Innovation in the service sector and the role of patents and trade secrets: Evidence from Japanese firms

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Highlights

- This study presents new empirical evidence on innovation in the service sector.
- We use an original firm survey data linked with government statistics in Japan.
- The productivity of innovative service firms is very high.
- Service firms' holding of trade secrets is comparable to that of manufacturing firms.
- Service innovations have positive association with holding patents and trade secrets.

Innovation in the service sector and the role of patents and trade secrets: Evidence from Japanese firms

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ABSTRACT

This study, using Japanese firm-level data, presents empirical findings on innovation in the service sector and the role of patents and trade secrets. Service firms have fewer product innovations than manufacturing firms do, but the productivity of innovative service firms is very high. Service firms have a low propensity to hold patents, but their holding of trade secrets is comparable to that of manufacturing firms. Product/service innovations have positive relationships with holding patents and trade secrets in both industries, but a positive association of process innovations is found only with holding trade secrets in the manufacturing industry.

JEL classifications: O31, O34, L80

Keywords: Innovation, Service sector, Patent, Trade secret, Productivity

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1. Introduction

This study, using Japanese firm-level data, presents empirical evidence on innovation in the service sector and the role of patents and trade secrets in innovation. In advanced countries including Japan, service industries account for more than 70% of GDP, and improving their productivity is crucial to increasing the growth potential of the overall economy. While numerous factors affect the productivity of industries and firms, innovation is one of the fundamental drivers of productivity growth. However, innovation in the service sector has not been subjected to sufficient empirical analysis in Japan or in other advanced economies. Cohen (2010), in a comprehensive survey of empirical studies of innovation, states that "a major lacuna in our understanding of the determinants of innovative activity and performance is our virtual ignorance of innovation in the service sector."[1] Here, we present novel findings about innovation in service firms in comparison with that in manufacturing firms.

In general, manufacturing firms are far more active in terms of formal R&D investment than are firms in the service sector. According to the Basic Survey of Japanese Business Structure and Activities (Ministry of Economy, Trade, and Industry: METI), the mean R&D intensity (R&D expenditure/sales) of service firms in 2013 was

[1] While many empirical studies of innovation focus on the manufacturing sector, several studies have examined innovation in the service sector. Miles (2005), Gallouj and Savona (2009), and Randhawa and Scerri (2015) survey the literature on innovation in services. Recent empirical studies include Tether (2005), Musolesi and Huiban (2010), Greenhalgh and Rogers (2012), Leiponen (2012), Basker (2012), Bartelsman *et al*. (2015), Battisti *et al*. (2015), Ortega-Argilés *et al*. (2015), Goy and Wang (2016), and Hall and Sena (2017).

0.35%, less than a third of the mean R&D intensity of manufacturing firms (1.29%).[2] However, innovation is not limited to the development of new products/services through formal R&D investment. According to the current guidelines for internationally comparable innovation surveys, "innovation" includes 1) products, 2) processes, 3) organizational innovations, and 4) marketing innovations (OECD, 2005).

The Japanese Innovation Survey 2012 (National Institute of Science and Technology Policy, 2014) indicates that the percentages of firms that invested in the four types of innovations between fiscal years 2009 and 2011 were 1) 15.8% (new businesses), 2) 15.6% (new products/services), 3) 28.3% (product/service improvements), and 4) 22.5% (new production/delivery methods). Innovations other than new product development are thus frequent.[3]

Although the R&D intensity of service firms, on average, is lower than that of manufacturing firms, these broadly defined innovations may play important roles in productivity improvements in the service industries. In fact, recent productivity studies argue that we should focus more on "soft innovations" related to human resources, organizational change, and other intangible investments when analyzing innovations in the service sector (Jorgenson and Timmer, 2011; Timmer *et al*., 2011).

Using an original firm survey, along with government statistics, this study presents empirical findings on innovative activities in the service sector and the role of patents and trade secrets in innovation, particularly in comparison with that in the manufacturing sector. The major research questions of this study are whether the relationship between innovative activities and firm performance differs between the service and manufacturing sectors and whether patents and trade secrets play an important role in service innovations.

This study offers three novel contributions. First, our data cover a large number of

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[2] The service industries included in this calculation are the wholesale, retail, and narrowly defined service industries (business services and personal services). The calculation of the mean figures includes firms with zero R&D expenditure.

[3] According to the report of the Survey, the percentages of firms engaged in these four types of innovations were smaller than those in Germany and France.

service firms, which enables us to compare the manufacturing and service industries. Second, the study covers new product/service development as well as improvements to existing products/services and the adoption of new production or delivery methods. Third, we use an accurate objective measure of holding trade secrets based on whether a firm has the "Trade Secret Management Rule."

The major findings of this study are as follows. First, service firms have fewer product innovations than manufacturing firms do, but the productivity of innovative service firms is very high. Second, service firms have a low propensity to hold patents, but their holding of trade secrets is comparable to that of manufacturing firms. Third, product/service innovation has a positive relationship with the possession of patents and trade secrets in both the manufacturing and the service sectors. However, a positive relationship between process innovation and the possession of trade secrets is found only in the manufacturing sector.

