacturer turned service provider, offering insights for product-service providers on how to move beyond the threat of value ‘destruction’ towards value creation. Furthermore, the presence of the reciprocal, positive revenue relationship between products and services may be seen as an indirect indicator of complementarities (Milgrom and Roberts, 1990, 1995; Siggelkow, 2001) on the customer side. It is interesting to note that complementarity will be contingent upon or ‘contextual’ to (Porter and Siggelkow, 2008) the managerial practices that help enact complementary feedback from services to products (e.g. systems that

econometric design is robust and appropriate since the p-value of the F-Statistics is 0.00 for all models.
transform service field information into product-relevant insights) and override the innate substitutive effect of services on products (Siggelkow, 2002). In itself, contextuality of complementary and substitutive effects is an interesting observation in itself, since extant literature perceives complements and substitutes to be mutually exclusive (Siggelkow, 2002).

Second, Models 3, 4 and 5 (H2), at first sight, disprove the quadratic relationship between service sales and overall profitability, and rather suggest a cubic relationship. Model 5 confirms that low levels of service scale, supported by economies of scope between products and services, can result in an improvement in profitability. Profitability is then temporarily decreased at a medium level of service scale, due to investment in service scaling. Finally, high levels of service scale, supported by service economies of scale and economies of scope with products, overtake the costs of service investments resulting in profitability increase. Furthermore, these insights offer advice to product-service providers to estimate the potential of the service business well in advance, in order to ensure they will be able to overcome the encountered investment hurdles. Besides the economies of scope and scale, preliminary tests we have conducted (available upon request from the authors) suggest that accumulating levels of service over time would result in service learning effects (Heim and Ketzenberg, 2011), which are likely to further improve profit margins. For example, the more a service technician visits his customer for machine maintenance, the more s/he learns about the machine itself and customer operations; the adequate application of information technology over the entire product population enhances predictability of servicing and decreases the risk of machine failure.

While these findings provide reassurance, they are also intended to warn manufacturers against a real risk; after going through an initial, lucrative phase, firms that expect the adoption of servitization to equate to the harvesting of low-hanging fruit may well become frustrated and inclined to discard service activities prematurely.
The presence of complementary dynamics on the level of product and service sales (M1 and M2) and economies of scope between products and services (M3 and M4) seems highly related to the manufacturer’s choice of business model (Casadesus-Masanell and Ricart, 2010; Zott and Amit, 2010). Our findings suggest that an integrated product-service business model – which creates opportunities for growth beyond the installed product base by relying on related services, coupled with managerial practices that reinforce complementarity through customer proximity – is important in this respect. An integrated product-service business model also requires services to be taken as a strategic complement to products; if services are approached merely as an add-on, revenue growth will be limited by the installed product base, which may well encourage firms to expand into independent services. However, if services become unrelated to the products, complementary dynamics and economies of scope with products will no longer act as sources of value creation, and specialized service providers (focused on accomplishing service economies of scale and learning effects) may be a more efficient choice for a customer. In short, our study makes three recommendations concerning service-oriented manufacturing firms: a) the adoption of an integrated business model as a way of creating reciprocal spillovers between products and services b) implementation practices that generate customer proximity and c) the envisaging of necessary investments as well as the enactment of economies of scale and learning effects in services in order to achieve long-term profitability.

6.2 Limitations of the research

We are fully aware of the limitations of the research reported in this paper. While our study has benefited immensely from the insights from practice as well as from direct access to proprietary company data, sourcing data from a single firm implies limitations in terms of external validity. Firstly, we focus only on one mother firm with one business model – the integrated service business model – while servitization can also imply the deployment of less related service offerings. As such, this research should be complemented by similar efforts in different
industries to assess the broader validity of the findings obtained. Finally, our analysis looks at the overall net effect of product-service dynamics rather than focusing on specific service offerings. Hence, it would be interesting to further analyze how specific services such as leasing (which implies retention of ownership on the manufacturer’s side) change the value functions of manufacturer and customer. Also, the impact of product monitoring services might be further scrutinized; though it clearly represents one of the more sophisticated service activities, it may reduce intimacy with the client due to remote provision. In general, future research efforts aimed at validating the occurrence of interdependencies on a larger sample of firms are necessary to assess to what extent our findings are common to different industrial settings and to examine additional contingencies that might affect the observed value dynamics. Between-firm comparisons are needed as well to further assess the extent to which integrated business models are indeed superior or sustainable compared to other service strategies, such as unrelated product-service diversification.

