The impact of participation within formal standardization on firm performance

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Abstract

Several studies highlight the economic benefits of standards, while the benefit of taking part in standardization remains a rather unexplored mystery to date. In theory, standard setters not only benefit from the possibility to monitor and shape the development of standards but also access a wide range of knowledge sources in the standards committee. Therefore, we investigate how the participation within formal standardization is related to the performance of 1,561 German companies. A Cobb-Douglas production function is estimated in order to use the Solow-residuals as indicator for the firm performance. Participation within formal standardization is measured by the number of committee seats within the German Institute for Standardization (DIN). Our results suggest that participation within formal standardization is in general positively related to the firm performance. More detailed analyses within the service industries revealed a striking pattern for technology-developing service providers insofar as for these companies only the combination of patenting and standardizing tends to be positively related to firm performance. Nevertheless, we interpret these results as a first indication for the microeconomic benefit of taking part in standardization.
1 Introduction

Several studies suggest positive macro- (Blind and Jungmittag, 2008; DTI, 2005; Jungmittag et al., 1999) and microeconomic benefits (for an extensive summary see Swann, 2010) of standards in general. Additionally, several scholars explored different benefits of the well-known quality standard ISO 9000 (Briscoe et al., 2005; Corbett et al., 2005; Pekovic and Galia, 2009) and the related ISO 14000 standard on environmental management (Tien et al., 2005; Zutshi and Sohal, 2004). However, while the economic benefit of standards seems to be widely acknowledged within scientific literature, the benefit of taking part in standardization remains a rather unexplored mystery to date. All the above mentioned studies take the output of the standardization process into account, i.e., the standard (stock). With regard to the standardization process itself, the literature, on the one hand, theoretically addresses possible benefits of the firm’s engagement in standardization (Antonelli, 1994). On the other hand, motives or driving factors that might foster the firm’s propensity to engage in standardization are explored (Blind, 2006). Consequently, the present paper aims at filling this research gap by theoretically and empirically investigating the impact of participation within standardization on firm performance.

Basically, two different types of standardization exist: de jure and de facto standardization. In the latter case, the standard arises from a standardization struggle (and sometimes from a standard war) between different solutions of different firms or coalitions (Chiesa and Toletti, 2003). This paper focuses on de jure standardization that is defined by the existence of independent organizations (such as the German Institute for Standardization (DIN) or the International Organization for Standardization (ISO)) and partly by the promulgation of standards by legislative bodies as in the case of mandated standards (David and Greenstein, 1990). However, the rather loose tag de jure standardization actually fits only in case of mandated standards so that we deem appropriate to use the wording “formal standardization”. Formal standardization processes are transparent and open to any company. Accordingly, formal standards are developed in consensus with all interested parties involved as defined within international rules (see, e.g., ISO/IEC Directives). Every organization is invited to join this process, but no organization is imposed to do so. The decision whether to participate in formal standardization or not is exclusively made at organizational level. Thus, organizations that become involved in standardization not only bear the costs for doing so but also derive benefits out of it that apparently exceed the costs.
In theory, standard setters not only benefit from the possibility to monitor and shape the development of standards but also access a wide range of knowledge sources in the standards committee. Consequently, the organizations’ benefit is manifold and can influence different profit generating parameters. Standard setters may use standards for the promotion of the diffusion of their innovative products or services so that participation within standardization constitutes a means of marketing. They also may gain competitive advantages by accessing the specifications of upcoming standards prior to their publication and, therewith, prior to competitors not involved in standardization. Besides, we also consider standards committees as a meeting point of different stakeholders (competitors, suppliers, customers, etc.) within a specific scope. The participants of these committees gain access to valuable knowledge that is not necessarily codified in the upcoming standard but shared implicitly. Hence, participation within formal standardization also constitutes a means of knowledge sourcing, which might increase an organization’s innovativeness. Chiesa and Toletti (2003) suggest that a single firm quite often is not able to adequately sponsor the adoption of its technology as a standard so that collaborations have to be formed. Consequently, participation within formal standardization is used not only for the diffusion of innovations but also for the generation of knowledge. To sum up, formal standardization might contribute to the performance of its participants in one of the above described manners. Against this background, the paper focuses on firms participating in formal standardization and investigates how this participation contributes to the firm’s performance. Methodologically, firm performance is estimated using Solow residuals of a Cobb-Douglas production function. Thereby, firm performance is considered to be an appropriate indicator to take all the above mentioned aspects simultaneously and holistically into account.

Within our analysis, two different types of standard setting firms are distinguished, namely manufacturers and service providers. The provision of services is more or less individual, which might cause a reluctance concerning standardization. Moreover, several service industries are still highly regulated and only some aspects seem to be worth standardizing so that standardization of services is rather complex compared to products (Blind, 2003). However, the analysis of the service providers’ activities within standardization (Wakke et al., 2012) revealed that service providers mainly use standardization for technology-related aspects, while only a minor share of service providers actually set up service standards.
As for the technology-related activities of service providers within standardization, a further distinction can be drawn between service providers that use technologies from the manufacturing industries and service providers that develop technologies themselves by means of research and development activities (Droege and Hildebrand, 2009; Miozzo and Soete, 2001). Thus, the so-called technology-using and technology-developing service industries are additionally distinguished in order to shed as much light as possible on the effects of participation within formal standardization on firm performance.

The paper is organized into five sections. The next section briefly reviews the literature on the relation between participation within formal standardization and firm performance, which is the major issue of this analysis to be solved. The third section deals with the methodology, while the fourth section reports the statistics and the results of the empirical analysis. Finally, the fifth section derives implications based on the results.

2 Theory

As outlined in the introduction, formal standardization might benefit its participants in different ways. The following paragraphs aim at laying down the theoretical frame of our research. We elaborate three different aspects that might constitute an incentive for companies to join standardization committees instead of behaving as free riders. The three aspects, namely the leverage, the temporal, and the network aspect, can be described as follows.

The Leverage Aspect

The participants of a standards committee are responsible for specifying standards within the scope of the committee. Thereby, the technical specifications within the standard are important elements for the successful diffusion of new technologies, services, and products not only domestically but also worldwide (Blind, 2006). At firm level, standards can be used to increase or defend market power (Lecraw, 1984) by minimizing the technical distance between the standard itself and the present technical specifications of each firm’s current product and processes (Antonelli, 1994, p. 200). More precisely, participants may adapt the standard content to their benefit in order to gain a competitive advantage (Fernández et al., 2000, p. 89), to prevent competitors from gaining advantages at their expense (Weiss and Sirbu, 1990) or to disadvantage rivals by raising their costs (Salop and Scheffman, 1983, 1987). This perspective is in line with the partially excludable characteristic of standards, meaning that outsiders of the standards committees might face considerable disadvantages when adhering to a standard (Antonelli, 1994, p. 200).
Thereby, the costs of adopting a given standard (switching costs) and the costs for participating in formal standardization (sponsoring costs) interact with each other. In this paper, a negative relation between the switching costs and sponsoring costs is assumed, i.e., the more effort is put into standardization, the less effort is needed to comply with the requirements of the standard later on. Accordingly, participation within standardization lowers switching costs.

