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Internationalisation, Innovation and Productivity in Services:

Evidence from Germany, Ireland and the United Kingdom[1]

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Abstract

This paper examines the links between internationalisation, innovation and productivity in service enterprises. For this purpose, we use micro data from the Community Innovation Survey 2008 in Germany, Ireland and the United Kingdom, and estimate an augmented structural model. Our empirical evidence highlights the importance of internationalisation in the context of innovation outputs in all three countries. Our results indicate that innovation in service enterprises is linked to higher productivity. Among the innovation types that we consider, the largest productivity returns were found for marketing innovations.

Key Words: Internationalisation of services; innovation; productivity.

JEL Classification: F61; L25; O31

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[1] An earlier version of this paper was circulated under the title "Innovation and Productivity in Services: Evidence from Germany, Ireland and the United Kingdom".

1 Introduction

The theoretical literature on international trade and firm heterogeneity (the New-New Trade Theory) has established that firms with international activities are more productive than those serving only the domestic markets. While in the early theoretical models firm productivity is treated as exogenous (Melitz 2003; Helpman, Melitz, and Yeaple 2004), more recent contributions allow for the possibility of productivity increases through innovation activities (Yeaple 2005; Lileeva and Trefler 2010; Bustos 2011). A small but growing literature strand models the complementarities between investing in innovation and export participation (Aw, Roberts and Winston 2007; Baldwin and Robert-Nicoud 2008; Van Long, Raff, and Stähler 2011; Aw, Roberts, and Xu 2011) and finds that export participation is more likely when firms innovate and innovation is more likely when firms anticipate export opportunities. A positive correlation between exporting and innovation activity has been found in several studies (Wagner 1996; Love and Roper 2002; Liu and Buck 2007; Bratti and Felice, 2012; Siedschlag and Zhang 2015). Furthermore, additional recent empirical evidence indicates that foreign-owned enterprises as well as exporters are more likely to innovate (Criscuolo et al. 2010; Siedschlag and Zhang 2015). However, empirical evidence on the links between internationalisation, innovation and productivity is scarce.

In the context of intensified global competition, innovation is of crucial importance for growth and competitiveness. Services account for a growing share of economic activity, and innovation in services is widely seen as a new source of economic growth (OECD 2005). Furthermore, technological advances, particularly in information and communication technologies (ICT), have enabled a greater tradability of services and thus greater exposure to competition. In this context, innovation in services is increasingly important for a firm's survival and also a pathway for sustainable economic growth.

Despite this growing importance of services in modern economies, existing empirical evidence on the links between internationalisation, innovation and productivity in services is still limited.

Previous analyses of innovation in services have highlighted a number of specific characteristics of services, such as their intangibility, simultaneity of production and consumption, and perishability (Johne and Storey 1998; Hipp and Grupp 2005; Miles 2005; Gallouj and Savona 2009, 2010; Savona and Steinmueller 2013). Following on from these specific characteristics, relative to manufacturing, it has been pointed out that innovation in services is predominantly non-technological, less related to R&D, and it is closer to consumer demand (Licht and Moch 1999; Tether 2005; Tether and Tajar 2008). Notwithstanding these specificities, the boundaries between manufacturing and services are less clear as they are becoming increasingly integrated (Howells 2001). A growing number of researchers argue that innovation in manufacturing and innovation in services are not clearly distinct (Evangelista 2000;

Hollenstein 2003; Cainelli et al. 2006). However, it has also been suggested that analysing innovation in services using a similar approach to the one applied for manufacturing may not adequately capture all the forms of innovation in services (Gallouj and Weinstein 1997; Sundbo 1997; Tether and Tajar 2008). A more recent approach has emerged that combines the insights gained from analysing both innovation in manufacturing – mainly of a technological type – and innovation in services – mainly non-technological innovation (Drejer 2004; Hipp and Grupp 2005; De Vries 2006; Siedschlag et al. 2011; Leiponen 2012).

While the links between innovation and productivity in manufacturing enterprises have been analysed for a large number of countries,[2] only a few studies have examined innovation and productivity in service enterprises (Lööf and Heshmati 2006 - for Sweden; Mairesse and Robin 2009 - for France; Polder et al. 2010 - for the Netherlands; Siedschlag, Zhang and Cahill 2010; and Siedschlag et al. 2011 - for Ireland; Masso and Vahter 2012 - for Estonia; Crespi et al. 2014 for Chile, Colombia and Uruguay). The evidence provided by these studies on innovation and productivity in service enterprises is country and model-specific. Furthermore, comparisons with innovation and productivity in manufacturing enterprises are only limited.

To fill the evidence gap mentioned above, this paper examines the links between internationalisation, innovation inputs, innovation outputs and productivity in service enterprises. More specifically, we ask the following research questions: (i) What types of service enterprises are more likely to invest in innovation? (ii) What types of service enterprises have higher innovation investment per employee? (iii) Does higher investment in innovation lead to higher innovation output in service firms and is this effect the same for different types of innovation? (iv) Is higher innovation output linked to higher productivity in service enterprises? To what extent do productivity effects differ by type of innovation? (v) Are there any cross-country differences in the relationships between internationalisation, innovation input, innovation output and productivity for service firms? For this purpose, we use micro data from the Community Innovation Survey[3] (CIS) 2008 covering Germany, Ireland and the United Kingdom (UK). By using micro-data for different service sectors across different countries, our analysis accounts for heterogeneity at the firm-, sector and country-level.

[2] Recent reviews of these studies are Hall (2011), Hall and Mohnen (2013), Ruane and Siedschlag (2013), and Siedschlag and Zhang (2015).

[3] The Community Innovation Survey is a harmonised survey on the innovation activities in enterprises. It is carried out on a voluntary basis, currently every two years, by European Union countries and other countries which are members of the European Statistical System (ESS) such as countries members of the European Free Trade Area (EFTA) and EU candidate countries. The concepts and underlying methodology of the core survey questionnaire are based on the Oslo Manual (OECD and European Commission 1997, 2005), an internationally recognised set of guidelines on collecting and interpreting data on innovation published jointly by the OECD and the European Commission.

The novelty of our contribution consists in improving, on the basis of theoretical foundations, previous conceptual frameworks and empirical methodologies in several ways. *First*, we account in the empirical analysis for the role of internationalisation of service activities on the links between innovation inputs, innovation outputs and productivity. *Second*, while most of previous analyses of the link between innovation and productivity have focused on technological innovations (i.e., product and process innovations), we consider in addition non-technological innovations, namely, organisational and marketing innovations. In particular, the link between marketing innovation and productivity has been seldom analysed.[4] Marketing innovations may increase productivity via increased demand for goods and services. This outcome could come about through significant changes in product design or packaging, product placement, promoting or pricing. These improvements help to better address customer needs, to open new markets or to re-position products on existing markets. Furthermore, in contrast to most previous studies, we model both technological and non-technological innovation outputs as being endogenous in the estimated production functions. *Third*, we set up and use a unified econometric framework which allows us to identify both similarities and differences in the innovation and productivity performance of enterprises in services. *Fourth*, in contrast to most previous studies, we consider a broader definition of innovation expenditures, beyond R&D expenditure which, as discussed above, is more appropriate for understanding innovation in services. *Finally*, while most of previous contributions are country-specific analyses, we compare the innovation and productivity performance in three countries, namely Germany, Ireland and the UK. The choice of these three countries is motivated by their different innovation and productivity performance of service enterprises. According to data from the CIS 2008, among European Union countries, Germany had the highest proportion of innovative service enterprises, 73.6 %, while the corresponding figures for Ireland and the UK were 54.1 % and 43.0 %, respectively. However, with respect to their productivity performance,[5] in 2008, productivity in services relative to the EU average was higher in Ireland by 28%, while in Germany and the UK it was lower by 8% and 22 %, respectively.

The innovation and productivity performance of Germany, Ireland and the UK is to be understood in the context of each country's policy mix and institutional framework. For instance, Germany has a science-collaboration focused institutional framework, in Ireland a science-competitive R&D focused policy mix operates whereas in the UK innovation policy focuses on commercialisation-driven innovation (Izsák et al. 2013; OECD, 2014). As such, these three countries demonstrate commonalities

[4] Masso and Vahter (2012) being an exception who analysed the role of marketing innovation on productivity in Estonia.