Finally, further substantiation of different sources of complementarities, as well as the presence of substitution effects, seems highly relevant in increasing our understanding of the effectiveness of service business models for manufacturing firms. For example, future studies can significantly improve our results by correcting for third-party competition. While, at this stage, we can only distinguish between the sale of spare parts and the sale of labor-intensive services such as maintenance; it is to be hoped that future studies would be able to provide more fine-grained insights with respect to the relationships between particular types of product and service. Also, this study is focusing on the sales complementarities; yet engaging in servicing can yield additional spillovers by generating insights that have a considerable impact on product development activities. On the other hand, product innovations may facilitate service provision by taking into account the requirements of the service environment in product design, or it may reduce the need for servicing and lead to cannibalization of the service business. Assessing the presence of complementarities and substitution effects over longer time periods would significantly add value to the result reported in this paper. For example, complementary effects from services to products may strengthen as
product-service providers spend more years servicing a customer. Finally, our findings reveal considerable implementation differences between subsidiaries operating within a similar service business model, strongly suggesting the relevance of scrutinizing further organizational antecedents that affect servitization performance. We hope that our findings inspire colleagues to engage in such efforts.
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Mont, O., 2004b. Product-Service Systems: Panacea or Myth? IIIEE, Lund University


### Tables

**Table 1. Overview of the variables and their use**

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Measure</th>
<th>Formula</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Independent variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total profit margin*</td>
<td>%</td>
<td>Subsidiary profits/ Subsidiary sales</td>
<td>Used as dependent variable (DV) to test Hypothesis H2 (Models M3, M4 and M5) and independent variable to test H1b (M2) and H2 (M3, M4, M5)</td>
</tr>
<tr>
<td>Service sales</td>
<td>EUR million</td>
<td>Sales of the full service portfolio in a subsidiary</td>
<td>Used as DV to test H1b (M2) and independent variable to test H1a (M1)</td>
</tr>
<tr>
<td>Product sales</td>
<td>EUR million</td>
<td>Sales of the full product portfolio in the subsidiary Maintenance sales/ Service sales</td>
<td>Used to test H1c (M2). Higher the % of labour-intensive services, more often technicians visits a customer. Depicts the level of proximity with customers.</td>
</tr>
<tr>
<td>Customer proximity</td>
<td>%</td>
<td>Maintenance sales + Spare parts sales</td>
<td></td>
</tr>
<tr>
<td><strong>Control variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GNP per capita</td>
<td>USD thousand</td>
<td>Gross National Product/ Number of people</td>
<td>Used in all models to control for differences in the level of development of a subsidiary's country market</td>
</tr>
<tr>
<td>Product portfolio</td>
<td>%</td>
<td>Sales of large products/ Sales of small products where Total products sales= large +small product sales</td>
<td>Used in all models to control for subsidiary differences in product portfolio</td>
</tr>
<tr>
<td>Year</td>
<td>Number</td>
<td>A year dummy variable</td>
<td>Used in all models to control for the yearly effects</td>
</tr>
<tr>
<td>Service coverage</td>
<td>EUR thousand</td>
<td>Volume of products sold in t-1, t-2, t-3 and t-4</td>
<td>Used in M3, M4 and M5 to control for the level of service provision relative to the size of the product base</td>
</tr>
<tr>
<td>Service staff increase</td>
<td>Number</td>
<td>Absolute annual increase in the number of service employees in a subsidiary Absolute annual increase in number of non-service employees in a subsidiary where Total employees= Non-service + Service employees</td>
<td>Used in M3, M4 and M5 where the DV is profit margin, to control for differences in labor efficiency</td>
</tr>
<tr>
<td>Non-service staff increase</td>
<td>Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Instrumental variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports</td>
<td>USD billion</td>
<td>Value of country exports</td>
<td>See the Methodology section for detailed discussion</td>
</tr>
<tr>
<td>Imports</td>
<td>USD billion</td>
<td>Value of country imports</td>
<td>See the Methodology section for detailed discussion</td>
</tr>
<tr>
<td>Service staff</td>
<td>Number 000</td>
<td>Number of service employees in a subsidiary</td>
<td>See the Methodology section for detailed discussion</td>
</tr>
<tr>
<td>Density</td>
<td>people/km²</td>
<td>Country population density</td>
<td>See the Methodology section for detailed discussion</td>
</tr>
</tbody>
</table>

