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INNOVATION IN SERVICES AND MANUFACTURING: A COMPARATIVE STUDY OF FINNISH INDUSTRIES

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Foreword

Service industries are expected to significantly reduce unemployment. Indeed, the service sector has continued to increase its share of employment in the economy. However, productivity growth in the sector lags behind that in the manufacturing sector. Technological progress has radically changed some services, such as financial intermediation, but in many other service industries, people remain the most important factor of production. This study seeks to understand how these service activities evolve.

This study builds on a long research tradition in Etla investigating technological change, competencies, and competitiveness of firms. Innovation is at the heart of these topics. However, innovation in the service sector has not been previously studied in Finland. In fact, the popular view is that services do not much innovate at all. It is true that service product development tends in many cases to be more incremental, but even gradual quality changes may have a considerable impact on the service firm's customers' competitiveness over time. Therefore, understanding the processes of innovation in services is relevant for the development of the sector *per se*, but even more importantly, for its indirect influence on the whole economy.

We would like to thank the National Technology Agency (TEKES) for financially supporting this research.

Helsinki, April 2000

Pentti Vartia

Preface

This research was funded by TEKES, the National Technology Agency of Finland. I am particularly grateful to Eija Ahola and other TEKES officers who brought this research area to my attention in the first place. Innovation in service firms is indeed a fascinating new field of research, and very topical at that. This research gave rise to another project focusing particularly on knowledge-intensive business services. My research on innovation in business services and its contribution to the broader economy thus continues.

In addition to this report, ETLA Working Papers No. 703 and No. 704 are also products of this research project, as well as the empirical parts of my forthcoming doctoral dissertation at the Helsinki School of Economics and Business Administration.

I would like to thank the steering group of the project, which included Eija Ahola (TEKES), Rita Asplund (ETLA), Pekka Ylä-Anttila (Etlatieto Ltd.), and Reija Lilja (Palkansaajien Tutkimuslaitos/Labor Institute for Economic Research). In addition, Risto Setälä (TEKES), Synnöve Vuori (ETLA), Olavi Lehtoranta (Statistics Finland), and Pentti Vuorinen (Ministry of Trade and Industry) provided useful suggestions in the early phases of the project. I also had numerous helpful discussions on the econometrics with Petri Rouvinen (Etlatieto Ltd.). Mikael Åkerblom and Ari Leppälahti (Statistics Finland) shared their knowledge of the datasets, especially innovation surveys, and also offered very useful comments on the manuscript. However, they are not responsible for any of the statistical analyses in this study. Steven Wolf helped editing parts of the report in an earlier stage.

During the final phases of the project I had the possibility to visit INRA (Institut National de Recherche Agricole) in Toulouse, France. I thank the ESR group, especially Gilles Allaire and Danielle Galliano, for hospitality and a stimulating research environment.

I have presented various papers arising from this project in international workshops and conferences including those at the following: Technical University of Delft, The Netherlands; INRA Toulouse, France; Amos Tuck School of Business, Dartmouth College, USA; Helsinki School of Economics and Business Administration; University of Grenoble, France. Seminar participants

in these meetings made valuable questions and remarks. Particularly those by Alfred Kleinknecht, Pierre Mohnen, José M. Labeaga, Chris Walters, Connie Helfat, Philip Anderson, Edward Lorenz, Emmanuel Duguet, and Eve Caroli were insightful.

Of course, the remaining errors are mine alone.

Aija Leiponen

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ABSTRACT: This study compares firms' innovation behavior in services and manufacturing using Finnish innovation survey data. Service industries are more heterogeneous in terms of innovation activities than manufacturing industries. Apart from this, services do not exhibit innovation patterns qualitatively much different from those in the manufacturing sector.
Employees' competencies are an important factor in firms' innovation activities. Research and technical competencies are significantly associated with internal and outsourced R&D, innovation collaboration, and product innovation. Competencies appear to be complementary with firms' external innovation activities – to benefit from external sources the firm needs sufficient absorptive capacity.
Service and manufacturing firms respond differently to knowledge spillovers and to dependence on equipment suppliers. Service firms tend to innovate more in environments of high spillovers and they are more likely to invest in R&D in supplier-dominated industries. These results are contrary to the received wisdom in innovation studies and merit further research. Additionally, innovation advantages arising from a larger scale of operations seem to be minor in most service industries.