The rest of this paper is structured as follows. Section 2 briefly explains the institutional background in Japan and reviews the literature. Section 3 provides the analytical framework and hypotheses of the study. Section 4 explains the data and method of analysis. Section 5 reports and interprets the empirical results. Finally, Section 6 concludes the paper, including a discussion of the policy implications of the findings.

2. Appropriation mechanisms: Institutional background and literature review

In Japan, patents and trade secrets are protected by the Patent Act and the Unfair Competition Prevention Act, respectively. While a detailed explanation of patents is unnecessary, inventions characterized by "a high level of technological creativity based on natural laws and rules" can be protected by the Patent Act. Similarly to other countries, novelty and non-obviousness are required to patent inventions, and filed patent applications are disclosed to the public.[4]

On the contrary, the prerequisites for information to be legally protected as trade secrets are as follows: 1) the information is the subject of reasonable efforts to maintain its secrecy, 2) the information has economic value, and 3) the information is not known to the public. Trade secrets are not limited to technological information such as manufacturing know-how. Non-technological information such as customer lists, recipes of restaurants, sales or service manuals, and contract information can also be protected as trade secrets. These types of non-technological information are often possessed by firms in the service sector. The Unfair Competition Prevention Act has been amended several times to strengthen the protection of trade secrets. To be legally protected by this Act, it is recommended that firms document a Trade Secret Management Rule in accordance with the Guideline of Trade Secret Management (METI).

Past studies of the choice of appropriation mechanisms by innovating firms, focusing on the manufacturing sector, indicate that patents are not necessarily the major protection mechanism for technological innovations (for surveys, see Encaoua *et al*., 2006; Hall *et al*., 2014; Moser, 2016).[5] The study of Levin *et al*. (1987) analyzes firms' choices of appropriation mechanisms for innovations based on a survey of manufacturing firms that conduct R&D in the United States. The authors indicate that appropriation mechanisms other than patent filing such as secrecy and lead-times play important roles.[6] Arundel (2001) analyzes the relative importance of secrecy and patents using data from the 1993 European Community Innovation Survey, indicating that many European manufacturing firms, especially smaller firms, rate secrecy as more valuable than patents. Cohen *et al*. (2002) conduct a

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[4] The characteristics of Japan's patent system can be found, for example, in Cohen *et al*. (2002).

[5] Rockett (2010) surveys theoretical analyses of the relationship between patents and secrecy.

[6] Png (2017) analyzes the effect of the US Trade Secrets Act on R&D, finding that the Act is associated with higher R&D in large firms and in firms in high-tech industries.

similar survey for Japanese manufacturing firms and compare the results with those for US firms. According to their study, the percentage of Japanese firms that choose secrecy as a mechanism for appropriation is far smaller than that in the United States.

While these studies are limited to manufacturing firms, Amara *et al*. (2008) conduct a similar analysis for knowledge-intensive business service (KIBS) firms in Canada. They show that the importance of patents as an appropriation mechanism is lower among these firms and that there is complementarity between patents and secrecy. More recently, a small number of studies have analyzed firms' choices of appropriation mechanisms, finding some evidence of differences between the manufacturing and service sectors. Hall *et al*. (2013), using a firm-level dataset for the United Kingdom, find that manufacturing firms prefer patents to product innovations, but prefer secrecy to process innovations. Furthermore, KIBS firms strongly prefer secrecy to patents. Hall and Sena (2017), using essentially the same dataset for UK firms, analyze firms' choices of appropriation mechanisms and their impact on firm-level innovation and productivity. They find that innovative firms that rate formal intellectual property protection mechanisms (patents, trademarks, copyrights, and design rights) highly are more productive than other firms are and that the relationship is stronger in the service sector than in the manufacturing sector. Goy and Wang (2016), using firm-level data for Australia covering both the manufacturing and the non-manufacturing industries, find that manufacturing firms are more likely to use patents than secrecy.

Overall, past studies have thus clarified the use of various appropriation measures. However, the differences between manufacturing and service firms in this regard have not yet been analyzed sufficiently.

3. Service innovation: Analytical framework and hypotheses

As described in the Introduction, innovation is the engine of productivity growth. However, despite the growing importance of the service economy, firm-level evidence on innovations in the service industry has been scarce, particularly in Japan. This study is an attempt to fill the lacuna using original firm survey data combined with official statistics to document several facts about the innovation and appropriation mechanisms used in the Japanese service industry.

In general, firm-level empirical studies, based mainly on data on manufacturing firms, indicate that innovation positively affects productivity (see Hall *et al*., 2010; Hall, 2011). Although firm-level empirical studies of the relationship between innovation and productivity in the service sector are limited, studies in Europe of service firms suggest a positive association between innovation and productivity (Musolesi and Huiban, 2010; Bartelsman *et al*., 2015). It is therefore natural to conjecture that firms engaged in innovative activities use formal appropriation mechanisms to protect their intellectual property. We expect that these relationships hold irrespective of the industry, leading to the following two hypotheses:

Hypothesis 1. The productivity of service firms that engage in innovative activities is higher than that of service firms that do not.