Furthermore, the demand for standardized products may be higher due to network externalities, lower transaction costs, and enhanced diffusion rates (Antonelli, 1994, p. 201). Blind (2006, p. 161) argues that “participation in standardization is certainly a strategy to shape foreign markets according to specifications of the own products or technologies”. Thus, manufacturers and service providers might leverage the standardization process to boost sales (Blind, 2002). Simultaneously, owners of intellectual property rights (IPRs) might leverage the standardization process to increase the firm’s royalties (Berger et al., 2012; Hytönen et al., 2011). The demand increasing effect is all the more important, the more novel the product or service is. Standards help to overcome uncertainties embodied in innovative technologies and therewith reduce adoption lags of new products or services (Antonelli, 1994, p. 201). In conclusion, we assume that participation within standardization raises the firm’s performance by reducing switching costs and/or increasing demand in one of the ways described above.

The Temporal Aspect

According to Blind (2006, p. 159), the temporal aspect can be elucidated in a way that “participants in the standardization process may have advantages compared with outsiders, due to their early involvement in the development of the standard”. Simultaneously, the standard setters can be regarded as owners of a club good (i.e., the specifications within the standard) until the standard is published (Antonelli, 1994). Consequently, standard setters might benefit from this temporary club good by adapting the production process or the service provision to the requirements of the upcoming standard before publication. Thereby, the lead time differs and depends mainly on the time it takes until all participants approve the final standard for publication in consensus. However, the temporal aspect might be decisive for “creating early knowledge” (Hytönen et al., 2011, p. 2) so that participation within standardization might increase the performance of its participants at least for a restricted time, but due to the delayed adoption by outsiders for a longer period.
The Network Aspect

Whereas both the leverage and the temporal aspect only come into effect after publication of the standard, the network aspect explicitly deals with the benefits resulting from participating within a standardization committee. Participation within standardization can be regarded as interorganizational cooperation. According to the relational view (Dyer and Singh, 1998), cooperating firms may realize “interorganizational competitive advantages” based on a joint combination of resources in unique ways. Many scholars have extended the “standard Schumpeterian analysis” (Love and Roper, 1999, p. 43) and emphasize the role of networks, communities, and linkages as alternative to internal R&D efforts (Chesbrough, 2003; Fernández et al., 2000; von Hippel, 1988). More detailed, von Hippel (1988) proves that a firm’s customers and suppliers are its main source of innovative ideas. Fernández et al. (2000) highlights the importance of collaborations to continuously update different kinds of intangible assets like the technological capital. Laursen and Salter (2006) evidence the contribution of openness to innovation performance among British manufacturing firms. Quite similarly, Leiponen and Helfat (2010) conclude that Finish manufacturing firms may improve their odds of successful innovation by accessing a large number of knowledge sources alongside pursuing multiple parallel objectives. Belderbos et al. (2004) analyze the impact of different types of R&D cooperation on firm performance differentiating between four R&D partners (competitors, suppliers, customers, and universities). Basically, competitor and supplier cooperation increases productivity due to incremental innovations, while customer and university cooperation is an important knowledge source for firms pursuing radical innovations. Thereby, the positive effect of openness towards innovativeness seems to be limited according to Duysters and Lokshin (2011). Among Dutch companies, they proved the existence of such a firm specific limit, above which the marginal costs of managing the portfolio complexity exceeds the expected benefits.

However, even though there is an inverse U-shape relation between openness of a company and its innovative performance, it seems obvious that participants within standardization might increase their (innovative) performance due to knowledge creation and exchange with competitors, suppliers, customers, and other stakeholders in the standards committees (Blind, 2006, p. 159). Thereby, participants access not only explicit knowledge that is formulated in the standard but also tacit knowledge the leakage of which cannot be controlled for within the standards committee. Thus, participation in standardization might raise the innovativeness and therewith increases firm performance.
Hypotheses

Based on these theoretical considerations, a positive relation between the participation in formal standardization and firm performance is hypothesized (Hypothesis 1).

However, we expect Hypothesis 1 to be only conditionally applicable for the technology-developing service providers. As briefly mentioned in Section 1, service providers mainly focus on technology-related aspects within standardization (Wakke et al., 2012). Moreover, service providers focusing on technologies either use technologies from the manufacturers in order to support their service provision or develop technologies by their own due to means of research and development. Information technology-related services as well as architectural and engineering activities or scientific research and development can be regarded as technology-developing services (Vence and Trigo, 2009; Hipp and Grupp, 2005, p. 523). With respect to these technology-developing service providers, some of the possible aspects outlined above might not be valid. In more detail, these service providers might face difficulties to benefit from the leverage aspect and the temporal aspect.

From a market perspective, technology-developing service providers do not use the technology by themselves. They contribute to technology development but have negligible product sales (Hytönen et al., 2011). Accordingly, they are reliant on selling the technology to manufacturers or technology-using service providers. Hence, only if the technology is effectively protected by intellectual property rights (IPR), the technology-developing service providers are able to take profits from standard setting by enhancing the visibility and diffusion of their technologies and therewith enhancing license revenues or similar incomes as shown by Blind et al. (2011). Consequently, it is hypothesized that participation within standardization of technology-developing service providers is positively related to firm performance conditional upon the adequate protection of the firm’s intellectual properties (Hypothesis 2).

3 Methodology

A two-stage regression analysis is used to empirically investigate the hypothesized relations. In the first stage, the firm performance is estimated. The second stage explores the relation between different factors (such as the engagement in standardization) and the estimated firm performance. As for the first stage, the Solow-residuals of a Cobb-Douglas production function are used as proxy for the firm performance as done by van de Wiele (2010).
The microeconomic production function (see Equation 1) uses two company-specific input factors, the number of employees \((L_i)\) and the capital stock \((C_i)\). The profit or value added \((Y_i)\) serves as the output measure. The estimated coefficients are normally taken as elasticity of the respective input factor.

\[
\ln Y_i = \alpha_1 + \beta_1 \ln L_i + \beta_2 \ln C_i + \epsilon_i \tag{1}
\]

However, we are not interested in the coefficients but in the estimated error terms \((\epsilon_i)\). Basically, the error term of a regression model aims at capturing all factors influencing the dependent variable other than the regressors. More precisely, the firm-specific error term (i.e., residual) constitutes an appropriate performance indicator for all factors other than the labor and capital stock (e.g., the firm’s innovativeness or the firm’s engagement in formal standardization). Accordingly, the error term of Equation 1 is used as proxy for the firm performance \((PERF_i)\).