KEY WORDS: Innovation, services, competencies, R&D collaboration.

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TIIVISTELMÄ: Tutkimuksessa vertaillaan innovaatiotoimintaa palvelu- ja teollisuusyrityksissä suomalaisen kyselyaineiston valossa. Palvelutoimialat ovat teollisuutta heterogeenisempiä innovaatiotoiminnan suhteen. Muuten innovoinnin taustatekijät eivät poikkea merkittävästi toisistaan näillä kahdella sektorilla.
Yrityksen henkilöstön osaaminen on tärkeä tekijä sen innovaatiotoiminnassa. Tutkimusosaaminen ja tekniset taidot liittyvät merkitsevästi sisäiseen ja ulkoistettuun T&K-toimintaan, innovaatioyhteistyöhön ja tuoteinnovaatioihin. Osaaminen näyttää täydentävän ulkoista innovaatiotoimintaa – hyötyminen ulkoisista tietolähteistä edellyttää omaksumiskykyä.

Tietovuodot ja riippuvuus laitetoimittajista saavat palveluyritykset käyttäytymään teollisuusyrityksistä poikkeavasti. Palveluissa tietovuodot lisäävät innovaatioita ja laitetoimittajista riippuvaiset palvelualat investoivat todennäköisemmin T&K-toimintaan. Nämä tulokset ovat odotusten vastaisia, siksi lisätutkimus näistä aiheista olisi tarpeen Lisäksi palveluyritysten innovaatio toiminnassa ei näytä olevan etua suuresta yrityskoosta toisin kuin teollisuudessa.

ASIASANAT: Innovaatio, palvelut, osaaminen, innovaatioyhteistyö.

Contents

Executive summary

This study examines investments in innovation-related activities and the nature of knowledge creation in Finnish firms. The patterns of innovation in the service sector are compared with those in the manufacturing sector. The Finnish Community Innovation Survey data collected by Statistics Finland are the basis of the analyses, which make use of a variety of statistical techniques. First, in addition to basic descriptive statistics, principal component analyses are carried out to examine the clustering of firms' attributes and innovation behaviors. Next, simple hypotheses concerning the determinants of firms' knowledge creation investments, collaborative arrangements, and innovation output are tested econometrically. Finally, case evidence of three business service firms is discussed to assess the usefulness of the survey data in describing service innovation processes. New empirical research questions concerning the growth and evolution of service firms, their knowledge creation and intellectual property strategies, and management of collaboration are also identified.

The main results of the study include that the survey data do not indicate any strikingly different innovation behavior for service firms in relation to manufacturing firms. Firms in the service industries surveyed innovate about as often as manufacturing firms. On average, innovating service firms in fact invest more in Research and Development (R&D) and other learning activities than innovating firms in the manufacturing sector do. Otherwise, largely similar investments in R&D, in-house training, and formal schooling, and engagements in collaborative arrangements are associated with product innovation in the two sectors. However, an analysis of the innovation and collaboration patterns reveals that equipment suppliers and the appropriability of innovation returns play qualitatively different roles in services and manufacturing. First, high reliance on equipment suppliers supports investments in R&D in service industries, while supplier-dominated manufacturing firms are less likely to invest. Thus "supplier-dominated industries" behave differently in the two sectors. Second, high knowledge spillovers (low appropriability of innovations) support product innovation in services, but reduce it in manufacturing.

In-depth case studies were carried out to supplement the statistical analysis. The case studies suggest that many established business service firms may be in the process of formalizing and institutionalizing their product and competence development processes. Before, knowledge creation and incremental product improvement has largely been performed through in-house training and on-the-job learning.

Incentives provided to employees are an important factor behind continuous improvement of products and processes. Firms studied here employ very diverse incentive schemes. It is argued that strong performance incentives for individuals can be very effective, but they need to be complemented by incentives to cooperate and share knowledge within the firm.

The main external opportunities facing knowledge-intensive business service firms are related to developments in information and communication technologies and increasing internationalization of services. Internally, systematic competence development and innovation processes that enable cumulative learning are the most important challenge.