[5] Gross value added per person employed in constant (2010) prices taken from the European Commission's *Ameco* data base available at: http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm.

and contrasts in their policy approaches to supporting and incentivising investment in innovation. The science-collaboration policy mix in Germany focuses on collaborative R&D funding especially between public research organisations and industry and favours support for loan and venture capital funds and no use of R&D tax incentives. In contrast, the science-competitive framework in Ireland focuses on competitive R&D programme funding rather than institutional funding of public organisations, support measures for business innovation and the use of R&D tax incentives which are close to the OECD median level. In the UK, commercialisation-driven innovation policy focuses on technology transfer mechanisms, strong support for entrepreneurship, support for loans and venture capital similarly to Germany and with extensive use of R&D incentives similarly to the policy approach in Ireland although far above the OECD median level.

Our empirical analysis highlights the importance of internationalisation in the context of innovation and productivity in services in all three countries. Furthermore, our results indicate that innovation in service enterprises is linked to higher productivity, over and above other enterprise and industry characteristics. The largest productivity returns were found for marketing innovations. Successful innovation in service enterprises appears to be associated with a number of factors, such as enterprise size, innovation expenditure intensity (Germany and the UK), foreign ownership (Ireland), exporting, and the engagement in cooperation for innovation activities.

The rest of this paper is organised as follows. Section 2 discusses the theoretical foundations of our analysis. Section 3 describes the data, variables used in the empirical analysis and summary statistics. Section 4 discusses the empirical methodology that we use. Section 5 presents the empirical results. Finally, section 6 summarises the key findings and policy implications.

2 Theoretical Foundations

It is widely acknowledged that investment in R&D and other investments in innovation contribute significantly to firm productivity. Research into the firm-level R&D-innovation-productivity relationship has a long-standing and a highly important place in the field of the economics of innovation. For example, Martin (2012) calls the issue of understanding returns to R&D "a central building block" in innovation studies.

Key contributions to understanding the firm-level R&D-innovation-productivity relationship include works on the knowledge production function by Griliches (1979, 1990), Pakes and Griliches (1980, 1984) and the extensions of the knowledge production function framework in Crépon, Duguet and Mairesse (CDM, 1998). Hall (2011), Mohnen and Hall (2013), Mairesse and Sassenou (1991) and Griliches (1979, 1990) provide reviews of the relationships between knowledge capital and firm

productivity. A large number of empirical papers have by now estimated models of innovation, linking firm level R&D and other innovation inputs to innovation outputs (e.g. innovative sales, measures of product, process and other types of innovation) and proxies of firm productivity.[6]

The analysis of the R&D-innovation-productivity relationship has been based on the general traditions of the neoclassical production economics and has been embedded in the analysis of the (augmented) production function (Griliches 1979), where productivity measures (TFP, labour productivity) are typically estimated as a function of past levels of investment in R&D (as a measure of innovation effort), physical and human capital, industry level factors and the size of the firm. Pakes and Griliches (1980, 1984) and Griliches (1979, 1990) add the key concept of the knowledge production function to the analysis of this relationship, arguing that R&D and similar investments can increase the stock of knowledge at the firm level that can lead to innovation and eventually to increase in output due to increased productivity.[7]

R&D is of course not the only innovation input. Focus on R&D alone would miss a number of other aspects and channels of innovation activities, and would lead to underestimation of the effects of innovation on productivity, especially in services. Firstly, it is the innovation outputs (process, product and other types of innovation), not innovation inputs that are directly affecting firm productivity. The effects of innovation inputs on firm performance work through innovation outputs. Secondly, there are difficulties of measurement of innovation inputs due to their latent and partly unobserved nature. Finally, there are other relevant key innovation inputs than own R&D, such as the intensity and breadth (variety) of knowledge sourcing from external partners, such as clients, suppliers and universities (Laursen and Salter 2006, Cassiman and Veugelers 2006).

As a result, empirical and conceptual studies have moved from: i) linking innovation inputs (such as R&D) directly to productivity to ii) the analysis of links of innovation outputs with productivity (see Hall et al. 2009, Hall 2011). For example, these include questions on how are sales of new and improved products or indicators of engaging in product, process, marketing or organisational innovation[8] related to firm productivity.

[6] For example, Mairesse and Mohnen (2010) and Hall (2011) provide a concentrated review of the literature.

[7] In particular, Pakes and Griliches (1980, 1984) introduce a general model and a 'path analysis diagram' linking 'research expenditures' with increases in 'knowledge capital' (this stage being the 'knowledge production function'), and increases in knowledge capital then with 'other expected or realized benefits from invention' (Pakes and Griliches 1984, p. 56).

[8] The Oslo Manual (OECD and European Commission 2005) defines that "a product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness and other functional characteristics." Product innovations in services can include improvements how they are provided (e.g. speed, efficiency), the addition of new functions or characteristics to existing services, and of course, introduction of fully new services. "A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software." An organisational innovation is "the

The seminal paper by Crépon, Duguet and Mairesse (1998) has refined the knowledge production function approach of Pakes and Griliches (1984) and formulated a structural model (the CDM model) for estimating the analysis of various stages in the innovation process. Their model was a clear step forward in accounting for the complexity of the innovation process. They provided an intuitively appealing theoretical and econometric model that enabled the researchers to go in more detail into the analysis of the 'black box' (e.g. a term used by Rosenberg 1982) of the process of knowledge development, and its effects on performance and relationship with innovation effort by the firm.

The CDM model is described in detail in Section 4 and applied in the empirical analysis after that. Here we outline some of its key aspects. The model is based on three steps in the innovation process of the firm. The first step is the firm's decision whether to engage in R&D and innovation investments, and given that decision, how much to invest. The second step is the knowledge production function of the firm (similarly to Pakes and Griliches 1984) linking the innovation inputs and other factors with innovation outputs. In the final step, an augmented (Cobb-Douglas) production function is used to link the innovation outputs to firm's productivity. The model is tailored to be estimated based on the firm level data from the Community Innovation Surveys (CIS).

The CDM model does not consider the role of internationalisation in the above three stages. However, existing evidence indicate that firms operating in international markets are more likely to invest in innovation and have a better innovation and productivity performance than firms operating in domestic markets only (Criscuolo, Haskel and Slaughter 2010; Castellani and Zanfei 2007; Siedschlag and Zhang 2015, OECD 2009). International trade can affect the speed and direction of innovation (Grossman and Helpman (1990, 1995). A firm operating in international markets may be in a better position to benefit from profit opportunities resulting from their own innovation which in turn incentivises firms to invest in innovation. However, note that the commonly found correlation between exporting and innovation may reflect the fact that innovation enables the firm to succeed at export markets, not necessarily the effect of exporting itself on innovation, as shown for example in Cassiman and Golovko (2011).

We add to understanding the role of internationalisation of services activities by investigating the role of internationalisation in different stages of the CDM model. Internationalisation and exposure to the international context can affect firm's own investments in R&D by increasing incentives to engage in

implementation of a new organisational method in the firm's business practices, workplace organisations or external relations (OECD 2005)." A further type of innovation that affects the benefits from product innovation is marketing innovation. According to the Oslo Manual (OECD 2005 and European Commission), "a marketing innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing." The aim of marketing innovation is to increase sales of the firm by improved addressing of customer needs, opening up of new markets and positioning firm's goods or services on the market

R&D, but it can affect innovation outputs and productivity also through potential knowledge transfer from abroad (Castellani and Zanfei 2007, de Loecker 2007, Wagner 2011, Bratti and Felice 2012).

The CDM model attempts to correct for selectivity and simultaneity biases in linking R&D and firm productivity. For example, it corrects for the selectivity into doing R&D by explicitly modelling the choice of the firm of engaging or not engaging in innovation investments (including R&D). The model handles some of the endogeneity in R&D and innovation. The CDM model has been widely used during the last decades for investigating the drivers and impediments of the innovation process of firms both in developed and also emerging economies,[9] allowing the analysis of issues like the Schumpeterian hypotheses about firm size and monopoly power, influences of public innovation support and FDI, and a variety of effects of R&D and co-operation on innovation outputs and performance. The majority of these studies have focused on the analysis of data from the manufacturing sector, with a clear need for more comparative country studies of these relationships in the services sector.