Hypothesis 2. Service firms engaged in innovative activities are more likely to hold patents and trade secrets.

However, most service industries have characteristics distinct from those of the manufacturing industry because their outputs are intangible, services are produced and consumed simultaneously, and they are often users of the innovations developed in other industries (Miles, 2005; Randhawa and Scerri, 2015). For example, in the case of information technology, the wholesale, retail, and transportation service industries are often classified as IT-using industries and productivity studies indicate that these industries have benefitted significantly from the IT revolution (Stiroh, 2002; Oliner *et al*., 2007; Draca *et al*., 2007). For example, Basker (2012) indicates that the use of barcodes and barcode scanners—an important innovation in the retail industry—has enhanced the productivity of supermarkets substantially. In addition, innovations by service firms are often non-technological in nature, and rather than being the result of formal R&D conducted in research laboratories, these innovations result from interactions with customers or in markets.

We expect that these characteristics of innovations in service industries affect service firms' choices of formal and informal appropriation mechanisms. To be patented, innovations must be novel and non-obvious. However, in contrast to physical artifacts, it is often difficult to prove that innovations in intangible services are patentable. For example, valuable non-technological information such as commercial information, financial data, sales or service manuals, and customer/supplier lists, which have strong relevance to service innovations, are difficult to protect using patents. The coverage of patent protection has recently expanded to include software and business models. However, compared with physical artifacts, the effectiveness of patents in these new areas is still limited. As a result, trade secrets, which offer wider coverage than patents and do not require disclosure, may be chosen as the appropriation mechanism. Several recent studies of the appropriation mechanisms of KIBS indicate the relative importance of secrecy in this service industry (Amara *et al*., 2008; Leiponen and Byma, 2009; Hall *et al*., 2013), although whether the result holds for other service industries remains unknown.

The effectiveness of patent protection differs significantly between product and process innovations (see Hall *et al*., 2014). This is because in contrast to new products purchasable in the market, production processes are difficult to reverse engineer. In addition, too much information may be disclosed to obtain patent protection for processes. Therefore, from an innovator's cost–benefit perspective, secrecy is preferred to patenting to protect process innovations. In fact, many empirical studies indicate that patents are less effective for process innovations than they are for product innovations (Levin *et al*., 1987; Arundel, 2001; Cohen *et al*., 2002). However, past studies have not analyzed the appropriation mechanisms specific to process innovations in the service industry.

Considering the distinct nature of service innovations and the available evidence found in past studies, we propose the following hypothesis with regard to the appropriation mechanisms employed in service industries:

Hypothesis 3. Trade secrets are a more important appropriation mechanism than patents for product innovations in the service industry as well as for process innovations in the manufacturing industry.

In the following sections, we empirically test these three hypotheses using a dataset of Japanese firms covering both the manufacturing and the service industries.

4. Data and methodology

This study uses cross-sectional micro data for fiscal year 2011 from the Survey of Corporate Management and Economic Policy (Research Institute of Economy, Trade and Industry: RIETI) as well as data from the Basic Survey of Japanese Business Structure and Activities (METI). The Survey of Corporate Management and Economic Policy is an original survey conducted by RIETI from December 2011 to February 2012. The questionnaire was sent to 15,500 Japanese firms, including large, medium, and small manufacturing and service firms. In all, 3,444 firms responded to the survey (a response rate of 22.2%). The survey questionnaires included questions on managerial objectives, the composition of shareholders, internal organization, innovations, and business restructuring.

In this study, we use the questions on innovative activities and the existence of the Trade Secret Management Rule in firms. Specifically, the surveys asked respondents to indicate their innovative activities during the previous three years from the following list: 1) the development of new products/services, 2) improvements to existing products/services, and 3) the adoption of new production or delivery methods.[7]

[7] The survey also asked about “entry into new businesses” as an innovative activity, but we do not use this question in this study.

Roughly speaking, activities 1) and 2) correspond to product innovation and activity 3) to process innovation. The specific question about trade secrets was "Does your firm have the Trade Secret Management Rule to protect technology and know-how important to your business?" If the answer is "yes," we can infer that the firms have trade secrets of economic value.

The Basic Survey of Japanese Business Structure and Activities, an annual survey first conducted in 1992, provides representative government statistics on Japanese firms with 50 or more regular employees, including those engaged in the mining, manufacturing, electricity and gas, wholesale, retail, and several service industries. The purpose of the survey is to capture a comprehensive picture of Japanese firms, including their basic financial information (e.g., sales, costs, profits, book value of capital), the number of employees, R&D expenditure, IT usage, and foreign direct investment. In this study, we use data from the Survey for fiscal year 2011 (conducted in 2012). The survey items used in this study include the industry classification, number of employees, year of establishment, holding of patents, and R&D expenditure. In addition, financial information, including sales, labor costs, and the book value of tangible assets, is employed to estimate total factor productivity (TFP).