The second stage of our regression model addresses different factors that might be related to the firm performance \((PERF_i)\) estimated in the first stage. Doing so, the hypothesized positive relation between the participation in standardization and firm performance is tested. However, to explain as much variety of the firm performance as possible, additional factors are considered as well.

First, the effect of the innovativeness on firm performance is addressed. Going back to the early work of Schumpeter (1934), innovation has been recognized as a key element of competition. Innovative companies gain market shares from non-innovators. Consequently, scholars evidenced a positive effect of innovation on performance or productivity (Crépon et al., 1998). However, meanwhile this one-way causality seems to turn into a “self-reinforcing virtuous circle between innovation and economic performance at firm level” (Cainelli et al., 2006, p. 454). A similar result is found by Koellinger (2008), who analyzes 7,302 European enterprises and comes to the result that service as well as product innovation is positively associated with profitability, although the direction of the causality is ambiguous. Artz et al. (2010) evidence a positive relation between product announcements and two measures for the firm performance, return on assets and sales growth. Though, an unexpected negative relationship between patents and firm performance is revealed as well. However, they argue that this result stems from an increased strategic patenting at firm level. Nevertheless, the possible effects of the firm’s innovativeness on firm performance are addressed within our second stage regression. The patent stock of each firm is used as proxy for the innovativeness.
Thereby, the patent stock is simultaneously used for measuring the protection of intellectual properties in order to test our second hypothesis.

Second, the size of a company might influence its performance. According to Tsai (2005), both large and small firms have higher competitive advantages with respect to the R&D productivity than middle sized companies. Dhawan (2001) first gives a short overview of the literature regarding the relationship between firm size and profit rate which slightly tends towards a decline with firm size before empirical evidence is found that larger US firms are less productive than their smaller counterparts. Irrespective of the different results, firm size might affect firm performance. Accordingly, the second stage allows for this possible effect and simultaneously tests whether a linear or a non-linear relationship responds to the data more adequately. Thus, two different regressions are estimated. The first model allows for a linear relationship and the second model allows for a U-shaped relationship that is estimated by the inclusion of a squared term of the size variable, which is expressed by the number of employees.

Third, we consider export as another factor that is probably related to the performance of a firm. As in the case of innovative companies, the available literature in this field considers a bidirectional relationship between export activities and firm performance. Thereby, two different patterns, “self-selection” and “learning-by-exporting”, are under investigation (Kneller and Pisu, 2010; Manez-Castillejo et al., 2010). The first pattern deals with the self-selection of companies into export markets, i.e., only the ex ante more efficient companies enter foreign markets, whereas the latter pattern addresses the effect of export on productivity, i.e., exporters are more productive than non-exporters. Kneller and Pisu (2010) evidence the effect of export on productivity among UK firms across a wide range of performance indicators (sales growth, profitability growth as well as several innovation indicators). Following this line of argumentation, the effect of exporting activities on firm performance is tested.

Fourth, we control for firm performance within the past in order to capture other unobserved factors like management skills for which we have no data. Finally, we control for differences between the more or less heterogeneous industries alongside the differentiation between the manufacturing and the service industries in general. Considering all the above mentioned control variables, we end up with the following model (Equation (2)) for a linear relationship between the company size and firm performance:
and for a possible U-shaped relation between the company size and firm performance we use Equation (3):

$$PERF_i = \alpha + \beta_1PART_i + \beta_2 INNO_i + \beta_3 SIZE_i + \beta_4 EXP_i + \beta_5 PAST_i + \beta_6 X_i + \epsilon_i$$  \hspace{1cm} (2)

with

$$PERF = \text{the firm performance estimated by Equation (1)},$$

$$PART = \text{the participation level within formal standardization},$$

$$INNO = \text{the innovativeness of the firm},$$

$$SIZE = \text{the size of the firm},$$

$$EXP = \text{the export activity of the firm},$$

$$PAST = \text{past firm performance},$$

$$X = \text{a vector of industry dummies based on the two-digit NACE code.}$$

In order to explicitly test the effect of the right hand side (RHS) variables of Equation (2) on the firm performance that is estimated for the year 2009, we use appropriate time-lags for the independent variables. More details in this regard will be provided in the statistics section.

However, the literature on the factors that influence the companies’ decision to join standardization (Blind, 2006; Blind and Mangelsdorf, 2010) heavily suggests interactions between the participation level and the remaining RHS variables in Equation (2) and (3) respectively. When estimating a multiple regression model with correlation among the RHS variables, also called multicollinearity, the estimated effects in terms of the coefficients cannot be regarded as being consistent. Consequently, the issue of multicollinearity is taken into account by performing one more step before estimating Equation (2) and (3) in which we regress the participation level \((PART_i)\) on all the remaining RHS variables as shown in Equation (4).

$$PART_i = \alpha + \beta_1 INNO_i + \beta_2 SIZE_i + \beta_3 EXP_i + \beta_4 PAST_i + \beta_5 X_i + \epsilon_i$$  \hspace{1cm} (4)

Moreover, we also allow for a non-linear relationship between the innovativeness and the participation level as proved by Blind (2006) at company level and Blind (2002) at industry level.
For reasons of unintended knowledge spillovers especially to competitors, highly innovative companies or industries might stay away from standardization. Empirically, we therefore test the model not only according to Equation (4) but also the following way:

\[ \text{PART}_i = \alpha + \beta_1 \text{INNO}_i + \beta_2 (\text{INNO}_i)^2 + \beta_3 \text{SIZE}_i + \beta_4 \text{EXP}_i + \beta_5 \text{PAST}_i + \beta_6 X_i + \varepsilon_i \] (5)

Once again, we use the estimated error terms (\(\varepsilon_i\)), i.e., in this case the participation level of a company independent of its innovativeness, size, export activities, and industry specific peculiarities. The new variable (the error term of Equation (4) or (5)) is called participation intensity (\(\text{PAIN}_i\)). The decision which of the equation is finally used depends on whether Equation (4) or (5) performs better. Equation (2) and (3) are adjusted (\(\text{PART}_i\) is replaced by \(\text{PAIN}_i\)), which leads us to the following equations:

\[ \text{PERF}_i = \alpha + \beta_1 \text{PAIN}_i + \beta_2 \text{INNO}_i + \beta_3 \text{SIZE}_i + \beta_4 \text{EXP}_i + \beta_5 \text{PAST}_i + \beta_6 X_i + \varepsilon_i \] (6)

\[ \text{PERF}_i = \alpha + \beta_1 \text{PAIN}_i + \beta_2 \text{INNO}_i + \beta_3 \text{SIZE}_i + \beta_4 (\text{SIZE}_i)^2 + \beta_5 \text{EXP}_i + \beta_6 \text{PAST}_i + \beta_7 X_i + \varepsilon_i \] (7)