The results from empirical applications of the CDM model clearly confirm the importance of own R&D in shaping innovation outputs (e.g. OECD 2009). A common finding from the 1st and 2nd stage in these models (see e.g. Griffith et al. 2006) is that firm size is strongly associated with the firm's propensity to engage in innovation investments, but does not necessarily affect the innovation intensity and the share of new or modified products in sales. Government support for innovation is usually found to lead to an increase in firm's own R&D (e.g. Czarnitzki et al. 2006). Co-operation or knowledge flows from external partners is a vital ingredient in the innovation success (Cassiman and Veugelers 2006), in addition to own R&D and often complementary with own R&D. Co-operation with suppliers matters for process innovation, while co-operation with clients for product innovation (e.g. Griffith et al. 2006, among others).

Measuring productivity and the impact of innovation on productivity

The central relationship in the CDM model that we are interested in is between innovation and productivity, and as the focus of our empirical analysis is on the services sector, especially between non-technological innovation and productivity. On average, there is a positive relationship found in the empirical literature between innovation and productivity or productivity growth (Hall 2011, Hall and Mairesse 2013, Mairesse and Mohnen 2010). However, studies using the standard available revenue-based productivity indicator find sometimes significant differences between the effects of product and process innovation, reflecting the potentially different effects on real output and revenue-based measures of productivity.

[9] This international evidence has been reviewed by Mairesse and Mohnen (2010) and Hall (2011).

Productivity is defined as a measure of the efficiency of production reflecting how much output is obtained with a given set of inputs.[10] The standard theoretical model to measuring productivity is derived from a Cobb-Douglas production function as follows:

$$Y = AC^{\alpha}L^{\beta} \quad (1)$$

Y denotes output, *A* is technological level, *C* is tangible capital stock and *L* is labour input. α, β are elasticities of output with respect to changes in tangible capital and labour inputs.

For the purposes of measurement and econometric estimation of the production function, the logarithm of Equation (1) is:

$$y_{it} = a_{it} + \alpha c_{it} + \beta l_{it}, \quad (2)$$

where *i* denotes the firm, *t* the time period, a_{it} is the total factor productivity (TFP).

While productivity should be measured in quantities, what is typically observed in the micro data is revenue-based productivity. To the extent that product quality and market power are reflected in prices, revenue-based productivity could be influenced by prices. The assumption made in the literature is that deflated revenue reflects accurately the producer's output. In reality, in the world with market power of firms and lack of idiosyncratic price indexes, this is of course not the case.

The simple model that we use to illustrate the effects of various types of innovation on revenue based productivity follows in detail the outline in Hall (2011). We add to Hall's econometric framework organizational and marketing innovation.

We first take into account that our observed measure of output is not physical output but real revenue *r*. If firms are able to exercise market power and have idiosyncratic prices, what we observe as an outcome variable for our econometric analysis is real revenue *r*, where $r_{it} = p_{it} + y_{it}$ (all variables in logs, p – idiosyncratic price).

In order to write down the revenue function, we first define an iso-elastic demand equation for each firm *i* as (in logs):

$$y_{it} = \eta p_{it} \quad (3)$$

Here η is the demand elasticity, $\eta < 0$. y_{it} denotes here the log of demanded quantity.

Combining equations (2) and (3), yields (as in Hall 2011, p.179) an equation for the observed revenue as a function of capital, labour and TFP.

[10] See Syverson (2011) for a recent review of productivity measurement issues.

$$r_{it} = \frac{\eta+1}{\eta}\left(a_{it} + \alpha c_{it} + \beta l_{it}\right) \tag{4}$$

In order to investigate how innovation affects the measured revenue and revenue-based productivity, we add to the analysis a measure of the knowledge stock *K.* We note that the knowledge stock can affect the revenue-based performance measure through its effects on the production function and through the demand function. Firms engage in innovation both to improve production efficiency and to gain monopolistic advantages in the market. In logs, k_{it}^{S} is the knowledge stock that enters and affects the production function, k_{it}^{D} is the knowledge stock that enters and affects the demand function. Both types of knowledge stocks result from previous investments in innovation.

An augmented production function with knowledge stock k_{it}^{S} is (in logs):

$$y_{it} = a_{it} + \alpha c_{it} + \beta l_{it} + \gamma k_{it}^{S}, \tag{5}$$

where $\gamma > 0$.

The knowledge stock k_{it}^{S} that is relevant for production efficiency is affected especially by past process innovation and also organizational innovation. These both, separately or jointly, affect production efficiency at the firm.

The augmented demand equation is the following.

$$y_{it} = \eta p_{it} + \varphi k_{it}^{D}, \tag{6}$$

where $\varphi > 0$.

k_{it}^{D} is the knowledge capital stock that affects demand, i.e. creates monopolistic advantages for the firm. Typically this knowledge stock would depend especially on product innovation, but also marketing innovation. Both of these, separately or jointly, would shift the demand curve outwards and make the firm's products or services more attractive for its consumers at a given price level, enabling to increase sales at a given price level.

Combining equations (5) and (6) into a revenue function $r_{it} = p_{it} + y_{it}$ yields:

$$r_{it} = \frac{\eta+1}{\eta}\left(a_{it} + \alpha c_{it} + \beta l_{it}\right) + \left(\frac{\gamma(\eta+1)}{\eta}\right)k_{it}^{S} - \frac{\varphi}{\eta}k_{it}^{D} \tag{7}$$

The above equation shows how the knowledge stock at the firm level affects the real revenue and therefore measured productivity. The effects that work through k_{it}^{D} are unambiguously positive (note that $-\varphi/\eta$ is positive as η is negative): i.e. product and marketing innovation have positive effects on revenue and revenue-based productivity. The effects of process and organizational improvements k_{it}^{S}

on revenue ($\gamma(\eta+1)/\eta$ are in fact ambiguous and depend on market power of the firm (Hall 2011). These effects are positive, unless demand is very inelastic. These broad predictions have been confirmed in empirical analyses. Hall (2011) provides a thorough review on this evidence. The effects of product innovation on the revenue-based productivity are usually found to be positive. The results about process innovation are more varied, negative, statistically not significant and positive results have been found (e.g. OECD 2009). This could reflect that product innovation (and marketing innovation) create market power effects that increase revenues, and efficiency improvement due to process (and organisational) innovation may not be visible in revenue-based measures if they result in lower prices and no corresponding growth in output (Mohnen and Hall 2013).

The general framework above does not address specifically the *complementarities* between different investments in knowledge capital. However, these are likely to be important among the effects of innovation on productivity. A typical characteristic of the innovation process is that many innovation activities tend to be adopted together and this bundling of activities is often likely to lead to stronger effects on innovation performance or productivity (e.g. Cassiman and Veugelers 2006, Polder et al. 2009, Battisti and Stoneman 2010, Love et al. 2014, Siedschlag and Zhang 2015). Milgrom and Roberts (1990, 1995) and Brynjolfsson and Milgrom (2013) emphasize the role of complementarities in organisational and technology-oriented innovative activities. In general, we can say that two activities are (Edgeworth) complementary if adding (more of) one activity increases the returns from the other.[11]

It is by now well established that there may be complementarities between product innovation and process innovation (e.g. Miravete and Pernias 2006, Martinez-Los and Labeaga 2002, Polder et al. 2009) as production of a new product or service requires often changes in the production process to realise its full effects. Also, there is abundant evidence that there are complementarities of organizational innovation with both process and product innovation. For example, this has been shown to be important in services sector of Netherlands and in Ireland (Polder et al. 2009; Siedschlag and Zhang 2015).

Most relevant to the key contributions of this study is the conclusion that there may be complementarities of marketing innovation and other types of innovation. This is discussed in a seminal contribution to the analysis of complementarities between firm's activities in Milgrom and Roberts (1990). In a recent contribution, Junge et al. (2016) point to likely complementarities between

[11] Complementarities exist between factors (X_i, X_j) when the mixed-partial derivatives of a payoff function $\Pi(X_i, X_j, Z)$ are positive: $\frac{\partial^2 \Pi(X_i, X_j, Z)}{\partial X_i \partial X_j} > 0$, i.e. if an increase in the level of adoption of one variable (X_i) raises the marginal payoff of the other variable(s) (X_j) (Milgrom and Roberts 1990, 1995). Note: Z denotes other exogenous determinants of payoff.

product and marketing innovation, as marketing innovation strengthens the growth effect of product innovation. That means that firms that introduce at the same time new products and also engage in improvements of design and put in effort to develop new sales or distribution or packaging methods for these products, would be expected to perform significantly better than firms that introduce these innovations separately.