Although the number of patent holdings is available from the Basic Survey of Japanese Business Structure and Activities, the data on trade secrets in the Survey of Corporate Management and Economic Policy are limited to whether the firm has trade secrets. Therefore, we treat both patent and trade secret holdings as discrete (dummy) variables to compare the relative importance of these two appropriation mechanisms for intellectual property.

After linking the two datasets at the firm-level, we test the statistical differences between manufacturing and service firms with regard to the percentages of firms engaged in innovative activities, holding patents, and holding trade secrets. Here, we compare the mean TFP levels of firms with and without the three innovative activities. The service firms in our dataset are those whose industries are classified into the wholesale, retail, and narrowly defined service industries (business services and personal services). In the analysis, service firms are further classified into high and low

IT intensity firms and similar productivity comparisons are made. IT intensity in this study is defined as IT expenditure divided by the sales of a firm. High IT intensity service firms are defined as those with an IT intensity at or above the sample median.

Next, we analyze the relationship between firms' innovative activities and possession of intellectual property rights. Specifically, we conduct bivariate probit estimations, where the three innovative activities mentioned above are used as the main explanatory variables and the holdings of patents (*patent*) and trade secrets (*secret*) are used as the dependent variables (equations (1) and (2)). In these estimations, firm size (natural logarithm of the number of regular employees), firm age, and industry dummies (one digit) are used as control variables.

$$Pr\ (patent=1) = F\ (\beta_{p0} + \beta_{p1}\ innovation + \beta_{p2}\ firm\ size + \beta_{p3}\ firm\ age + \beta_{p4}\ industry\ dummies) + \varepsilon_p \quad (1)$$

$$Pr\ (secret=1) = F\ (\beta_{s0} + \beta_{s1}\ innovation + \beta_{s2}\ firm\ size + \beta_{s3}\ firm\ age + \beta_{s4}\ industry\ dummies) + \varepsilon_s \quad (2)$$

$$\mathrm{Cov}\ (\varepsilon_p, \varepsilon_s) = \rho$$

The reason behind using a two-equation bivariate probit model instead of a simple probit model is that firms' propensity to use patents and trade secrets as innovation appropriation mechanisms is likely to be correlated with each other. Past studies of innovation in the manufacturing sector point out that patents and trade secrets are not mutually exclusive and that innovative firms often adopt a combined patent–secrecy strategy (Hall *et al*., 2014). For example, the codified aspects of an innovation might be patented, while the remaining aspects of the innovation are kept secret.[8] In other instances, secrecy is used for works in progress and patents are applied to final products. In these cases, patents and trade secrets play a complementary role in protecting firms' innovation processes. Therefore, it is better to use a two-equation

[8] For example, Arora (1997) presents historical evidence of the combined patent–secrecy strategy in the US chemical industry.

bivariate probit model to allow correlated disturbances ($\rho \neq 0$).

In the estimations, we are interested in the statistical significance and size of the coefficients $ß_{p1}$ and $ß_{s1}$. In addition to the estimation for the full sample, separate estimations are conducted for the subsamples of manufacturing and service firms. These estimations depend on cross-sectional data and do not aim to detect the causality between the holding of intellectual properties and innovations. We are interested in determining a statistical relationship between firms' engagement in innovative activities and their use of appropriation measures by industry, after accounting for basic firm characteristics.

The overall sample comprises 3,444 firms, including 1,567 manufacturing and 1,860 service firms.[9] Further classification reveals that 697, 396, and 767 firms are classified into the wholesale, retail, and narrowly defined service industries, respectively.[10] Table 1 presents the summary statistics of the major variables.

5. Results

5.1. Overview of innovation in the service industry

Table 2 shows the percentages of firms engaged in innovative activities between fiscal years 2009 and 2011 and the t-test results for the statistically significant differences between manufacturing and service firms (column (1)) and between high and low IT intensity service firms (column (2)). Among the three types of innovative activities, the percentages of firms engaged in the development of new

[9] The remaining 17 firms are classified into other industries such as mining and construction.

[10] The narrowly defined service industries include other services, software, information processing, machine repair services, sports facilities, laundries, healthcare services, and restaurants. In this study, electricity, gas, heat supply, and water are not included in the service industry.

products/services are the highest, followed by improvements to existing products/services, in both manufacturing and service firms. The figures are higher among manufacturing firms than service firms by 12 to 13 percentage points and the differences are statistically significant at the 1% level, indicating that manufacturing firms are more active in terms of product innovations. The figures for adopting new production or delivery methods (process innovation) are significantly higher for manufacturing firms, but the difference is quantitatively small. Overall, manufacturing firms are more active in terms of both product and process innovations compared with service firms. Service firms using IT intensively are more likely to engage in product innovations than low IT intensity service firms, but the percentages are still lower than for manufacturing firms (column (2) of Table 2).