The national innovation survey seems to perform reasonably well for many service industries. Nevertheless, the survey instrument for service firms could be improved by collecting slightly more detailed information on the adoption of information and communication technologies, effects of spillovers on innovation, the role of in-house training in innovation, and the extent of firms' collaboration activity. However, this study did not manage to unveil such "peculiar" phenomena within services that new research concepts or a whole new model of innovation would need to be developed.

Yhteenveto

Tässä raportissa selvitetään suomalaisten palveluyritysten investointeja innovaatiotoimintaan ja niiden innovaatiotoiminnan luonnetta. Palveluyritysten innovointia on tutkittu kansainvälisestikin vähän eikä Suomessa juuri lainkaan. Saatuja tuloksia verrataankin teollisuusyritysten vastaavaan aineistoon. Tutkimus perustuu suurelta osin Tilastokeskuksen kokoamaan innovaatiokyselyaineistoon, johon osallistui noin 1000 teollisuusyritystä ja noin 600 palveluyritystä vuonna 1997. Tiedot koskevat innovaatiotoimintaa vuosina 1994-96. Tärkeimpänä tutkimuskysymyksenä on, eroaako palveluyritysten innovaatiotoiminta olennaisesti teollisuusyritysten innovaatiotoiminnasta tilastoaineiston valossa.

Raportissa kuvaillaan ensin tilastollista aineistoa sekä hyödynnetään pääkomponenttianalyysiä aineiston ryhmittelyjen havainnollistamiseksi. Näiden analyysien mukaan palveluyrityksiä koskevan aineiston antama yleiskuva ei kokonaisuutena suuresti poikkea teollisuuden aineistosta. Kummassakin voidaan havaita ”korkean teknologian” aloja, joiden yritykset innovoivat ahkerasti, tekevät innovaatioyhteistyötä monenlaisten tahojen kanssa, ja investoivat runsaasti tutkimus- ja kehitystoimintaan (T&K) ja henkilöstökoulutukseen. Tässä on kuitenkin hienoinen ero palveluyritysten ja teollisuuden välillä: ”korkean teknologian” strategiaan liittyy teollisuudessa mittavat T&K-investoinnit, kun taas palveluissa henkilöstökoulutus on hieman keskeisemmässä roolissa. On mahdollista, että monissa palveluyrityksissä sisäinen henkilöstökoulutus on T&K:ta tärkeämpi osaamisen kehittämisinvestointi. Suurelta osin inhimilliseen osaamiseen perustuvassa liiketoiminnassa koulutus voi jopa korvata T&K-toiminnan uusien tuotteiden kehittämisfoorumina.

Kummastakin aineistosta löytyy myös ”matalan teknologian” aloja, joiden yritykset toimivat päinvastoin: vähän investointeja ja innovaatioita. Näyttää kuitenkin siltä, että palvelusektori on innovaatiotoiminnan osalta heterogeenisempi kuin teollisuus. Innovatiiviset palveluyritykset investoivat T&K-toimintaan enemmän kuin vastaavat teollisuusyritykset, toisaalta on olemassa varsin suuri joukko palveluyrityksiä, jotka eivät investoi lainkaan. Lisäksi palvelusektorilta voidaan löytää aloja, jotka ovat varsin osaamis- ja tutkimusintensiivisiäkin, mutteivät investoi suuremmin perinteiseen T&K-toimintaan. Varsinkin rahoitukseen liittyvillä aloilla monet yritykset toimivat näin. Tuotekehitystoiminnan ja osaamisen kehittämisen määritelmät ovat ehkä liian suppeita eräiden palvelualojen toiminnan ymmärtämiseksi.

Yhteen innovaatiotoiminnan lajiin osallistuvat palvelu- ja teollisuusyritykset osallistuvat moniin muihinkin suurella todennäköisyydellä. Innovaatiotoimintaan panostavien yritysten työntekijät ovat myös korkeammin koulutettuja, ja heitä koulutetaan edelleen yritysten omissa ohjelmissa. Lisäksi ulkoistettuja T&K-toiminnan investointeja ja innovaatioyhteistyötä tekevät yleensä yritykset, jotka investoivat myös sisäiseen toimintaan. Ei siis vaikuta siltä, että yritykset korvaisivat sisäisiä kehittämisinvestointeja ulkopuolisilla toimittajilla, vaan että omaa toimintaa *täydennetään* ulkopuolelta ostetuilla palveluilla. Seurauksena erilaiset innovoimiseen ja osaamiseen liittyvät investoinnit kasautuvat samoihin yrityksiin. Nämä investoinnit saattavat olla toisiaan täydentäviä.