We can conclude that the four types of innovation outlined here can affect revenue-based productivity through their individual and complementary effects with other types of innovation, with their effects functioning both through impacts on production efficiency and through effects on demand. Given the large number of complementary innovations to be considered and compared in the context of the three countries, in this paper we focus on the individual effects of the four technological and non-technological innovations on productivity in services.

3 Data, Variables and Summary Statistics

In order to compare the impact of innovation on productivity in the service sector, we use data from the Community Innovation Survey (CIS) 2008 from Germany, Ireland and the UK. The CIS is a bi-annual European-wide harmonized survey on innovation activities of firms administered by Eurostat and in most countries carried out by the National Statistical Offices. It is a stratified random sample, stratified by firm size and 2-digit industries (as well as region in Germany). In each country, it is representative for the target population of enterprises[12] with more than 10 employees. For each enterprise we observe basic firm characteristics in the data such as sales, employment, industry belonging, whether it is part of a group and whether it is exporting. In addition, CIS provides detailed information about a firm's innovation process like innovation expenditure, different types of innovation outcomes, cooperation partners etc. The data we use is a cross-sectional data set in which most variables, however, cover the three-year period 2006–2008.[13] Exceptions are e.g. sales and employment which are annual data available for the first and last year of the period, i.e. 2006 and 2008. Our analysis focuses on market services, including the following service sectors: wholesale trade; transport, storage and communications; financial services; computer and related activities; and other business activities.[14] Unfortunately, data confidentiality requirements prevent us from merging the CIS data of the three countries. Instead of analysing a pooled sample, we will investigate the relationship between

[12] The term enterprise and firm are used interchangeably.

[13] The specific characteristics of the data collected with CIS and related implications for econometric analysis are discussed extensively by Mairesse and Mohnen (2010). Our econometric methodology discussed above deals, as satisfactorily as possible, with the qualitative and censored nature of the data.

[14] A number of service sectors (e.g. retail) that are available in the CIS for Germany and the UK are excluded to facilitate comparison with the CIS data for Ireland.

innovation input, output and productivity for each country separately. In total, the samples consist of the following numbers of service enterprises in the three countries analysed: 1,333 in Germany; 1,286 in Ireland; and 4,344 in the UK.

Table 1 shows the weighted summary statistics[15] for services enterprises for the main variables used in the empirical analysis as well as the definition of the variables. The summary statistics reveal a lot of heterogeneity in terms of size, innovation and productivity performance across the three countries.

[Table 1 about here]

Looking at the sample composition, we find the UK sample to consist of on average larger firms (86 employees) than in Germany (50.5 employees) and in Ireland (50.4 employees). Firm size is measured by SIZE calculated as log number of employees. But note that the mean number of employees is substantially higher in the UK than the median number of employees due to some very large enterprises in the sample.[16]

Our key interest is in explaining productivity impacts of innovation in services. As explained in Section 2, we measure productivity as labour productivity (LP), i.e. sales per employees in year 2008. Table 1 reveals large variation across countries: average labour productivity of service firms in Ireland is 3.7 times higher than in Germany and 2.3 times higher than in the UK.

Interestingly, the descriptive statistics indicate that the better productivity performance in Ireland is accompanied by a higher innovation input intensity. The latter is measured as the log innovation expenditure per employee in year 2008 (INNOEXP). Innovation expenditure is a broader concept than R&D expenditure (RDEXP). In addition to expenses for intramural and extramural R&D, it covers expenses for the acquisition of machinery, external knowledge, training, product preparation and marketing related to innovation activities. Since many service firms innovate without investing in formal research and development (R&D) activities as is impressively shown in Table 1 as well, using the broader concept of innovation expenditure seems to be more appropriate in order to measure service firms' innovation efforts. The average innovation expenditure per employee (across enterprises) is in Ireland higher than in Germany (2.3 times higher) or the UK (9 per cent higher). However, the proportion of service firms that decide to invest in innovation (INNO) in the first place, is highest in the UK. 51 per cent of UK service firms report innovation expenditures, whereas the

[15] For comparability purposes, these summary statistics are weighted to correct for the stratification of the CIS sample by size class, industry and region. Weighting factors are provided the statistical offices (IE and UK) and The Centre for European Economic Research (ZEW) which conducts the survey in Germany on behalf of the Federal Ministry of Education and Research. Discrepancies to published statistics may arise because our focus here is on the estimation sample.

[16] The sampling unit in the UK is the establishment rather than the enterprise (though the vast majority of establishments are in fact single establishment enterprises). Exclusion of the top 0.5% of establishments by employee size brings the mean number of employees in the UK service sector establishments much closer to that in Germany and Ireland.

corresponding figures for Germany and Ireland are substantially lower (37 per cent and 26 per cent, respectively).

Different and mixed results are found when considering innovation output indicators. The CIS data allow us to differentiate between two types of technological innovation: new and significantly improved products (PROD) and processes (PROC), respectively. Product innovation refers to the introduction of new or significantly improved goods and services within a three-year period (2006-2008). The highest proportion of product innovators can be found in the UK (30.3 per cent), closely followed by Germany (28.6 per cent) and Ireland (24.7 per cent). In contrast, Ireland is leading when it comes to process innovations. Within product innovation, we can further differentiate between those new to the market (MARKET) and only new to the firm (FIRM). While UK and Ireland have a much stronger focus on market novelties, Germany is by far leading in terms of service firms adopting innovations. This pattern is different from manufacturing where Germany is the leading country for both types of product innovation.

In addition to the two technological innovation output indicators, CIS also provides two non-technological innovation output measures: organisational innovation (ORGA) and marketing innovation (MARK). Organisational innovation refer to the introduction of new or significantly changed business practices, workplace organisations or changes in external relationships in the three-year reference period. Marketing innovation is a binary variable taking the value one when firms have significantly changed product design or packaging, product placement, promoting or pricing. The predominant type of innovation in service enterprises appears to be organisational innovation in Ireland and the UK, and marketing innovations in Germany. However, in Germany the share of service enterprises with organisational innovations is only slightly lower than the share with marketing innovations. Furthermore, both marketing and organisational innovations are substantially higher in Germany than in Ireland and the UK.

In addition to heterogeneity in innovation investments, differences in innovation outcome might also be explained by differences in the innovation process itself leading to innovation efficiency differences. For instance, Table 1 shows that firms differ in their engagement to cooperate in innovation activities with other actors like customers (COOP_CUST), suppliers (COOP_SUP), consultants (COOP_CON), universities (COOP_UNI) or public research institutes (COOP_PUB). The patterns of engagement in cooperation for innovation activities differ in the three countries, with the highest engagement rates reported in the UK. Amongst cooperation types, the highest engagement rates in all three countries are reported for cooperation with suppliers and cooperation with clients or customers.

In addition to productivity, innovation input and output measures, our empirical specification, explained in more detail in the subsequent section, will use information on the degree of internationalisation of firms. We distinguish between three types of firms: firms which are a subsidiary of a foreign company (FOREIGN), domestic firms being active on the export market (DOM_EXP) and domestic non-exporters (DOM_NONEXP). While the proportion of domestic exporting service firms is pretty similar across countries, Ireland has a substantially higher proportion of foreign-owned firms.

4 Econometric Methodology

To analyse the relationships between innovation inputs, innovation outputs and productivity, we estimate an augmented version of the widely used structural model proposed by Crépon, Duguet and Mairesse (1998), known as the CDM model. The CDM model estimates three groups of relationships linking innovation and productivity. The first group consist of two equations explaining the propensity of enterprises to invest in innovation and the innovation expenditure intensity. The second relates the various types of innovation outputs to innovation expenditure intensity and to other determinants of innovation. The third links productivity to innovation outputs and other determinants of firm-level productivity.

We estimate an augmented version of the original CDM model underpinned by the theoretical and empirical literature discussed in Section 2. More specifically, we add to the original CDM model non-technological innovation outputs and explanatory variables that measure internationalisation of service enterprises and their engagement in cooperation for innovation activities within national innovation systems.

Below, we describe in more detail the augmented version of the CDM model that we have estimated in this paper.