Next, we compare the mean TFP levels of firms with and without the three types of innovative activities. TFP is calculated using data from the Basic Survey of Japanese Business Structure and Activities in a nonparametric manner, adopting a hypothetical representative firm as a reference. This is called the index number method, which is often used for measuring TFP in the literature (e.g., Nishimura *et al*., 2005; Fukao and Kwon, 2006; Morikawa, 2010). Specifically, the input and output of the hypothetical representative firm are calculated as the respective geometric means of all firms and the cost shares of labor and capital are calculated as the arithmetic means. The TFP for each firm is calculated relative to the hypothetical representative firm.[11]

The cross-tabulation results in Table 3 show the TFP levels of innovators and non-innovators, along with the t-test statistics of the differences. For the full sample (column (1) of Table 3), the TFP values for firms that developed new products/services and for firms that improved existing products/services are about 6 and 9 percentage points, respectively, higher than those without these activities. Because the data used in this study are cross-sectional, the results do not necessarily indicate causal relationships. However, they suggest that product innovations are strongly related to

[11] All the firms included in the Basic Survey of Japanese Business Structure and Activities were used to measure firm-level TFP accurately.

productivity at the firm-level.[12] While the adoption of new production and/or delivery methods (process innovation) is also related to higher TFP levels, the difference is statistically insignificant (row C of the table).

With regard to the subsamples of manufacturing and service firms, positive and significant relationships between product innovations and TFP are observed for both sectors (columns (2) and (3) of Table 3). However, interestingly, the difference in TFP with and without product innovations is larger among service firms. This result is in line with a study of European firms (Bartelsman *et al.*, 2015) that indicates that the effect of product innovations on productivity is larger for the service industry than it is for the manufacturing industry. In the service sector, the mean TFP level of the firms that developed new services is about 12 percentage points higher than the firms without such an activity (the comparable figure is about 6 percentage points for manufacturing firms). On the contrary, process innovation—improvements to existing products/services—has a positive and statistically significant relationship with TFP among manufacturing firms only (the difference is about 9 percentage points) and the relationship is statistically insignificant among service firms.

When dividing service firms into high and low IT intensity firms (columns (4) and (5) of Table 3), the TFP premiums of those who developed new products/services are similar. However, in the case of improvements to existing products/services, the TFP premium of innovators is statistically significant only for high IT intensity service firms, suggesting complementarity between the use of IT and improvements to services.

As a robustness check, we eliminate firms with a TFP level three standard deviations higher or lower than the sample mean. The results are qualitatively and quantitatively similar to those obtained from the whole sample. Thus, the productivity premium of innovators observed above is not the result of the small number of outliers

[12] Hall (2011) surveys the literature on the relationship between innovation and productivity. He points out that product innovation has a substantial positive impact on productivity, but that the impact of process innovation on productivity is ambiguous.

(Appendix Table A1).

Finally, we run OLS regressions to control for firm size, firm age, and industry. The estimation results in Appendix Table A2 confirm the statistical significance of innovators' higher TFP presented in Table 3. The regression results also verify that the difference in TFP with and without product/service innovations is larger among service firms than it is among manufacturing firms.

To summarize, Hypothesis 1 is supported for both product and process innovations in the manufacturing sector and strongly supported for product innovations in the service sector. However, the hypothesis is not supported for process innovations in the service sector.

5.2. The role of patents and trade secrets

Table 4 presents the percentages of firms holding patents and trade secrets along with the t-test results for the significant differences between industries. Almost four in 10 (39.2%) manufacturing firms hold patents compared with just 11.3% of service firms, representing a large and statistically significant difference (panel A of Table 4). On the contrary, the percentages of firms holding trade secrets are 33.0% and 32.6% for manufacturing firms and service firms, respectively. These figures are much closer and the difference is statistically insignificant. These observations suggest that in comparison with the manufacturing industry, trade secrets are a relatively important appropriation measure to protect intellectual property in the service industry.

When dividing service firms by their IT intensity, the possession of patents by firms' IT intensity is statistically insignificant, but service firms with high IT intensity tend to have trade secrets compared with low IT-intensive firms (column (2) of Table 4).

Panels B and C of Table 4 show separate calculations for firms that perform R&D and those that do not, respectively. Firms that perform R&D are defined as those with positive R&D expenditure during fiscal years 2009 and 2011. Thus, 53.0% (i.e., 831 of 1,567) of manufacturing firms invest in R&D, while only 16.5% (i.e., 267 of 1,614) of firms in the service industry do so. This finding confirms that a relatively small number of service firms conduct formal R&D. After restricting the sample to those firms that invest in R&D (panel B), the percentage of firms holding patents is higher in the manufacturing industry (60.4% in manufacturing and 41.2% in service), whereas the percentage of firms holding trade secrets is higher in the service industry (39.3% in manufacturing and 51.0% in service). The differences are both statistically significant at the 1% level. In particular, IT-intensive service firms that conduct R&D show a very high propensity to hold trade secrets (54.9%).