Aineistossa kaikkein vahvimmin esiin tuleva osaamisstrategia on ”korkean teknologian” innovaatiostrategia. Sen mukaan käyttäytyvät yritykset investoivat laajasti T&K-toimintaan ja/tai koulutukseen, tekevät innovaatioyhteistyötä monenlaisten kumppanien kanssa ja hankkivat tietoa innovoinnin pohjaksi varsinkin asiakkailta. Teknologian hankintaan perustuvassa osaamisstrategiassa taas investointeja teknologiaan täydennetään laitetoimittajilta ja konsulttiyrityksiltä hankitulla tietämyksellä.

Korkean teknologian strategiaa toteuttavia palvelualoja ovat luonnollisesti tietotekniikan ja televiestinnän palvelut mutta myös tekniset palvelut. Teollisuuden puolella tämäntyyppistä käyttäytymistä löytyy kemian-, kone- ja elektroniikkateollisuudesta. Toimittajakeskeisiä aloja taas ovat esimerkiksi rahoitus- ja kuljetuspalvelut sekä elintarviketeollisuus ja kirjapaino- ja julkaisuala. Yritykset näillä viimeksi mainituilla toimialoilla nojautuvat usein laitetoimittajien tai konsulttiyritysten osaamiseen ja ostavat teknologiaa ulkopuolelta eivätkä kehitä sitä itse. Toisaalta on huomattava, että kullakin alalla voi esiintyä monenlaisia yritysstrategioita. Esimerkiksi televiestinnän palveluissa on huippuinnovatiivisten yritysten lisäksi ovat vahvasti edustettuina myös teknologian ostamiseen ja laitetoimittajapalveluihin strategiansa perustavat yritykset. Kunkin alan sisällä on siis strategisia erikoistumismahdollisuuksia, eivätkä kaikki ”korkean teknologian” toimialojen yritykset välttämättä ole innovatiivisia ja dynaamisia.

Tässä tutkimuksessa käytetään yritysten teknologisen toimintaympäristön kuvaamiseen uudenlaisia mittareita. Tärkeimpiä näistä ovat tiedon omistamisregiimi (kuinka helppo yritysten on "omistaa" synnyttämänsä tietämys, sen sijaan että se leviää kilpailijoille), innovaatioiden kysyntä (kuinka paljon tietoa ja ideoita yritys saa asiakkailtaan innovointinsa tueksi, mikä heijastaa asiakkaiden kiinnostusta uusien tuotteiden kehittämiseen), laitetoimittajien rooli (jos toimittajat ovat tärkeitä, yritys todennäköisesti delegoi suuren osan innovaatiotoiminnasta toimittajayrityksille), ja tieteelliset innovaatiomahdollisuudet (kuinka nopeasti tiede ja teknologia etenevät synnyttäen uusia innovaatiomahdollisuuksia). Esimerkiksi "korkean teknologian" osaamisstrategian yrityksiä tavataan usein ympäristöissä, joilla innovaatioiden kysyntä on voimakas, eli markkinoilla syntyy paljon innovaatiomahdollisuuksia. Toisaalta heikko tiedon omistettavuus eli merkittävät tietovuodot korreloivat teollisuudessa patentoinnin kanssa. Teknologiaympäristön luonne vaikuttaa siis yritysten innovaatiostrategiaan ja organisaatiopäätöksiin.

T&K-investoinnit näyttävät ekonometrisen analyysin perusteella korreloivan vahvasti yrityksen henkilöstön osaamisen kanssa, myös otettaessa toimialan erityisominaisuudet huomioon. Tuottava T&K-toiminta edellyttää sekä teknistä että tutkimustoiminnan osaamista, myös muualla yrityksessä kuin itse T&K-toiminnassa. Lisäksi korkean tutkimusosaamisen yritykset investoivat keskimääräistä enemmän uusien tuotteiden markkinointiin. Korkeaan osaamiseen perustuvaa innovaatiostrategiaa täydentää siis voimakas panostus menestymiseen markkinoilla. Osaaminen on merkittävä tekijä myös innovaatioyhteistyössä. Henkilöstön osaaminen on siten olennainen osa yrityksen sisäistä "innovaatiojärjestelmää".