The innovation investment equations

This stage of the model comprises two equations that explain the firms' decision to invest or not to invest in innovation and, if investing, the amount of innovation expenditure per employee. However, we only observe the innovation expenditure reported by innovative firms. To the extent that this group of firms is not random, this implies a possible selection bias. To account for this potential bias, the propensity of firms to invest in innovation is modelled by the following selection equation:

$$y_i = \begin{cases} 1 \;\; if \;\; y_i^* = x_i\gamma + u_i > \tau \\ 0 \;\; if \;\; y_i^* = x_i\gamma + u_i \le \tau \end{cases} \qquad (8)$$

where y_i is an observed binary variable which equals one for firms engaged in innovation investment, or zero for the rest of the firms. Firms engage in innovation and/or report innovation expenditure if y_i^*, an unobserved latent endogenous variable, measuring the propensity to innovate, is above a certain threshold level τ. The latent variable can be interpreted as a decision criterion, such as the expected present value of a firm's profit accruing to innovations. x_i is the vector of the variables explaining the innovation decision, γ is the vector of parameters and u_i is the error term.

The vector of independent variables to explain the propensity of enterprises to invest in innovation includes enterprise characteristics such as size, indicators of engagement in international activities (international investment and exporting) and NACE three-digit industry dummies. As highlighted by the previous literature (for example, Crépon, Duguet and Mairesse 1998; Mairesse and Mohnen 2002; Griffith et al. 2006), enterprise size captures the effect of access to finance, scale economies and different organisation structures, while industry dummies proxy unobserved industry-specific technological opportunities, intensity of competition, demand growth and industry-targeted innovation policies.

Conditional on investing in innovation, the innovation intensity measured as the amount of innovation expenditure per employee (w_i) is given by the following equation:

$$w_i = \begin{cases} w_i^* = z_i\beta + \omega_i, & if\ y_i = 1 \\ 0 \quad if \quad y_i = 0 \end{cases} \qquad (9)$$

where w_i^* is the unobserved latent innovation intensity variable, z_i is a vector of enterprise and industry characteristics (engagement in international activities and NACE-three digit industry-specific effects) explaining innovation intensity and ω_i is an error term.

We allow the error terms of both equations to be correlated and assume that they follow a bivariate normal distribution with zero mean, variances σ_u^2 and σ_ω^2 and correlation coefficient ρ. Equations (8) and (9) are thus simultaneously estimated using the Heckman two-step estimator (Heckman 1976, 1979). For identification purposes, we follow Griffith et al. (2006) and exclude enterprise size in Eq. (9). Excluding size corresponds to the stylised fact established by Cohen and Klepper (1996). Their survey of empirical evidence led them to conclude that among R&D performers, R&D expenditure rises monotonically with enterprise size. This implies that R&D intensity, measured as R&D expenditure per employee, is independent of enterprise size.

The innovation output equation

This second stage of the model explains the innovation outcomes given by the following innovation production function:

$$g_i = \overline{w_i}\alpha + h_i\delta + e_i \quad (10)$$

where g_i is the innovation output proxied by the product, process, organisational or marketing innovation indicators, and $\overline{w_i}$ is the predicted innovation expenditure per employee estimated from the selection model. These values are predicted for all the enterprises and not just for the sample reporting innovation expenditure. By doing this, we follow the modified CDM approach suggested by Griffith et al. (2006).[17] By using the predicted, rather than the observed, values of the innovation effort w_i, we account for the possibility that the innovation expenditure per employee and the innovation outputs could be simultaneously determined. Equations (8) and (9) correct for the endogeneity in this instrumental variables approach. The three-digit industry dummies used in estimating Equations (8) and (9) are excluded in estimating Eq. (10); instead, we use two-digit industry dummies when estimating Eq. (10) (note, the statistical tests validate these exclusion restrictions). h_i is the vector of the other determinants of innovation output, namely enterprise size, indicators of engagement in international activities, and indicators of engagement in co-operation for innovation activities. α and δ are the parameter vectors, and e_i is the error term.

The output production equation

The last stage of the model explains the output production as a function of production inputs including innovation outcomes, as follows:

$$p_i = k_i\lambda + \overline{g_i}\mu + \nu_i \quad (11)$$

where p_i is the labour productivity (log of sales per employee), k_i is a vector that includes employment and other enterprise and industry characteristics, $\overline{g_i}$ denotes the innovation outcomes (product, process, organisational and marketing innovations), λ and μ are the corresponding parameters vectors, and ν_i is the error term. Due to data limitations, variation of capital intensity is captured at industry-level by industry-specific fixed effects. To correct for the fact that innovation output and productivity could be simultaneously determined, the predicted innovation output estimated in the previous stage by Eq. (10) are used for g_i.

[17] In the original CDM model, this equation was only estimated for the sample of innovative enterprises.

5 Empirical Results

Tables 2 to 5 show the estimates of the augmented CDM model for innovation and productivity in service enterprises in Germany, Ireland and the UK over the period 2006-2008.

Table 2 presents the estimates of the Heckman two–stage model of innovation investment. The propensity to invest in innovation (first stage) is estimated by a probit model as a function of enterprise size (measured by the log number of employees in 2008), international activities (a dummy variable which is equal to one for foreign-owned enterprises, and zero otherwise), exporting (a dummy variable which is equal to one for domestic exporters, and zero otherwise) and industry specific effects (industry dummies at the three-digit NACE Rev. 1 classification). The innovation expenditure intensity is measured as the log innovation expenditure per employee in 2008 and is estimated as a function of ownership, exporting and industry specific effects. Following Griffith et al. (2006), we use the enterprise size as an exclusion restriction in the innovation investment equation. The figures shown in Table 2 are marginal effects.

[Table 2 about here]

Our results indicate that service enterprises that invested in innovation are more likely to be large enterprises and enterprises with export markets. Domestic exporters are more likely to invest in innovation by 15.3 percentage points in Germany, by 16.5 percentage points in Ireland and by 9.3 percentage points in the UK. In Germany and the UK, innovation expenditure intensity is likewise significantly higher for domestic service enterprises with export markets, than for domestic non-exporters and foreign-owned enterprises, while in Ireland, foreign-owned enterprises have a significantly higher innovation expenditure intensity. Conditional on investing in innovation, the innovation expenditure intensity in domestic exporters is significantly higher than in firms serving only the domestic market: by 40% in Germany and by 69% in the UK. The intensity of innovation expenditure in foreign-owned firms is higher by 96% in Ireland, almost double than in Irish-owned non-exporting firms. In the UK, both foreign-owned enterprises and domestic exporters show significantly higher innovation intensity than domestic non-exporters by 38% and 69%, respectively. Furthermore, industry-specific characteristics matter for the decision to invest in innovation in services as they are highly significant. The likelihood ratio test on whether $\rho = 0$ rejects the null hypothesis, and hence, selection bias has to be corrected for.

Table 3 shows the estimates of the determinants of product innovation in the three countries analysed. In addition to the indicator for product innovation, it distinguishes between product innovations that are new to the market (market novelties) and those that are only new to the firm enterprise but not new to the market (firm novelties). The dependent variable is a categorical variable

that takes the value of one if product innovation was reported in the period 2006-2008, or zero otherwise. The explanatory variables include the innovation expenditure intensity predicted on the basis of the innovation investment equations,[18] enterprise size, ownership, exporting, engagement in cooperation for innovation activities (dummy variables are equal to one if cooperation was reported, or zero otherwise) and industry specific effects (industry dummies at a two-digit level NACE Rev. 1 classification[19]). Since the predicted innovation expenditure intensity has been estimated in the first stage and is thus a generated regressor in the innovation outcome equation, standard errors will be biased. We address this problem by estimating bootstrapped standard errors (using 300 replications).[20]

[Table 3 about here]

The results in Table 3 highlight that a higher innovation expenditure intensity significantly increases the likelihood of successfully introducing product innovations in services (in Ireland these effects are positive but not statistically significant). An increase by 1% in the innovation expenditure intensity is associated with an increase in the probability to introduce product innovation by 8.3 percentage points in Germany, and by 5.5 percentage points in the UK. The probability of implementing product innovations is also higher for large enterprises (not in the UK's case), and for enterprises with exporting markets. In Ireland, foreign-owned enterprises were more likely to successfully implement product innovations by 42.1 percentage points, in particular as market novelties (an increase by 40.4 percentage points). In all three countries, service enterprises that are engaged in cooperation for innovation activities with other enterprises within the same enterprise group are more likely to successfully introduce a product innovation. The same result is found for cooperation with suppliers (Ireland and the UK); cooperation with customers (Germany and the UK); with universities (Germany); and with public research labs (the UK). Cooperation with the science base (universities in Germany or public research labs in the UK) has an impact, particularly for introducing market novelties in services. The strong association between co-operation in innovation activities and enterprise innovation performance reflects the similarities and differences in innovation policy in the three countries: science-collaboration in Germany; science-competitive in Ireland; and commercialisation-driven in the UK.