Note: Total profit margin represents a subsidiary profit margin before the deduction of the headquarters overhead that is proportional in all subsidiaries.
### Table 2: Summary statistics and correlation coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total profit margin</td>
<td>287</td>
<td>0.30</td>
<td>0.06</td>
<td>0.14</td>
<td>0.45</td>
<td>1.00</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product sales</td>
<td>308</td>
<td>17.89</td>
<td>23.40</td>
<td>0.54</td>
<td>141.8</td>
<td>-0.21*</td>
<td>1.00</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Service sales</td>
<td>308</td>
<td>10.56</td>
<td>10.97</td>
<td>0.22</td>
<td>75.9</td>
<td>-0.22*</td>
<td>0.81*</td>
<td>1.00</td>
<td></td>
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<tr>
<td>Customer proximity</td>
<td>308</td>
<td>0.58</td>
<td>0.23</td>
<td>0.09</td>
<td>0.96</td>
<td>-0.04</td>
<td>-0.07</td>
<td>0.13*</td>
<td>1.00</td>
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</tr>
<tr>
<td>GNP/capita</td>
<td>308</td>
<td>15.4</td>
<td>12.7</td>
<td>0.4</td>
<td>45.8</td>
<td>-0.31*</td>
<td>0.17*</td>
<td>0.48*</td>
<td>0.47*</td>
<td>1.00</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Product portfolio</td>
<td>308</td>
<td>1.09</td>
<td>0.51</td>
<td>0.08</td>
<td>3.00</td>
<td>0.02</td>
<td>0.38*</td>
<td>0.28*</td>
<td>0.02</td>
<td>-0.12*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Service coverage</td>
<td>287</td>
<td>4.48</td>
<td>2.46</td>
<td>0.71</td>
<td>14.6</td>
<td>0.12*</td>
<td>-0.29*</td>
<td>-0.05</td>
<td>0.29*</td>
<td>0.06</td>
<td>0.05</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Service staff</td>
<td>241</td>
<td>18.2</td>
<td>15.5</td>
<td>0</td>
<td>93</td>
<td>-0.25*</td>
<td>0.60*</td>
<td>0.68*</td>
<td>0.17*</td>
<td>0.16*</td>
<td>0.21*</td>
<td>0.02</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service staff increase</td>
<td>192</td>
<td>1.3</td>
<td>8.6</td>
<td>-31</td>
<td>54</td>
<td>-0.08</td>
<td>0.18*</td>
<td>0.12</td>
<td>0.00</td>
<td>0.03</td>
<td>0.12</td>
<td>0.05</td>
<td>0.5*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-service staff increase</td>
<td>192</td>
<td>10.4</td>
<td>23</td>
<td>-54</td>
<td>169</td>
<td>-0.17*</td>
<td>0.68*</td>
<td>0.53*</td>
<td>-0.24*</td>
<td>-0.11</td>
<td>0.19*</td>
<td>-0.23*</td>
<td>0.34*</td>
<td>-0.22*</td>
<td>0.77*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports</td>
<td>308</td>
<td>219</td>
<td>292</td>
<td>1</td>
<td>1666</td>
<td>-0.23*</td>
<td>0.88*</td>
<td>0.88*</td>
<td>0.03</td>
<td>0.37*</td>
<td>0.38*</td>
<td>-0.13*</td>
<td>0.57*</td>
<td>0.16*</td>
<td>0.77*</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports</td>
<td>308</td>
<td>221</td>
<td>333</td>
<td>3</td>
<td>2260</td>
<td>-0.24*</td>
<td>0.86*</td>
<td>0.91*</td>
<td>-0.02</td>
<td>0.37*</td>
<td>0.34*</td>
<td>-0.11</td>
<td>0.55*</td>
<td>0.17*</td>
<td>0.77*</td>
<td>0.96*</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>301</td>
<td>1.17</td>
<td>1.14</td>
<td>0.02</td>
<td>4.84</td>
<td>-0.05</td>
<td>0.16*</td>
<td>0.17*</td>
<td>-0.03</td>
<td>0.12*</td>
<td>0.31*</td>
<td>-0.12*</td>
<td>-0.03</td>
<td>-0.05</td>
<td>0.05</td>
<td>0.27*</td>
<td>0.2*</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* p < 0.05.
Table 3. Results from Hypotheses Testing