As mentioned in the introduction, the two most prominent types of service providers are distinguished within the model dealing explicitly with the service industries: technology-users and technology-developers. In order to test the hypothesized differences (Hypothesis 1 for the technology-using and Hypothesis 2 for the technology-developing service providers), a dummy variable (\(\text{TECH}_i\)) that responds to the technology-developing service providers is set up. This dummy and an interaction term of this dummy with the participation intensity (\(\text{PAIN}_i\)) are included in Equation (6) and (7). Moreover, an interaction between the dummy variable (\(\text{TECH}_i\)), the participation intensity (\(\text{PAIN}_i\)), and the innovativeness (\(\text{INNO}_i\)) allows for testing our second hypothesis. Integrating these three factors into Equation (6) and (7) leads us to the following regression model for studying peculiarities within the service industry:

\[ \text{PERF}_i = \alpha + \beta_1 \text{PAIN}_i + \beta_2 (\text{PAIN}_i \times \text{TECH}_i) + \beta_3 (\text{PAIN}_i \times \text{TECH}_i \times \text{INNO}_i) + \beta_4 \text{TECH}_i + \beta_5 \text{INNO}_i + \beta_6 \text{SIZE}_i + \beta_7 \text{EXP}_i + \beta_8 \text{PAST}_i + \beta_9 X_i + \varepsilon_i \] (8)

\[ \text{PERF}_i = \alpha + \beta_1 \text{PAIN}_i + \beta_2 (\text{PAIN}_i \times \text{TECH}_i) + \beta_3 (\text{PAIN}_i \times \text{TECH}_i \times \text{INNO}_i) + \beta_4 \text{TECH}_i + \beta_5 \text{INNO}_i + \beta_6 \text{SIZE}_i + \beta_7 (\text{SIZE}_i)^2 + \beta_8 \text{EXP}_i + \beta_9 \text{PAST}_i + \beta_{10} X_i + \varepsilon_i \] (9)
With the methodology described above, we end up with three steps. First, the firm performance ($PERF_t$) is estimated by applying Equation (1) to the data. Second, the participation intensity ($PAIN_t$) is estimated by applying Equation (4) or (5). Third, Equation (6) to (9) is estimated, while using the estimates of the first and second step.

Alongside this parametric approach, in which we perform several OLS-regression analyses, the non-parametric bootstrap method is used additionally. This approach checks the reliability of our results. Bootstrapping basically means constructing a sampling distribution based on random sampling with replacement from the original data instead of making distributional assumptions for hypothesis testing as in the case of parametric statistics (Friedman and Friedman 1995). Consequently, the data is resampled and the resamples or pseudo-samples are used to perform the above described methodology. Thereby, the size of the resamples is equal to the size of our dataset. The system bootstrapping with 1,000 replications leads to 1,000 estimates for the effect of the participation intensity ($PAIN_t$) on the firm performance, i.e., 1,000 values for the respective coefficient $\beta_1$ from Equation (6) and (7) and for the coefficients $\beta_1$, $\beta_2$ and $\beta_3$ from Equation (8) and (9). In a final step, the sampling distribution of the coefficients is described in order to derive conclusions with regard to our hypotheses. The following section describes our sample and applies the methodology to the data.

4 Statistics and results

Our sample is based on the Hoppenstedt database, which provides basic information of German companies. Prior to applying our methodology, the sample is corrected for outliers by excluding observations ±4.0 standard deviations (SD) away from the mean for each of the variables as suggested by Cohen et al. (2003). Even though the Hoppenstedt database provides access to more than 300,000 company profiles, only for 1,561 of these companies all variables required for our analysis are available. The sample consists of 823 service providers and 738 manufacturers. The decision whether a company is assigned to the service industries or manufacturing industries is made by considering all NACE (Statistical Classification of Economic Activities in the European Community) classifications provided by the Hoppenstedt database.

In order to attach a greater importance to the first NACE classification, two conditions are imposed for the purpose of detecting service providers. The first NACE classification and the majority of all NACE classifications of each organization have to be within the NACE divisions above 44 to be assigned to the service industries.
The level of participation within standardization is measured by the number of committee seats that every company held within DIN in early 2010. Unfortunately, no earlier data was accessible. Though, only full expert status, i.e., no temporary engagement (e.g., visitor status), is considered. It can, therefore, be assumed that all companies have participated in standardization for at least one year, which is supported by the low level of fluctuation found by comparing most recent data of involvement in 2011 with the data from 2010.

Innovativeness is measured by the stock of national, European and international patents calculated from 2000 to 2008 by the perpetual inventory method with a constant depreciation rate (15 percent) as being well described by Czarnitzki and Kraft (2010). Certainly, this rather technical innovation indicator does not fully capture the various forms of innovation in the service industries and scholars have meanwhile developed more appropriate indicators in this regard (Schmoch and Gauch, 2009; Gotsch and Hipp, 2011). However, service providers use standardization mainly for technology-related innovation activities (Wakke et al., 2012) so that we regard patents as an appropriate indicator for innovation within our sample. The dummy variable that differentiates between technology-developing and technology-using service providers is built based on the first NACE classification. Thereby, service providers primarily classified within NACE 2.0 division 62, 63, 71 or 72 were assigned to the technology-developing service providers. This approach is based on the literature (Glueckler and Hammer, 2011; Hipp and Grupp, 2005, p. 523; Vence and Trigo, 2009.). Table 1 provides a summary of all variables including a short description, the measurement, and the source.