[18] OLS regressions indicate in all three countries large and highly significant correlations between the observed innovation expenditure intensity and the predicted innovation expenditure intensity. These results are available from the authors upon request.

[19] The industry dummies are at a two-digit level NACE Rev. 1 classification to ensure the identification of the determinants of innovation outputs, as we used three-digit industry dummies in the innovation expenditure intensity equation. Wald tests validate the exclusion of three-digit industry dummies.

[20] We thank an anonymous referee for making this point.

Table 4 shows the results of the probit model for other innovation outputs, namely, process, organisational and marketing innovations in service enterprises in the three countries analysed. The dependent variables in the probit models are binary variables, which take the value of one if the respective innovation output was reported in the period 2006-2008, and zero otherwise.

[Table 4 about here]

As shown in Table 4, process innovation in service enterprises is more likely in larger enterprises, in enterprises with higher innovation expenditure intensity (Germany and the UK), and in foreign-owned and exporting enterprises (in Ireland). An increase of 1% in the number of employees is associated with a higher probability to introduce process innovations in all three countries: by 7.6 percentage points in Germany; by 7.9 percentage points in Ireland and by 1 percentage point in the UK. An increase in the innovation expenditure intensity by 1% is associated with an increase in the probability to introduce process innovations by 8.9 percentage points in Germany and by 2.7 percentage points in the UK. In Ireland, relative to enterprises which serve only the domestic market, the propensity of foreign-owned firms to introduce process innovation is higher by 31 percentage points. Irish-owned exporters are more likely by 28.2 percentage points than non-exporters to introduce process innovations. Moreover, successful process innovation was positively linked to engagement in cooperation for innovation activities with other enterprises (Germany and the UK), with suppliers (Ireland and the UK), with customers (all three countries) and with consultants (Ireland and the UK) and universities (Ireland). In contrast, in the sample analysed, in the UK, service enterprises cooperating with competitors were less likely to introduce process innovations.

Furthermore, our results indicate that organisational innovation in service enterprises is more likely in larger enterprises, in enterprises with higher innovation expenditure intensity (Germany and the UK), in foreign-owned enterprises (Ireland and the UK), and amongst domestic exporters (Ireland). A 1% increase in the number of employees is associated with a probability to introduce organisational innovation higher by 6.1 percentage points in Germany, by 16.6 percentage points in Ireland and by 3.5 percentage points in the UK. Innovation expenditure intensity higher by 1% is associated with a probability to introduce organisational innovations higher by 5 percentage points in Germany and by 2.9 percentage points in the UK. Foreign-owned enterprises are more likely than domestic non-exporters to introduce organisational innovations by 30.1 percentage points in Ireland and by 5.9 percentage points in the UK. Organisational innovations are also more likely in Irish-owned exporters than in non-exporters, by 44.9 percentage points. Moreover, the successful implementation of organisational innovation in service enterprises was positively linked to cooperation in innovation activities with other enterprises within the same enterprise group (Germany and the UK), and with suppliers and customers (Ireland and the UK). In contrast, in Germany, service enterprises that

cooperated with public research institutes were less likely to successfully implement organisational innovations.

Finally, Table 4 indicates that marketing innovations in service enterprises were more likely among enterprises with higher innovation expenditure intensity, larger enterprises (Germany and Ireland), and for domestic exporters (Ireland). A 1% increase in the number of employees is associated with a probability to introduce marketing innovations higher by 3.8 percentage points in Germany, and by 7.5 percentage points in Ireland. Innovation expenditure per employee higher by 1% is associated with a probability to introduce marketing innovations higher by 5.5 percentage points in Germany, by 14.9 percentage points in Ireland and by 2.3 percentage points in the UK. Irish-owned exporters are more likely by 26 percentage points than non-exporters to introduce marketing innovations. Moreover, the successful implementation of marketing innovations is positively linked to cooperation with other enterprises within the same enterprise group (Germany), with suppliers (Ireland and the UK), with customers (the UK), and with universities (Germany). Once again the patterns of the links between co-operations in innovation and innovation performance seem to reflect the specificities of the innovation policy frameworks in the three countries.

Table 5 shows the estimates of the productivity equation for service enterprises in the three countries analysed. The dependent variable is labour productivity measured as turnover per employee. The explanatory variables include the predicted innovation outcomes for (product, process, organisational or marketing innovations, enterprise size, ownership, and exporting. Unfortunately, the CIS data does not contain data on the physical capital in all three countries. We control for differences in capital endowment by including industry dummies at the three-digit level (NACE Rev. 1 classification). The productivity equation for Germany also includes a dummy variable which is equal to one for enterprises located in East Germany, since even 20 years after reunification, there is a productivity gap between firms in West and East Germany. Similar to the argument made for predicted innovation expenditure in the innovation outcome equation, we have to address the fact that predicted innovation outcome is a generated regressor in the productivity equation. To account for possible errors in the estimated values of the predicted innovation outcome and the resulting bias in the standard errors, we bootstrap standard errors in the productivity equation using 300 replications.

[Table 5 about here]

The results shown in Table 5 indicate that innovative service enterprises had higher productivity. This positive link is evident for all types of innovation in Germany (except for market novelties) and the UK; in Ireland innovation was also positively correlated with productivity, but it was statistically significant

only for process and marketing innovations.[21] In all three countries, the largest productivity returns were found for marketing innovations.

The productivity returns to innovation vary by innovation type across the three analysed countries. Labour productivity in enterprises with product innovations is higher by 16.3% in Germany and by 4.3% in the UK. While the strongest link in Germany is for firm novelties (27%), in the UK the productivity elasticity is highest for market novelties (5.5%). In Ireland, product innovations do not appear to impact significantly on the productivity of services enterprises.

Enterprises with process innovations have a higher labour productivity by 21.1% in Germany, 17.4% in Ireland and 6.5% in the UK. The productivity returns to introducing organisational innovations are 22.6% in Germany and 5.6% in the UK. In Ireland, organisational innovations do not seem to be significantly associated with productivity performance. Finally, marketing innovations are associated with productivity gains of 32.0% in Germany, 25.9% in Ireland and 7.0% in the UK.

The estimates furthermore indicate that foreign-owned enterprises and domestic exporters are more productive than enterprises with no international activities in the service sector. These results are in line with the literature on international trade with heterogeneous firms discussed in Section 2, mainly based on manufacturing firms.

6 Summary and Policy Implications

This paper examines the links between internationalisation, innovation inputs, innovation outputs and productivity in service enterprises. For this purpose, we estimate a structural model using micro data from the Community Innovation Survey over the period 2006-2008 from Germany, Ireland and the UK to answer the following research questions: (i) What types of service enterprises are more likely to invest in innovation? (ii) What types of service enterprises have higher innovation investment per employee? (iii) Does higher investment in innovation lead to higher innovation output in service firms and is this effect the same for different types of innovation? (iv) Is higher innovation output linked to higher productivity in service enterprises? To what extent do productivity effects differ by type of innovation? (v) Are there any cross-country differences in the relationships between internationalisation, innovation input, innovation output and productivity for service firms?

While the cross-sectional nature of the CIS data we analyse does not allow us to draw conclusions about causality, we identify a number of structural stylized facts which are informative for both research and policy design.

[21] The elasticity of productivity with respect to marketing innovation in Ireland is significant at the 11% level.

The predominant innovation types in service enterprises over the period analysed in the three countries are organisational and marketing innovations.

Our empirical evidence highlights the importance of internationalisation in the context of engagement in innovation and innovation outputs in all three countries. For all types of innovations, innovation rates are the highest in enterprises with international activities (foreign-owned and domestic exporters) in Ireland and the UK. In Germany, this is true only for domestic exporters with product innovations.

Our econometric analysis reveals that investment in innovation in service enterprises is more likely in larger enterprises and in enterprises with export markets. Conditional on investing in innovation, we then find a link between the internationalisation activities of service enterprises and the degree to which they invest in innovation. In comparison to enterprises that serve only domestic markets, in Ireland and the UK, the innovation expenditure per employee is significantly higher in foreign-owned enterprises, while in Germany, this was the case for German-owned enterprises with export markets. Innovation expenditure intensity is positively and significantly linked to all innovation outputs in Germany and the UK, while in Ireland this result holds true only in the case of marketing innovations.