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Service sales</th>
<th>Product sales</th>
<th>Profit margin</th>
<th>Profit margin</th>
<th>Profit margin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypotheses</strong></td>
<td>H1a</td>
<td>H1b &amp; H1c</td>
<td>H2</td>
<td>H2</td>
<td>H2</td>
</tr>
<tr>
<td>Two-stage least square model with best instruments</td>
<td>M1</td>
<td>M2</td>
<td>M3</td>
<td>M4</td>
<td>M5</td>
</tr>
<tr>
<td><strong>Variable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product sales t-1</td>
<td>0.91***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service sales</td>
<td>1.56***</td>
<td>0.001</td>
<td>-0.04</td>
<td>0.01***</td>
<td>0.01***</td>
</tr>
<tr>
<td>Service sales(^2)</td>
<td></td>
<td>(-3.5\times10^{-5})‡</td>
<td>(-2.6\times10^{-4})**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service sales(^3)</td>
<td></td>
<td></td>
<td>(1.8\times10^{-6})**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer proximity</td>
<td>33.45*</td>
<td>-0.04</td>
<td>-0.05</td>
<td>-0.9</td>
<td></td>
</tr>
<tr>
<td><strong>Controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GNP/capita</td>
<td>0.41**</td>
<td>0.45†</td>
<td>0.01**</td>
<td>0.01**</td>
<td>0.01**</td>
</tr>
<tr>
<td>Product portfolio</td>
<td>0.02</td>
<td>4.19**</td>
<td>-0.002</td>
<td>-0.004</td>
<td>-0.005</td>
</tr>
<tr>
<td>Year trend</td>
<td>-0.55*</td>
<td>-0.25</td>
<td>-0.004</td>
<td>-0.005</td>
<td>-0.01†</td>
</tr>
<tr>
<td>Service coverage</td>
<td>0.01**</td>
<td></td>
<td>0.01*</td>
<td>0.01*</td>
<td>0.01**</td>
</tr>
<tr>
<td>Service staff increase</td>
<td>(-6.6\times10^{-5})‡</td>
<td>(-5.2\times10^{-4})</td>
<td>(-6.7\times10^{-4})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-service staff increase</td>
<td>(-3.0\times10^{-5})‡</td>
<td>(-1.7\times10^{-4})</td>
<td>(-2.5\times10^{-4})</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>0.14*</td>
<td>0.14*</td>
<td>0.14*</td>
<td>0.13**</td>
<td></td>
</tr>
</tbody>
</table>

**Instruments for product sales t-1**

- Instrument 1: Exports t-1
- Instrument 2: GNP/capita increase t-1

**Instruments for service sales**

- Instrument 1: Imports
- Instrument 2: Service

**Instruments for customer proximity**

- Instrument 1: Density
- Instrument 2: Customer proximity t-1

**Model statistics**

- Number of observations: 220
- F statistics (P-value): 0.00
- R-squared (%): 44%

† p < 0.10. * p < 0.05. ** p < 0.01. *** p < 0.001.

Table 4. Summary of the Results from Hypotheses Testing

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Model</th>
<th>Result of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1a</td>
<td>M1</td>
<td>Supported</td>
</tr>
<tr>
<td>H1b</td>
<td>M2</td>
<td>Supported</td>
</tr>
<tr>
<td>H1c</td>
<td>M2</td>
<td>Supported</td>
</tr>
<tr>
<td>H2</td>
<td>M3, M4, M5</td>
<td>Disproved</td>
</tr>
</tbody>
</table>
Appendix A. Additional model statistics and information

Table 1. Model statistics

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Service sales</th>
<th>Product sales</th>
<th>Profit margin</th>
<th>Profit margin</th>
<th>Profit margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotheses</td>
<td>H1a</td>
<td>H1b &amp; H1c</td>
<td>H2</td>
<td>H2</td>
<td>H2</td>
</tr>
<tr>
<td>Two-stage least square model with best instruments</td>
<td>M1</td>
<td>M2</td>
<td>M3</td>
<td>M4</td>
<td>M5</td>
</tr>
</tbody>
</table>