Table 2 provides the descriptive statistics for all variables that entered the analysis. With regard to the entire Hoppenstedt database (see last column in Table 2), our sample is slightly skewed towards the larger companies caused by the restricted data availability of the smaller companies. However, the regression model controls for the company size so that this possible bias is taken into account. Based on the tendency towards larger companies in our dataset, one might expect that standardization \((PART_{i})\) and innovation activities \((INNO_{i})\) (that are not gathered through Hoppenstedt) are above average and therewith do not adequately represent the population of German companies. However, the average number of committee seats of the standard setters in our dataset (2.1 seats) is beyond the average number of seats held by German standard setting companies (3.7 seats). Moreover, the average patent stock of the patent holders in our sample (5.0 patents) is beyond the average patent stock of German patent holding companies (31.2 patents).
Table 1: Variables

| Variable | Description | Measure | Source |
|----------|-------------|---------|--------|
| $Y$      | Profit      | Profit realized in 2009 (Mio. Euro) | Hoppenstedt database |
| $L$      | Number of employees | Number of employees in 2009 | Hoppenstedt database |
| $C$      | Capital stock | Capital stock (Mio. Euro) | Hoppenstedt database |
| $PART$   | Participation level | Number of committee seats within the German Institute for Standardization | DIN German Institute for Standardization |
| $INNO$   | Innovativeness | Patent stock in 2000-2008 divided by the number of employees | PATSTAT database |
| $SIZE$   | Number of employees | Natural logarithm of the number of employees in 2008 | Hoppenstedt database |
| $EXP$    | Export      | 1 if the company sells products outside Germany; 0 otherwise | Hoppenstedt database |
| $PAST$   | Past firm performance | Profit realized in 2008 (Mio. Euro) divided by the number of employees in 2008 | Hoppenstedt database |
| $PAIN$   | Participation intensity | Error term of Equation (4) and (5) respectively | Own calculation |
| $PERF$   | Firm performance | Error term of Equation (1) | Own calculation |
| $TECH$   | Technology-developing service providers | 1 if service provider is classified within NACE 2.0 division 62, 63, 71 or 72; 0 otherwise | Hoppenstedt database |

Table 2: Descriptive statistics

| Service providers | Manufacturers | All industries | Hoppenstedt |
|-------------------|--------------|----------------|-------------|
| (N=823)           | (N=738)      | (N=1,561)      | (N=1,561)   |
| $\ln Y$           | -0.454       | -0.154         | -0.312      | -0.131 |
| $\ln L$           | 4.599        | 4.549          | 4.576       | 2.995 |
| $\ln C$           | 0.019        | -0.016         | 0.026       | -2.519 |
| $PART$            | 0.063        | 0.176          | 0.117       | -     |
| $INNO$            | 0.008        | 0.009          | 0.008       | -     |
| $SIZE$            | 4.574        | 4.553          | 4.564       | 3.002 |
| $EXP$             | 0.074        | 0.293          | 0.177       | 0.065 |
| $TECH$            | 0.094        | 0.262          | -           | -     |

Table 3 presents the estimation results of the Cobb-Douglas production function (Equation (1)). The error terms of the three models are used to build the new variable firm performance ($PERF_i$) as described in Section 3. Figure A1 in the Appendix plots the histogram of the firm performance ($PERF_i$), i.e., the (Solow) residuals of Equation (1).
Within the second step, the standardization intensity \((PAIN_t)\) is estimated by applying Equation (4) and (5) respectively to the data (see Table 4). We opt for using Equation (5) for estimating the participation intensity \((PAIN_t)\) since the reversed U-shaped relationship between the innovativeness and the participation level fits the data better (see Table 4). Finally, these results are used to estimate the effects of all the independent variables on the firm performance as described by Equation (6) to (9) respectively. Table 5 and Table 6 provide the results that we are eventually interested in.

| Service provider | Manufacturer | All industries |
|------------------|--------------|----------------|
| Coef.            | Coef.        | Coef.          |
| \(Ln L\)         | 0.295***     | 0.272***       | 0.286***       |
| \(Ln C\)         | 0.318***     | 0.376***       | 0.338***       |
| Constant          | -1.817***    | -1.386***      | -1.619***      |
| \(R^2\)          | -9.76        | -5.90          | -11.23         |
| \(F\)-value      | 147.73***    | 116.29***      | 261.84***      |
| Obs.              | 823          | 738            | 1,561          |

Note: The asterisks represent the levels of significance: ***<0.001, ** <0.01, *<0.05 and † <0.1.
Table 4: Estimation of Equation (4) and (5) (Step 2)

|                | Service provider | Manufacturer | All   |
|----------------|------------------|--------------|-------|
|                | Equation (4)     | Equation (5) | Equation (4) | Equation (5) | Equation (4) | Equation (5) |
|                | Beta  | T-value | Beta  | T-value | Beta  | T-value | Beta  | T-value | Beta  | T-value | Beta  | T-value |
| SIZE           | 0.16*** | 3.92    | 0.16*** | 3.94    | 0.19*** | 4.82    | 0.18*** | 4.60    | 0.17*** | 5.92    | 0.17*** | 6.07    |
| INNO           | -0.01   | -0.46   | 0.58   | 1.32    | 0.07†   | 1.92    | 0.42*** | 3.97    | 0.01    | 0.34    | 0.24**  | 2.79    |
| (INNO)^2       | -       | -       | -0.59  | -1.36   | -       | -       | -0.38***| -3.52   | -       | -       | -0.24** | -2.79   |
| EXP            | -0.02   | -0.75   | -0.03  | -0.77   | 0.07†   | 1.74    | 0.07†   | 1.87    | 0.04    | 1.50    | 0.04    | 1.40    |
| PAST           | -0.01   | -0.41   | -0.02  | -0.50   | 0.03    | 0.81    | 0.03    | 0.83    | 0.01    | 0.37    | 0.01    | 0.33    |
| Constant       | -0.16** | -2.70   | -0.16***| -4.71   | -0.12   | -1.03   | -0.13   | -1.10   | -0.27***| -4.22   | -0.26***| -4.39   |
|                | R²     |        |       |        |        |        |        |        |        |        |        |        |
|                | 10.4%  |        | 10.6% |        | 13.4%  |        | 14.9%  |        | 12.3%  |        | 12.8%  |        |
|                | F-value |       |       |        |        |        |        |        |        |        |        |        |
|                | 1.91*** |       | 1.91***|        | 2.85***|        | 3.14***|        | 2.53***|        | 2.61***|        |
|                | Obs.   |       |       |        |        |        |        |        |        |        |        |        |
|                | 823    |        | 823   |        | 738    |        | 738    |        | 1,561  |        | 1,561  |        |