Further, our results illustrate the importance of knowledge and technology transfer for successful innovation in service firms. Over and above enterprise size, innovation expenditure intensity (in Germany and the UK), foreign ownership (Ireland) and exporting, successful innovation in service enterprises appears to be positively associated with engagement in cooperation for innovation activities with other enterprises (suppliers and customers) and with knowledge providers (universities, public and private research institutes, consultants). In contrast, cooperation for innovation activities with competitors is associated with a lower probability to innovate.

Innovation in service enterprises appears positively and significantly linked to labour productivity for all types of innovation in Germany and the UK. In Ireland, this positive link is statistically significant only in the cases of process and marketing innovations. In all three analysed countries, the largest productivity returns in service enterprises are found for marketing innovations. The productivity elasticity with respect to marketing innovations is estimated to be 0.32 in Germany, 0.26 in Ireland and 0.07 in the UK. Given the specificities of services, this result is noteworthy. It could be interpreted as indicating a positive link between marketing innovations and demand for new or improved services. It also highlights the importance of investment in intangible capital items such as organisational capital for productivity growth in services.

The similarities and differences in the relationships between internationalisation, innovation and productivity in the three analysed countries may reflect their institutional framework for innovation

policy as well as their structural characteristics such as economic size and engagement in internationalisation.

Our findings suggest that innovation in service enterprises could benefit from many of the policies designed to incentivise and foster innovation in manufacturing enterprises, such as policies which enable firm growth, and which enhance innovation capability and cooperation in innovation activities with other enterprises and knowledge providers. In addition, our results suggest that targeting resources to foster marketing innovation in service enterprises would be beneficial in terms of productivity.

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Table 1. Summary statistics of the services samples, CIS 2008

		Services		
		GERMANY	IRELAND	UK
Productivity				
Labour productivity (turnover per emp., euros)	LP	242,600	897,863	389,850
Enterprise characteristics				
Size (number of employees)	SIZE	50.5	50.4	86.0
Foreign-owned (%)	FOREIGN	3.1	18.6	8.3
Domestic exporter (%)	DOM_EXP	32.5	31.7	29.2
Domestic non-exporter (%)	DOM_NONEXP	64.5	49.7	62.5
Innovation inputs				
Decision to invest in innovation (%)	INNO	36.6	25.9	50.7
Innovation expenditure per employee (euros)	INNOEXP	2 131	4 969	4 547
Decision to invest in R&D (%)	RD	14.3	14.6	28.1
R&D expenditure per employee (euros)	RDEXP	697	2 094	2 826
Innovation outputs				
Product innovation (%)	PROD	28.6	24.7	30.3
Market novelties (%)	MARKET	9.0	15.1	14.6
Firm novelties (%)	FIRM	25.2	18.1	22.7
Process innovation (%)	PROC	27.5	29.9	18.8
Organisational innovation (%)	ORGA	39.1	32.2	32.9
Marketing innovation (%)	MARK	39.3	26.5	24.4
Cooperation for innovative activities with…				
other enterprises within the same group (%)	COOP_GRP	2.5	4.9	17.0
suppliers (%)	COOP_SUP	2.5	5.7	20.9
clients or customers (%)	COOP_CUST	2.0	5.4	25.4
competitors (%)	COOP_COMP	1.2	2.8	11.4
consultants, commercial or private R&D labs (%)	COOP_CON	2.1	2.9	9.3
universities or other higher education institutes (%)	COOP_UNI	2.0	3.3	8.1
government or public research institutes (%)	COOP_PUB	0.4	1.8	8.1
Observations		1333	1286	4344

Notes: Innovators are enterprises that report having at least one of the following types of innovation: product, process, organisational or marketing innovation. Enterprises reporting no innovation are considered non-innovators. The samples are weighted by number of enterprises stratified by size class, industry and region. UK figures converted from £ to € using the exchange rate £1 = €1.2588 (2008 year average provided by the Bank of England). Labour productivity, size and innovation expenditure per employee are measured in non-log values in Table 1. For the estimation, the log-transformed values of these variables are used in order to account for the high skewness of these variables.

Table 2. Innovation investment in service enterprises, 2006-2008

	GERMANY		IRELAND		UK	
	Selection equation: INNO	Innovation input: INNOEXP	Selection equation: INNO	Innovation input: INNOEXP	Selection equation: INNO	Innovation input: INNOEXP
SIZE	0.085***	-	0.050***	-	0.046***	-
	(0.012)		(0.011)		(0.006)	
FOREIGN	0.033	0.171	0.049	0.962***	-0.070***	0.375**
	(0.066)	(0.254)	(0.037)	(0.271)	(0.026)	(0.148)
DOM_EXP	0.153***	0.399***	0.165***	0.179	0.093***	0.686***
	(0.035)	(0.118)	(0.032)	(0.233)	(0.018)	(0.099)
3 digit Industry FE	yes	yes	yes	yes	yes	yes
Obs.	1333		1286		4346	
Lambda	0.936***		1.5683**		1.828***	
	(0.179)		(0.6055)		(0.139)	
Rho	0.627		0.742		0.822	
Wald test for H0: rho = 0	24.31***		6.37**		130.2***	
Wald test (3-digit Industry FE)	578.06***		3 630.50***		865.59***	
Log-likelihood	-1787.9		-1374.9		-7246.0	

Notes: Estimates obtained with maximum likelihood on a generalised Tobit model. Selection equation: marginal effects on the probability to innovate. Innovation input equation: marginal effects on the expected innovation intensity conditional on investing in innovation. Robust standard errors. CIS 2006-2008. Included in all models but not reported: constant and industry fixed effects (3-digit). * p<0.1, ** p<0.05, *** p<0.01.

Table 3. Impact of innovation input on product innovation outcome in service enterprises, 2006-2008

	GERMANY			IRELAND			UK		
	PROD	MARKET	FIRM	PROD	MARKET	FIRM	PROD	MARKET	FIRM
Pred. INNOEXP	0.083***	0.033***	0.074***	0.127	0.137	0.093	0.055***	0.022***	0.043***
	(0.015)	(0.010)	(0.015)	(0.096)	(0.092)	(0.097)	(0.009)	(0.005)	(0.007)
SIZE	0.022**	0.007	0.029***	0.131***	0.055	0.089**	0.005	0.001	0.002
	(0.011)	(0.006)	(0.010)	(0.045)	(0.046)	(0.041)	(0.006)	(0.003)	(0.005)
FOREIGN	0.012	0.041	-0.006	0.421***	0.404**	0.238	-0.033	0.001	-0.025
	(0.059)	(0.034)	(0.057)	(0.162)	(0.185)	(0.170)	(0.030)	(0.016)	(0.024)
DOM_EXP	0.142***	0.050***	0.148***	0.375***	0.499***	0.206	0.050**	0.040***	0.030*
	(0.036)	(0.019)	(0.032)	(0.122)	(0.152)	(0.141)	(0.022)	(0.012)	(0.018)
COOP_GROUP	0.221**	0.022	0.144**	0.824***	0.717***	0.427*	0.104***	0.038***	0.066***
	(0.094)	(0.041)	(0.071)	(0.270)	(0.241)	(0.233)	(0.025)	(0.014)	(0.021)
COOP_SUP	0.069	0.018	0.062	0.854***	0.425*	0.721***	0.125***	0.035***	0.082***
	(0.111)	(0.045)	(0.090)	(0.258)	(0.247)	(0.223)	(0.022)	(0.013)	(0.019)
COOP_CUST	0.372***	0.091**	0.148*	0.279	0.275	0.382*	0.391***	0.148***	0.267***
	(0.118)	(0.042)	(0.089)	(0.283)	(0.238)	(0.226)	(0.021)	(0.012)	(0.018)
COOP_COMP	-0.022	0.046	-0.035	0.325	0.258	0.144	0.009	-0.000	0.023
	(0.109)	(0.041)	(0.086)	(0.350)	(0.406)	(0.296)	(0.034)	(0.017)	(0.024)
COOP_CON	0.134	-0.019	0.051	0.177	0.241	0.305	0.022	0.023	0.011
	(0.097)	(0.049)	(0.083)	(0.347)	(0.294)	(0.311)	(0.034)	(0.017)	(0.026)
COOP_UNI	0.155	0.094**	0.105	0.599	0.107	0.470	-0.068*	-0.027	-0.026
	(0.102)	(0.039)	(0.089)	(0.416)	(0.334)	(0.296)	(0.040)	(0.023)	(0.033)
COOP_PUB	-0.041	0.046	-0.085	0.131	0.058	-0.342	0.006	0.051**	-0.035
	(0.175)	(0.059)	(0.128)	(0.494)	(0.419)	(0.369)	(0.045)	(0.022)	(0.032)
Obs.	1 333	1 327	1 333	1 256	1 247	1 256	4 346	4 333	4 346
Log-likelihood	-665.7	-385.8	-660.1	-530.4	-451.4	-530.4	-1956.0	-1360.0	-1 851
Pseudo R^2	0.204	0.176	0.174	0.202	0.185	0.152	0.272	0.234	0.211
Wald test (Industry FE)	47.13***	10.99	55.52***	7.46	13.59*	9.37	37.44***	49.61***	10.54

Notes: Reported are marginal effects of probit model estimates; bootstrap standard errors after 300 replications; CIS 2006-2008. Included in all models but not reported: constant and industry fixed effects (2-digit). * p<0.1, ** p<0.05, *** p<0.01.