Model robustness

- Heteroscedasticity consistent standard errors: YES YES YES YES YES YES
- Autocorrelation consistent standard errors: YES YES YES YES YES YES
- Non-stationarity controlled with year trend: YES YES YES YES YES YES

Instruments relevance (Stock and Yogo F-statistic for each instrumented variable should be >9.08)

| Product sales t-1 (Stock and Yogo F-statistic) | 16.36 |
| Service sales (Stock and Yogo F-statistic) | 33.11 N/A N/A N/A |
| Customer intimacy (Stock and Yogo F-statistic) | 12.31 N/A N/A N/A |

Instruments exogeneity for all instruments jointly (Hansen J statistic P-value should be >0.10)

| Hansen J statistic (P-value) | 0.28 0.25 N/A N/A N/A |

Instruments exogeneity for each instrument (C-statistic P-value should be >0.10)

| Exports t-1 (C-statistic P-value) | 0.28 N/A N/A N/A |
| GNP per capita increase t-1 (C-statistic P-value) | 0.28 N/A N/A N/A |
| Imports (C-statistic P-value) | 0.12 N/A N/A N/A |
| Service staff (C-statistic P-value) | 0.12 N/A N/A N/A |
| Density (C-statistic P-value) | 0.57 N/A N/A N/A |
| Customer proximity t-1 (C-statistic P-value) | 0.66 N/A N/A N/A |

Stata codes (see Appendix A. Table 2)

| M1a | M2a | M3 | M4 | M5 |

Alternative estimators yield very similar* estimates to the two-stage least square estimator

- Limited information maximum likelihood (LIML): YES YES N/A N/A N/A
- Fuller’s modified LIML (FULL): YES YES N/A N/A N/A
- Generalized method of moments (GMM): YES YES N/A N/A N/A

Two-stage least square models with alternative instruments yield very similar results

<table>
<thead>
<tr>
<th>Instruments for product sales t-1</th>
<th>Product volume t-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument 1</td>
<td></td>
</tr>
<tr>
<td>Instrument 2</td>
<td>GNP/capita increase t-1</td>
</tr>
</tbody>
</table>

| Instruments for service sales | Density |
| Instrument 1                 |        |
| Instrument 2                 | Service staff |

| Instruments for customer proximity | GNP/capita |
| Instrument 1                     |           |
| Instrument 2                     | Customer proximity t-1 |

| Stata codes (see Appendix Table 2) | M1b | M2b | N/A | N/A | N/A |

* ‘very similar results’ stands for a) significance of the independent variable does not change b) sign of the independent variable does not change c) effect size does not change substantially to have any impact on interpretation.
Table 2. Model STATA commands

**M1a:** xtivreg2 servicesales gnppercapita productportfolio yeartrend (L.productsales= L. exports L.D.gnppercapita, fe ffirst r bw(2))

**M1b:** xtivreg2 servicesales gnppercapita productportfolio yeartrend (L.productsales= laggedproductvolume L.D.gnppercapita), fe ffirst r bw(2)

**M2a:** xtivreg2 productsales gnppercapita productportfolio yeartrend (servicesales customerproximity=imports L.customerproximity density servicestaff), fe robust ffirst bw(2)

**M2b:** xtivreg2 productsales gnppercapita productportfolio yeartrend (servicesales customerproximity= gnppercapita density servicestaff L.customerproximity),fuller(4) fe robust ffirst bw(2)

**M5:** xtreg totalprofitmargin servicesales customerproximity gnppercapita productportfolio yeartrend servicecoverage D.servicestaff D.noneservicestaff, fe vce(robust)

**M4:** xtreg totalprofitmargin servicesales servicesales2 customerproximity gnppercapita productportfolio yeartrend servicecoverage D.servicestaff D.noneservicestaff, fe vce(robust)

**M5:** xtreg totalprofitmargin servicesales servicesales2 servicesales3 customerproximity gnppercapita productportfolio yeartrend servicecoverage D.servicestaff D.noneservicestaff, fe vce(robust)
Servitization: Disentangling the impact of service business model innovation on the performance of manufacturing firms