Note: The asterisks represent the levels of significance: ***<0.001, ** <0.01, *<0.05 and † <0.1. All regression models include industry dummies (42 service industries and 33 manufacturing industries respectively) which are not reported here; reference industries (omitted categories): NACE 2.0 division 46 “Wholesale trade, except of motor vehicles and motorcycles” within the service provider model and the aggregated model as well as NACE 2.0 division 28 “Manufacture of machinery and equipment n.e.c.” within the manufacturer model.
### Table 5: Estimation of Equation (6) and (7) (Step 3)

| Service provider | Manufacturer | All |
|------------------|--------------|-----|
| **Equation (6)** | **Equation (7)** | **Equation (6)** | **Equation (7)** | **Equation (6)** | **Equation (7)** |
| **Beta** | **T-value** | **Beta** | **T-value** | **Beta** | **T-value** | **Beta** | **T-value** | **Beta** | **T-value** |
| PAIN | 0.05* | 1.40 | 0.05 | 1.43 | 0.09*** | 3.14 | 0.07 | 2.41 | 0.07*** | 3.00 | 0.06** | 2.94 |
| INNO | 0.05*** | 6.00 | 0.05*** | 5.75 | 0.07*** | 4.05 | 0.05* | 2.46 | 0.05*** | 3.73 | 0.04*** | 4.07 |
| SIZE | 0.13** | 2.99 | -0.02 | -0.08 | 0.06 | 1.61 | -0.54*** | -3.64 | 0.07** | 3.00 | -0.34* | -1.93 |
| (SIZE)² | - | - | 0.15* | 1.08 | - | - | 0.61*** | 4.44 | - | - | 0.43** | 3.14 |
| EXP | 0.01 | 0.46 | 0.01 | 0.51 | -0.05 | -1.51 | -0.05 | -1.18 | -0.02 | -0.70 | -0.01 | -0.66 |
| PAST | 0.20*** | 4.30 | 0.19*** | 4.06 | 0.16** | 2.91 | 0.12** | 2.75 | 0.18** | 3.01 | 0.16** | 2.89 |
| Const. | -0.55* | -2.38 | -0.26 | -0.68 | -0.26 | -0.89 | 1.27** | 2.65 | -0.26 | -1.12 | 0.37 | 1.28 |

**Note:** The asterisks represent the levels of significance: ***<0.001, **<0.01, *<0.05 and †<0.1. All regression models include industry dummies (42 service industries and 33 manufacturing industries respectively) which are not reported here; reference industries (omitted categories): NACE 2.0 division 46 “Wholesale trade, except of motor vehicles and motorcycles” within the service provider model and the aggregated model as well as NACE 2.0 division 28 “Manufacture of machinery and equipment n.e.c.” within the manufacturer model; ΔR² is the difference to the model without PAIN.
Table 6: Estimation of Equations (8) and (9) (Step 3) with robust standard errors

| Service provider | Equation (8) | Equation (9) |
|------------------|--------------|--------------|
|                  | Beta | T-value | Beta | T-value |
| PAIN             | 0.16** | 3.30 | 0.16** | 3.33 |
| PAIN*TECH        | -0.17*** | -3.71 | -0.16*** | -3.71 |
| PAIN*TECH*INNO   | 0.06** | 3.05 | 0.06** | 3.07 |
| TECH             | 0.14*** | 4.00 | 0.13*** | 3.86 |
| INNO             | 0.05*** | 6.93 | 0.05*** | 6.66 |
| EXP              | 0.01 | 0.21 | 0.01 | 0.26 |
| SIZE             | 0.13** | 3.01 | 0.01 | 0.04 |
| (SIZE)^2         | - | - | 0.13* | 0.94 |
| PAST             | 0.20*** | 4.31 | 0.19*** | 4.09 |
| Const.           | -0.53* | -2.32 | -0.23 | -0.59 |

R^2: 17.9% 17.9%
F (sign.): 3.34*** 3.30***
\(\Delta R^2\): 1.4% 1.4%
Obs.: 823 823

Note: The asterisks represent the levels of significance: ***<0.001, ** <0.01, *<0.05 and † <0.1. All regression models include 42 service industry dummies which are not reported here; reference industry (omitted category): NACE 2.0 division 46 “Wholesale trade, except of motor vehicles and motorcycles”; \(\Delta R^2\) is the difference to the model without PAIN.

With reference to Table 5, the regression results support Hypothesis 1 for manufacturers and within the aggregated model. The participation intensity \((PAIN_i)\) is able to significantly and positively explain the firm performance, which confirms the hypothesized positive relationship between participation within standardization and firm performance. Thereby, participation within formal standardization is able to explain up to one percent of the firm performance. For the service industries, no significant positive relation between the participation intensity and the firm performance is estimated (see Table 5). However, as mentioned in Section 2, we further differentiate between technology-developing and technology-using service providers by applying Equation (8) and (9) to the data. Table 6 presents the results in this regard.

As for the technology-using service providers (i.e., without the interaction terms), the results suggest a positive and significant relationship between participation intensity and firm performance as hypothesized (Hypothesis 1). As for the technology-developing service providers (i.e., \(TECH_i = 1\)), the second term \((PAIN_i \times TECH_i)\) cancels out the first term \((PAIN_i)\). Thus, participation intensity and firm performance are negatively related as long as the third term \((PAIN_i \times TECH_i \times INNO_i)\) does not affect the relationship (i.e., no or low innovativeness).
Given a certain level of innovativeness, participation intensity is positively and significantly related to the firm performance of technology-developing service providers. Since innovativeness is measured by the patent stock, we can interpret this result in the way that technology-developing service providers’ participation within standardization is positively related to firm performance conditional upon the adequate protection of the firm’s intellectual properties, which supports our second hypothesis.

For the sake of robustness, the models are additionally estimated with a binary dummy reflecting whether a company participates in standardization or not. Using this proxy instead of the participation intensity based on the number of committee seats within DIN, similar results are found. Moreover, the problem of potential endogeneity within the estimation of the firm performance is taken into account. Equation (1) certainly suffers from an omitted variable bias that might cause endogeneity. Therefore, Equations (6) to (9) are additionally estimated using the profit (\(\ln Y_t\)) instead of the estimated firm performance as dependent variable. Again, similar results are found with R squares around 35 percent.

Alongside the several parametric regression analyses above, the dataset is bootstrapped and the entire methodology is performed 1,000 times. This additional step aims at reducing a possible bias caused by the fact that the dependent variable (\(PERF_t\)) is not observed but estimated, which might harm inference. Therefore, a sampling distribution of the coefficient \(\beta_1\) from Equation (6) and (7) as well as for the three coefficients (\(\beta_1, \beta_2, \text{ and } \beta_3\)) of interest from Equation (8) and (9) are estimated. Table 7 provides the characteristic features (mean, SD, the 5\(^{th}\) and the 95\(^{th}\) percentile) of the sampling distribution of the coefficient \(\beta_1\) from the Equations (6) and (7). Table 8 contains the characteristic features of the three coefficient distributions from Equation (8) and (9).