Table 5 reports the estimation results of the bivariate probit model (equations (1) and (2)) to explain holdings of patents and trade secrets, where the three types of innovations are used as the main explanatory variables. Panels A, B, and C of the table report the results for the development of new products/services, improvement of existing products/services, and adoption of new production or delivery methods, respectively. As described in the previous section, the purpose of the estimation is not to detect causality between innovations and intellectual property holdings. The estimation results should thus be interpreted as an indication of a possible bidirectional relationship.

According to the Wald test statistics, the null hypothesis of zero correlation ($\rho=0$) is rejected at the 1% or 5% level in all estimations, meaning that the unobservable firm characteristics explaining *patent* and *secret* are correlated. This result supports the use of the bivariate probit model instead of two univariate probit models.

In the case of the development of new products/services (panel A), after controlling for firm size and firm age, innovators' propensity to use patents is higher than their propensity to have trade secrets irrespective of industry. By contrast, according to the estimations for the improvement of existing products/services (panel B), the coefficients of this type of innovation are similar for patents and trade secrets irrespective of industry. Interestingly, the coefficients in the patent equation in panel B are substantially smaller than the corresponding coefficients in panel A, whereas the coefficients in the trade secret equation are somewhat larger in panel B, suggesting that trade secrets are a relatively important appropriation mechanism for this type of *gradual* product innovation.

When comparing the results for the manufacturing and service industries, the coefficients of product/service innovation for patents and trade secrets are both greater in the former, suggesting that both the legal appropriation mechanisms examined here are more effective in the manufacturing industry.

In the estimations for process innovation (panel C), the coefficients of innovation in the patent equation are generally insignificant, whereas those in the trade secret equation are positive and significant for the full sample and the manufacturing subsample (rows (1) and (2)). This result confirms the findings of past studies that secrecy is important for process innovations in the manufacturing industry (Levin *et al*., 1987; Harabi, 1995; Brouwer and Kleinknecht, 1999; Arundel, 2001; Cohen *et al*., 2002). However, the coefficients of process innovation are insignificant for the subsample of service firms (row (3)), meaning that both patents and trade secrets are not necessarily an effective measure of process innovations in the service industry.

To check the differences by the use of IT among service firms, we include the interaction terms of IT intensity and innovative activities as additional explanatory variables. According to the estimations, the coefficients of the interaction term are generally insignificant and the size and significance of the innovator dummies are unaffected by the inclusion of the interaction term in both the patent and the trade secret equations (Appendix Table A3). That is, we do not detect the different use of appropriation measures by the IT intensity of innovating service firms.

To summarize the above results from the viewpoint of innovation in the service sector, patents and trade secrets play an important role in the product/service innovation of service firms. That is, Hypothesis 2 is supported. However, in comparison with manufacturing firms, the quantitative relationships of these appropriation measures and product/service innovation are somewhat smaller in the service industry. In addition, both these appropriation mechanisms are not necessarily associated with process innovation in the service industry. Although the number of service firms holding patents is far smaller than that of manufacturing firms (see Table 4), which is consistent with Hypothesis 3, the estimation result does not fully support the importance of trade secrets as an appropriation measure in the service industry.

The finding of the low usage of these two legal appropriation measures in the innovations of service firms relative to manufacturing firms is worth paying attention to. As we have seen, manufacturing firms are more active in innovations than service firms (see Table 2). The relatively small role of the legal appropriation measures analyzed in this study might therefore be related to the weaker innovation performance in the service industry.

However, we need to bear in mind that alternative formal and informal appropriation measures other than patents and trade secrets exist such as copyrights and lead-times. Since data on these other appropriation measures are unavailable in our dataset, the estimated coefficients in the equations used to explain the possession of patents and trade secrets may be biased. At the same time, while application and maintenance fees apply only to patents, both patents and trade secrets are costly to enforce (Hall *et al.*, 2014). Thus, selection mechanisms based on firms' ability to invest in appropriation costs may affect the estimations. In this respect, the estimations control for firm size, which is likely to affect firms' ability to bear the appropriation costs. Hall *et al.* (2014), a representative survey of such appropriation measures, state that appropriability strategies vary across firms of different size. In fact, the coefficients of firm size are generally positive and statistically significant as expected (not reported in the table), although we cannot eliminate the possibility that other observable/unobservable firm characteristics may be correlated with firms' investment ability.[13]

6. Conclusion

[13] As a robustness check, we included the ratio of cash flow to (tangible and intangible) assets, a representative measure of financial constraints, as an additional control variable in the estimations. This additional variable is insignificant and the coefficients of innovations are unaffected by its inclusion. These results suggest that different from firm size, the availability of cash flow is not an important determinant of firms' investment ability to use patents and trade secrets.

This study, using an original firm survey combined with government statistics, presents empirical findings on innovative activities in the service sector and the role of patents and trade secrets on such innovations by comparing the results with those of the manufacturing sector.