Table 4. Impact of innovation input on process, organisational and marketing innovations in service enterprises, 2006-2008

	GERMANY			IRELAND			UK		
	PROC	ORGA	MARK	PROC	ORGA	MARK	PROC	ORGA	MARK
Pred. INNOEXP	0.089***	0.050***	0.055***	0.036	0.107	0.149*	0.027***	0.029***	0.023***
	(0.016)	(0.015)	(0.015)	(0.084)	(0.078)	(0.079)	(0.006)	(0.008)	(0.007)
SIZE	0.076***	0.061***	0.038***	0.079**	0.166***	0.075*	0.008*	0.035***	0.003
	(0.011)	(0.012)	(0.011)	(0.039)	(0.041)	(0.041)	(0.004)	(0.006)	(0.005)
FOREIGN	-0.050	-0.027	-0.010	0.310**	0.301**	-0.030	-0.019	0.059**	-0.017
	(0.067)	(0.070)	(0.061)	(0.142)	(0.134)	(0.155)	(0.019)	(0.026)	(0.021)
DOM_EXP	0.027	0.028	-0.022	0.282***	0.449***	0.260**	0.007	0.009	0.005
	(0.036)	(0.038)	(0.040)	(0.109)	(0.111)	(0.112)	(0.016)	(0.023)	(0.018)
COOP_GROUP	0.441***	0.484***	0.207**	0.132	-0.062	0.181	0.057***	0.124***	0.033
	(0.105)	(0.121)	(0.094)	(0.246)	(0.223)	(0.195)	(0.018)	(0.028)	(0.023)
COOP_SUP	0.154	0.021	-0.071	1.070***	0.439*	0.789***	0.128***	0.113***	0.109***
	(0.111)	(0.126)	(0.107)	(0.252)	(0.238)	(0.215)	(0.021)	(0.025)	(0.020)
COOP_CUST	0.201**	-0.022	0.053	0.513*	0.643***	0.043	0.195***	0.326***	0.201***
	(0.100)	(0.128)	(0.106)	(0.279)	(0.236)	(0.247)	(0.017)	(0.022)	(0.019)
COOP_COMP	-0.016	0.004	0.115	-0.000	-0.009	0.192	-0.060***	-0.008	-0.019
	(0.103)	(0.115)	(0.107)	(0.377)	(0.294)	(0.302)	(0.022)	(0.037)	(0.026)
COOP_CON	0.085	0.147	0.016	0.660*	0.311	0.312	0.063***	0.032	0.032
	(0.103)	(0.128)	(0.095)	(0.370)	(0.297)	(0.311)	(0.024)	(0.039)	(0.026)
COOP_UNI	-0.065	0.061	0.172*	0.694*	0.410	0.126	-0.034	-0.030	-0.047
	(0.099)	(0.111)	(0.104)	(0.384)	(0.296)	(0.280)	(0.028)	(0.044)	(0.032)
COOP_PUB	-0.100	-0.294*	-0.135	-0.739	-0.272	-0.024	-0.022	0.018	0.030
	(0.154)	(0.166)	(0.145)	(0.551)	(0.386)	(0.388)	(0.030)	(0.045)	(0.031)
Obs.	1 333	1 333	1 333	1 256	1 247	1 256	4 346	4 346	4 346
Log-likelihood	-737.580	-843.752	-855.947	-699.129	-729.851	-689.118	-1 686	-2 333	-2 016
Pseudo R^2	0.1340	0.0864	0.0616	0.115	0.102	0.079	0.206	0.181	0.135
Wald test (Industry FE)	16.13*	28.83***	24.44***	4.46	18.10**	5.98	30.54***	47.57***	32.39***

Notes: Reported are marginal effects of probit model estimates; bootstrap standard errors after 300 replications; CIS 2006-2008. Included in all models but not reported: constant and industry fixed effects (2-digit). * p<0.1, ** p<0.05, *** p<0.01.

Table 5. Impact of innovation on productivity in service enterprises, 2006-2008

		Pred. INNOOUT		SIZE		FOREIGN		DOM_EXP		EAST GERMANY		Obs	R^2	Wald test: 3-digit industry FE
		coeff	s.d.	coeff.	s.d.	coeff.	s.d	coeff.	s.d	coeff.	s.d			
GERMANY	PROD	0.163***	(0.059)	0.009	(0.021)	0.454***	(0.144)	0.270***	(0.070)	-0.221***	(0.047)	1333	0.504	1241.18***
	MARKET	0.131	(0.083)	0.016	(0.021)	0.403***	(0.142)	0.296***	(0.073)	-0.215***	(0.046)	1327	0.505	1110.93***
	FIRM	0.270**	(0.117)	-0.005	(0.024)	0.457***	(0.142)	0.200**	(0.101)	-0.220***	(0.041)	1333	0.504	1375.86***
	PROC	0.211***	(0.074)	-0.027	(0.026)	0.474***	(0.145)	0.317***	(0.062)	-0.223***	(0.043)	1333	0.506	1337.33***
	ORGA	0.226***	(0.085)	-0.017	(0.025)	0.467***	(0.137)	0.337***	(0.058)	-0.222***	(0.039)	1333	0.505	1226.38***
	MARK	0.320**	(0.133)	-0.013	(0.024)	0.468***	(0.126)	0.356***	(0.060)	-0.221***	(0.043)	1333	0.504	1214.09***
IRELAND	PROD	0.089	(0.088)	0.042	(0.044)	0.719***	(0.142)	0.284***	(0.095)	-		1256	0.201	357.15***
	MARKET	0.161	(0.136)	0.040	(0.044)	0.675***	(0.157)	0.223*	(0.104)	-		1247	0.202	351.87***
	FIRM	0.178	(0.128)	0.036	(0.041)	0.705***	(0.150)	0.274***	(0.095)	-		1256	0.203	317.34***
	PROC	0.174*	(0.094)	0.038	(0.042)	0.707***	(0.153)	0.266**	(0.108)	-		1256	0.203	318.78***
	ORGA	0.194	(0.156)	0.019	(0.051)	0.691***	(0.142)	0.213	(0.131)	-		1247	0.202	337.15***
	MARK	0.259[a]	(0.162)	0.033	(0.044)	0.733***	(0.134)	0.226**	(0.104)	-		1256	0.203	320.33***
UK	PROD	0.043*	(0.025)	-0.092***	(0.013)	0.867***	0.056	0.455***	(0.038)	-		4346	0.401	3903***
	MARKET	0.055*	(0.032)	-0.092***	(0.014)	0.869***	0.062	0.449***	(0.038)	-		4333	0.399	3655***
	FIRM	0.051*	(0.030)	-0.092***	(0.013)	0.867***	0.056	0.455***	(0.038)	-		4346	0.401	3883***
	PROC	0.065**	(0.031)	-0.095***	(0.014)	0.867***	0.056	0.458***	(0.038)	-		4346	0.401	3712***
	ORGA	0.056*	(0.032)	-0.097***	(0.014)	0.854***	0.057	0.462***	(0.037)	-		4346	0.401	3781***
	MARK	0.070*	(0.039)	-0.093***	(0.013)	0.868***	0.056	0.462***	(0.037)	-		4346	0.401	3700***

Notes: Dependent variable: log labour productivity measured as log(turnover/employees). IV estimates using predicted innovation outputs; bootstrap standard errors after 300 replications; CIS 2006-2008. Included in all models but not reported: constant and industry fixed effects (3-digit). * p<0.1, ** p<0.05, *** p<0.01. [a] p = 0.11.