### Table 7: Characteristic features of the sampling distribution of \(\beta_1\) from Equation (6) and (7) estimated by system bootstrapping with 1,000 replications

| Equation | Service providers | Manufacturers | All industries |
|----------|-------------------|---------------|---------------|
|          | (6)               | (7)           | (6)           | (7)           | (6) | (7) |
| Mean     | 0.19              | 0.19          | 0.23          | 0.17          | 0.21| 0.19|
| SD       | 0.17              | 0.16          | 0.08          | 0.08          | 0.07| 0.07|
| 5\(^{th}\) Perc. | -0.06            | -0.04         | 0.11          | 0.04          | 0.09| 0.08|
| 95\(^{th}\) Perc. | 0.49             | 0.45          | 0.36          | 0.30          | 0.33| 0.32|
With regard to Table 7, the bootstrap method confirms our first hypothesis. As for the manufacturers and for the aggregated analysis, a positive effect ($\beta_1$) is estimated in more than 95 percent of all resamples. This result is in line with the significant coefficients estimated by regression analysis (see Table 5). As for the service industries, a negative effect is estimated in 132 of the 1,000 resamples which is also in line with the insignificant effect of the participation intensity on the firm performance for the service industries estimated by regression analysis (see Table 5). However, the resamples are also used to estimate the Equations (8) and (9), dealing with the peculiarities of the service industries in order to test the second hypothesis (see Table 8).

In general, Table 8 suggests a positive effect of the participation intensity on firm performance. The respective coefficient ($\beta_1$) of Equation (8) and (9) is estimated positively in more than 95 percent of all resamples, which is in accordance with our regression results (see Table 6). The second coefficient seems to be quite robust as well so that technology-developing service providers do not benefit from standardization in general as theoretically derived. Though, the distribution of the effect of the interaction term ($PAIN_i \times TECH_i \times INNO_i$) does not support the hypothesized positive relation between the benefit and participation within standardization conditional upon an adequate protection of the technology-developing service providers’ intellectual properties. Even though the mean is estimated positive by the bootstrap method, the effect ($\beta_2$) of this interaction term seems to be highly instable (see Table 8). A positive effect is estimated in only 68.6 percent of all resamples and the standard deviation of the coefficient ($\beta_3$) indicates a highly dispersed distribution. Thus, the regression result for this interaction term (see Table 6) is called into question.

|                         | Service providers | Service providers | Service providers |
|-------------------------|-------------------|-------------------|-------------------|
| Equation                | (8)               | (9)               | (8)               | (9)               |
| Coeff.                  | $\beta_1$         | $\beta_1$         | $\beta_2$         | $\beta_2$         |
| Mean                    | 0.61              | 0.61              | -0.81             | -0.80             |
| SD                      | 0.29              | 0.26              | 0.49              | 0.57              |
| 5% Perc.                | 0.21              | 0.24              | -1.62             | -1.49             |
| 95% Perc.               | 1.08              | 1.08              | -0.31             | -0.32             |

Table 8: Characteristic features of the sampling distribution of $\beta_1$ to $\beta_3$ from Equation (8) and (9) estimated by system bootstrapping with 1,000 replications.
5 Implications and limitations

In conclusion, a positive and significant relation between the intensity of participation in standardization and the firm performance is evidenced. This result seems to be robust against several company and industry specific factors, against potential endogeneity within the estimation of the firm performance, and against the methodology applied. Thus, we uncovered a first indication for the microeconomic benefit of taking part in formal standardization. This implication rests upon the following trains of thoughts. First, a company always tries to maximize firm performance. Thus, if a company would not experience a benefit from taking part in formal standardization, the company would not get engaged in standardization any longer. Second, based on our results one could argue the other way around insofar as only better performing companies get engaged in formal standardization, which would also explain the positive relation. However, we refuse this reasoning because why should only better performing companies get engaged in formal standardization, when participation in formal standardization would not even benefit these companies. Consequently, we encourage managers to exploit the microeconomic benefit of participation within standardization whenever possible.

As for the standard developing organizations, these results might be used to justify tariffs (necessary to fund the administrative organization of standardization) to the standard setters. Given the already acknowledged positive effects of standards on the demand-side of standardization, an increase in the participation intensity on the supply-side would even further expedite the acceptance of future standards and, therewith, the economic and societal benefits of standards including sustainability issues. Consequently, the paper’s findings might contribute to the promotion of the entire standardization system.

With regard to the separate consideration of the service industries, a positive relation between the engagement in standardization and firm performance is evidenced in general. However, as for a specific group of service providers, the technology-developing service providers, the results do not conclusively support our second hypothesis, i.e., that participation within standardization is positively related to firm performance conditional upon the protection of the firm’s intellectual properties. While the regression analysis supports this theory, the bootstrapping approach reveals an instable effect that heavily depends on the sample distribution. Thus, only anecdotal evidence is found for the benefit of the technology-developing service providers’ engagement in standardization.
This peculiarity with regard to the service industries’ standardization activities raises issues about the appropriate protection of the firm’s intellectual properties. Consequently, standard developing organizations are well advised to deal with this issue in order to exploit the innovativeness of these companies within standardization.

Based on our results, we see a couple of promising research directions for the future. First of all, the findings only give a first indication for the benefit of participation in standardization. The validation of these findings including more advanced analyses should motivate future research. Especially the causality issue, which is not yet adequately explored in this paper, might be of interest for other scholars. Moreover, this research does not allow for long-term predictions about a possible benefit of continuously taking part in standardization. Finally, the relationship between patenting and standardization behavior of firms might be examined more detailed and more sophisticated within the future, especially for the technology-developing service providers.
References

Antonelli, C., 1994. Localized technological change and the evolution of standards as economic institutions. Information Economics and Policy 6, 195-216.

Artz, K. W., Norman, P. M., Hatfield, D. E., Cardinal, L. B., 2010. A Longitudinal study of the impact of R&D, patents, and product innovation on firm performance. Journal of Product Innovation Management 27, 725-740.

Belderbos, R., Carree, M., Lokshin, B., 2004. Cooperative R&D and firm performance. Research Policy 33, 1477-1492.

Berger, F., Blind, K., Thumm, N., 2012. Filing behaviour regarding essential patents in industry standards. Research Policy 41, 216-225.

Blind, K., 2002. Driving forces for standardization in standards development organizations. Applied Economics 34, 1985-1998.

Blind, K., 2003. Standards in the service sector: An explorative study. Fraunhofer Institute for Systems and Innovation Research, Karlsruhe.

Blind, K., 2006. Explanatory factors for participation in formal standardisation processes: Empirical evidence at firm level. Economics of Innovation and New Technology 15, 157-170.

Blind, K., Jungmittag, A., 2008. The impact of patents and standards on macroeconomic growth: A panel approach covering four countries and 12 sectors. Journal of Productivity Analysis 29, 51-60.

Blind, K., Mangelsdorf, A., 2010. Driving factors for service companies to participate in formal standardization processes: An empirical analysis. Proceedings of the 18th RESER conference 2008, Stuttgart, Germany.

Blind, K., Neuhaeusler, P., Pohlmann, T., 2011. Standard essential patents to boost financial returns. Proceedings of the 6th Annual conference of the EPIP Association: Fine-tuning IPR debates, Brussels, Belgium.