We detected a variety of distinct characteristics of innovative activities among service firms. First, service firms have fewer product/service innovations than manufacturing firms do, but the TFP of innovative service firms is very high. Second, service firms have a low propensity to hold patents, but the holding of trade secrets is comparable to that of manufacturing firms, suggesting the importance of knowledge and know-how, which are difficult to patent for innovations in the service sector, particularly for IT-intensive service firms. Third, firms' product/service innovations have positive associations with the possession of patents and trade secrets both in the manufacturing and in the service industries, but the association is quantitatively larger in the manufacturing industry. On the contrary, a positive association between trade secrets and process innovations is found only in the manufacturing sector.

The findings that innovative service firms exhibit high productivity and that holding intellectual property is strongly related to innovation in service firms suggest that legal appropriation measures may contribute to productivity growth in the service sector. However, whether the current legal system for intellectual property is sufficient to promote soft innovations specific to the service industry requires further research. Another implication of this study is that patent data are an incomplete measure for analyzing innovation in the service sector. In this respect, additional data on firms' use of alternative appropriation mechanisms, particularly for trade secrets, would be valuable.

While this study presents new findings on the differences between innovations in the manufacturing and service industries, some limitations should be mentioned. Because the results of this study depend on a cross-sectional dataset, the detected relationships cannot be interpreted as being causal. In addition, we cannot eliminate the possibility of omitted variable bias; that is, some unobservable firm characteristics such as management quality and the skill of managers may affect both the holding of patents/trade secrets and the innovativeness of firms. However, it should be emphasized that the purpose of this study was to provide understudied facts about innovation in service firms and its relationship with intellectual property. To deepen our understanding of service innovation, panel data on innovations and intellectual property rights covering a large number of service firms are required.

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Table 1

Summary statistics.

Table 1

Variables	Nobs.	Mean	SD.	Min.	Max.
		A. Full sample			
Patent	3,444	0.232	0.422	0	1
Secret	3,056	0.328	0.470	0	1
Firm size	3,198	5.245	1.031	3.912	11.249
Firm age	3,198	44.726	19.456	1	168
TFP	2,572	-0.174	0.500	-3.124	1.797
		B. Manufacturing firms			
Patent	1,567	0.392	0.488	0	1
Secret	1,402	0.330	0.470	0	1
Firm size	1,567	5.084	0.896	3.912	11.249
Firm age	1,567	48.669	18.343	1	168
TFP	1,277	-0.247	0.456	-3.124	1.672
		C. Service firms			
Patent	1,860	0.098	0.297	0	1
Secret	1,640	0.326	0.469	0	1
Firm size	1,614	5.407	1.127	3.912	10.546
Firm age	1,614	40.877	19.708	1	106
TFP	1,283	-0.101	0.530	-2.711	1.797

Notes. Patent and *secret* are dummies for firms holding patents and trade secrets, respectively. *Firm size* is the natural logarithm of the number of employees. *Firm age* is the number of years since establishment. *TFP* is the index measure expressed in logarithm form. The sum of the manufacturing firms and service firms is different to the number of firms in the full sample because a small number of firms do not belong to either of these industries.

Table 2

Innovations of manufacturing and service firms.

Table 2

Type of innovations	(1) Manufacturing	Service	Diff.	(2) High IT service	Low IT service	Diff.
A. Development of new products/services	48.6%	36.5%	12.1% ***	38.5%	32.0%	6.5% ***
B. Improvement of existing products/services	47.5%	33.8%	13.7% ***	36.7%	29.1%	7.6% ***
C. Adoption of new production or delivery methods	19.8%	15.4%	4.4% ***	15.3%	15.5%	-0.1%

Note. *** indicates statistically significant differences between manufacturing and service industries (or between high- and low IT-intensive service firms) at the 1% level.

Table 3

Innovators' productivity premium.

Table 3

Type of innovations	(1) Full sample	(2) Manufacturing	(3) Service	(4) High IT service	(5) Low IT service
A. Development of new products/services	0.0614 ***	0.0558 **	0.1172 ***	0.1108 ***	0.1220 **

B. Improvement of existing products/services	0.0866***	0.1007***	0.1258***	0.1501***	0.0848
C. Adoption of new production or delivery methods	0.0373	0.0913***	0.0016	-0.4153	0.0528

Notes. The figures are the differences in TFP level between firms with and without innovations. *** and ** indicate statistically significant differences at the 1% and 5% levels, respectively.

Table 4

Percentages of firms holding patents and trade secrets.

Table 4

	(1)				(2)		
	Manufacturing	Service	Diff.		High IT service	Low IT service	Diff.	
A. Full sample	(1,567)	(1,614)			(923)	(691)		
Patent	39.2%	11.3%	28.0%	***	11.7%	10.7%	1.0%	
Secret	33.0%	32.6%	0.4%		35.7%	28.4%	7.4%	***
B. R&D performing firms	(831)	(267)			(178)	(89)		
Patent	60.4%	41.2%	19.2%	***	39.3%	44.9%	-5.6%	
Secret	39.3%	51.0%	-11.8%	***	54.9%	42.9%	12.1%	*
C. Non-R&D performing firms	(736)	(1,347)			(745)	(602)		
Patent	15.4%	5.3%	10.0%	***	5.1%	5.6%	-0.5%	
Secret	25.8%	28.9%	-3.1%		31.0%	26.3%	4.7%	*

Notes. The figures in parentheses are the number of sample firms. The R&D-performing firms are firms with positive R&D expenditure during the three fiscal years between 2009 and 2011. *** indicates statistically significant differences at the 1% level.

Table 5

Bivariate probit estimation results on the relationship between innovative activities and patents/trade secrets.

Table 5

A. Development of new products/services

Industry	Patent		Secret		Wald test: ρ=0		N.
(1) Full Sample	0.6198	***	0.2625	***	20.547	***	2,821
	(0.0561)		(0.0506)				
(2) Manufacturing	0.6507	***	0.2792	***	7.926	***	1,399
	(0.0711)		(0.0720)				
(3) Service	0.5570	***	0.2138	***	11.262	***	1,408
	(0.0924)		(0.0726)				

B. Improvement of existing products/services

Industry	Patent		Secret		Wald test: ρ=0		N.
(1) Full Sample	0.3356	***	0.2953	***	25.229	***	2,821
	(0.0555)		(0.0508)				
(2) Manufacturing	0.3714	***	0.3390	***	9.972	***	1,399
	(0.0705)		(0.0718)				
(3) Service	0.2537	***	0.2180	***	13.573	***	1,408
	(0.0920)		(0.0732)				

C. Adoption of new production or delivery methods

Industry	Patent		Secret		Wald test: ρ=0		N.
(1) Full Sample	-0.0304		0.2202	***	31.936	***	2,821
	(0.0702)		(0.0638)				
(2) Manufacturing	-0.0010		0.3468	***	13.987	***	1,399

	(0.0872)	(0.0861)			
(3) Service	-0.0811	0.0684	15.095	***	1,408
	(0.1230)	(0.0966)			

Notes. These tables present the bivariate probit estimation results with robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The three types of innovation are used as the main explanatory variables. Firm age is used as a control variable. Estimations in (1) and (3) include one-digit industry dummies as additional control variables.

Appendix Table A1

Innovators' productivity premium.

Table A1

Type of innovations	(1) Full sample	(2) Manufacturing	(3) Service	(4) High IT service	(5) Low IT service
A. Development of new products/services	0.0585***	0.0512**	0.1107***	0.1071***	0.1128**
B. Improvement of existing products/services	0.0726***	0.0776***	0.1166***	0.1462***	0.0688
C. Adoption of new production or delivery methods	0.0159	0.0652**	-0.0051	-0.0458	-0.0514

Notes: The figures are the differences in TFP levels between firms with and without innovations. In this table, firms with TFP levels three standard deviations higher or lower than the sample mean (29 firms) are eliminated. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix Table A2

Relationship between innovations and TFP (regression results).

Table A2

Type of innovations	(1) Full sample	(2) Manufacturing	(3) Service	(4) High IT service	(5) Low IT service
A. Development of new products/services	0.0783***	0.0441*	0.0960***	0.0874**	0.1121**

	(1)		(2)		(3)		(4)		(5)
	(0.0201)		(0.0254)		(0.0313)		(0.0405)		(0.0502)
B. Improvement of existing products/services	0.1020	***	0.0790	***	0.1219	***	0.1502	***	0.0744
	(0.0200)		(0.0250)		(0.0314)		(0.0395)		(0.0512)
C. Adoption of new production or delivery methods	0.0409		0.0699	**	0.0046		-0.0233		0.0430
	(0.0252)		(0.0305)		(0.0393)		(0.0465)		(0.0680)

Notes: The OLS estimations with robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The explanatory variables include firm size and firm age. The estimations in columns (1), (3), (4), and (5) include one-digit industry dummies as additional control variables.

Appendix Table A3

Bivariate probit estimations for service firms including an interaction with IT intensity.

Table A3

	A. Development of new products/services				B. Improvement of existing products/services				C. Adoption of new production or delivery methods			
	Patent		Secret		Patent		Secret		Patent		Secret	
Innovation	0.5371	***	0.2135	***	0.2269	**	0.2112	***	-0.0111		0.1116	
	(0.0939)		(0.0741)		(0.0938)		(0.0747)		(0.1557)		(0.1055)	
IT*innovation	2.2491		0.0375		2.9906	*	0.8250		-18.2682		-9.9194	
	(1.7333)		(1.7280)		(1.7587)		(1.7890)		(24.7186)		(9.2944)	
Wald test: ρ=0	11.219	***			13.366	***			14.965	***		
N.	1,408				1,408				1,408			

Notes. The bivariate probit estimation results with robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The explanatory variables include firm size and firm age.