Briscoe, J. A., Fawcett, S. E., Todd, R. H., 2005. The implementation and impact of ISO 9000 among small manufacturing enterprises. Journal of Small Business Management 43, 309-330.

Cainelli, G., Evangelista, R., Savona, M., 2006. Innovation and economic performance in services: a firm-level analysis. Cambridge Journal of Economics 30, 435-458.

Chesbrough, H., 2003. Open Innovation. Havard University Press: Cambrigde, MA.

Chiesa, V., Toletti, G., 2003. Standard-setting strategies in the multimedia sector. International Journal of Innovation Management 7, 281-308.

Cohen, J., Cohen, P., West, S. G., Aiken, L. S., 2003. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Erlbaum: Mahwah, NJ.

Corbett, C. J., Montes-Sancho, M. J., Kirsch, D. A., 2005. The financial impact of ISO 9000 certification in the United States: An empirical analysis. Management Science 51, 1046-1059.
Crépon, B., Duguet, E., Mairesse, J., 1998. Research, innovation and productivity: An econometric analysis at the firm level. Economics of Innovation and New Technology 7, 115-158.

Czarnecki, D., Kraft, K., 2010. On the profitability of innovative assets. Applied Economics 42, 1941-1953.

David, P. A., Greenstein, S., 1990. The economics of compatibility standards: An introduction to recent research. Economics of Innovation and New Technology 1, 3-41.

Dhawan, R., 2001. Firm size and productivity differential: Theory and evidence from a panel of US firms. Journal of Economic Behavior & Organizations 44, 269-293.

Droege, H., Hildebrand, D., 2009. Innovation in services: Present findings, and future pathways. Journal of Service Management 20, 131-155.

DTI, 2005. The empirical economics of standards. DTI Economics Paper 12, London: Department of Trade and Industry, www.bis.gov.uk/files/file9655.pdf.

Duysters, G., Lokshin, B., 2011. Determinants of alliance portfolio complexity and its effect on innovative performance of companies. Journal of Product Innovation Management 28, 570-585.

Dyer, J. H., Singh, H., 1998. The relational view: Cooperative strategy and sources of interorganizational competitive advantage. The Academy of Management Review 23, 660-679.

Fernández, E., Montes, J. M., Vázquez, C. J., 2000. Typology and strategic analysis of intangible resources. Technovation 20, 81-92.

Friedman, L. W., Friedman, H. H., 1995. Analyzing simulation output using the bootstrap method. Simulation 64, 95-100.

Glueckler, J., Hammer, I., 2011. A pragmatic service typology: Capturing the distinctive dynamics of services in time and space. The Service Industries Journal 31, 941-957.

Gotsch, M., Hipp, C., 2011. Measurement of innovation activities in the knowledge intensive services industry: A trademark approach. The Service Industries Journal forthcoming article first published on: 23 May 2011, DOI:10.1080/02642069.2011.574275.

Hipp, C., Grupp, H., 2005. Innovation in the service sector: The demand for service-specific innovation measurement concepts and typologies. Research Policy 34, 517-535.

Hippel, E. von, 1988. The sources of innovation. Oxford University Press: New York.

Hytönen, H., Jarimo, T., Salo, A., Yli-Juuti, E., 2011. Markets for standardized technologies: Patent licensing with principle of proportionality. Technovation (in Press), doi: 10.1016/j.technovation.2011.08.002.

Jungmittag A., Blind, K., Grupp, H., 1999. Innovation, standardisation and the long-term production function. A cointegration analysis for Germany 1960–96. Zeitschrift fuer Wirtschafts- und Sozialwissenschaften (ZWS) 119, 205–222.

Kneller, R., Pisu, M., 2010. The returns to exporting: Evidence from UK firms. Canadian Journal of Economics 43, 494-519.
Koellinger, P., 2008. The relationship between technology, innovation, and firm performance – Empirical evidence from e-business in Europe. Research Policy 37, 1317-1328.

Laursen, K., Salter, A., 2006. Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms. Strategic Management Journal 27, 131-150.

Lecraw, D. J., 1984. Some economic effects of standards. Applied Economics 16, 507-522.

Leiponen, A., Helfat, C. E., 2010. Innovation objectives, knowledge sources, and the benefit of breadth. Strategic Management Journal 31, 224-236.

Love, J. H., Roper, S., 1999. The determinants of innovation: R&D, technology transfer and networking effects. Review of Industrial Organizations 15, 43-64.

Manez-Castillejo, J. A., Rochina-Barrachina, M. E., Sanchis-Llopis, J. A., 2010. Does firm size affect self-selection and learning-by-exporting? World Economy 33, 315-346.

Miozzo, M., Soete, L., 2001. Internationalization of services: A technological perspective. Technological Forecasting and Social Change 67, 195-185.

Pekovic, S., Galia, F., 2009. From quality to innovation: Evidence from two French employer surveys. Technovation 29, 829-842.

Salop, S. C., Scheffman, D. T., 1983. Raising rivals costs. American Economic Review 73, 267-271.

Salop, S. C., Scheffman, D. T., 1987. Cost-raising strategies. Journal of Industrial Economics 36, 19-34.

Schmoch, U., Gauch, S., 2009. Service marks as indicators for innovation in knowledge-based services. Research Evaluation 18, 323-335.

Schumpeter, J. A., 1934. The theory of economic development. Harvard University Press: Cambridge, MA.

Swann, G. M. P., 2010. The economics of standardization: An update. Report for the UK Department of Business, Innovation and Skills (BIS).

Tien, S.-W., Chung, Y.-C., Tsai, C.-H., 2005. An empirical study on the correlation between environmental design implementation and business competitive advantages in Taiwan's industries. Technovation 25, 783-794.

Tsai, K.-H., 2005. R&D productivity and firm size: A nonlinear examination. Technovation 25, 795-803.

Vence, X., Trigo, A., 2009. Diversity of innovation patterns in services. The Service Industries Journal 29, 1635-1657.

Wakke, P., Blind, K., Vries, H. de., 2012. The relationship between innovation in services and standardization: Empirical evidence of service providers’ involvement in standardization. Working paper available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2045484.

Weiss, M. B. H., Sirbu, M., 1990. Technological choice in voluntary standards committees: An empirical analysis. Economics of Innovation and New Technology 1, 111-133.
Wiele, P. van de, 2010. The impact of training participation and training costs on firm productivity in Belgium. The International Journal of Human Resource Management 21, 582-599.

Zutshi, A., Sohal, A., 2004. Environmental management system adoption by Australasian organisations: Part 1: Reasons, benefits and impediments. Technovation 24, 335-357.
Figure A1: Histogram of the Solow residuals in terms of the standard deviation (SD)