Innovaatioyhteistyön avulla voidaan hyödyntää yrityksen ulkopuolisia tietolähteitä. Palveluyritykset toimivat hieman harvemmin yhteistyössä kuin teollisuusyritykset. Etenkin innovaatioyhteistyö yliopistojen tai tutkimuslaitosten kanssa on selvästi harvinaisempaa palvelualoilla. Ekonometrisen analyysin perusteella yhteistyö eri kumppanien kanssa vaatii hieman erilaista sisäistä osaamista yritykseltä. Erityisesti yhteistyö yliopistojen kanssa edellyttää yritykseltä huomattavaa omaa tutkimusosaamista, mikä edesauttaa tieteellisen tiedon omaksumista ja hyödyntämistä yrityksen omassa liiketoiminnassa.

Molemmista otoksista havaitaan, että yhteistyö kilpailijoiden kanssa ei ole läheskään niin yleistä kuin yhteistyö asiakkaiden, toimittajien tai yliopistojen kanssa. Taloustieteissä on toisaalta eniten tarkasteltu juuri kilpailijoiden välisten yhteistyösuhteiden syitä ja seurauksia. Innovaatiotoiminnan ymmärtäminen vaatisi kuitenkin erityisesti asiakas- ja toimittajasuhteiden sekä yliopistojen ja tutkimuslaitosten roolien tarkempaa analyysiä.

Tutkimuksen yllättävimmän tuloksen mukaan tietovuodoilla eli tiedon omistettavuudella on erilainen vaikutus yritysten innovaatiotoiminnan tuloksellisuuteen palvelualoilla ja teollisuudessa. Heikko tiedon omistettavuus nimittäin lisää yritysten innovatiivisuutta palvelusektorilla ja heikentää innovatiivisuutta teollisuuden toimialoilla. Palveluja koskeva tulos on teorioiden vastainen. Mahdollinen tulkinta on, että palveluissa saadut tietovuodot lisäävät innovaatiotoiminnan tuottavuutta enemmän kuin teollisuudessa, ehkä siksi, että palveluissa kilpailijoilta omaksutun tiedon hyödyntäminen on helpompaa. Innovaatioiden kopioiminen ei siis ole vaikeaa tai kallista, toisin kuin monilla teollisuuden toimialoilla. Tiedon omistettavuuden taustatekijöitä ja vaikutuksia palvelualoilla olisi kuitenkin tutkittava tarkemmin, koska esimerkiksi älyllisen omaisuuden suojaan liit-tyvä lainsäädäntö vaikuttaa yritysten innovointikannustimiin. Toistaiseksi tutkimustuloksia ei ole olemassa palvelujen osalta.

Laitetoimittajien keskeinen osallistuminen yrityksen innovaatiotoimintaan on aiemman tutkimuksen mukaan luonteeltaan matalan osaamisen strategia (Pavitt, 1984). Saadut tulokset kuitenkin osoittavat, että toimittajakeskeisyys lisää T&K-toiminnan todennäköisyyttä palvelualoilla. Teollisuuden yritykset toimivat ”teorian mukaan”: riippuvuus toimittajista vähentää omien T&K-investointien todennäköisyyttä. Palveluyritysten innovointiin liittyy siis joitakin ”anomalioita”, teoriat ja aiemmat empiiriset tutkimukset kun ovat kohdistuneet teollisuustoimialoille.

Tutkimuksen yhteydessä tehdyissä yrityshaastatteluissa pohdittiin mm. yhteistyön kannustimia. Yritysten kannustinjärjestelmät vaihtelevat suuresti. Voimakkaita yksilökannustimia kannattaa yrityksissä yleensä täydentää henkilöstön yhteistyötä ja tiedonvaihtoa tukemalla, koska henkilökohtaiset kannustimet muuten lannistavat sisäistä yhteistyötä.

Palveluyritysten ulkoiset haasteet ja mahdollisuudet liittyvät erityisesti uuteen tieto- ja viestintätekniikkaan. Yritykset ovat hyvin aktiivisesti kehittämässä näistä omia sovelluksia, mutta on otettava huomioon myös ihmisten vajavainen kyky tehdä luottamukseen perustuvaa yhteistyötä sähköisen viestimen välityksellä. Henkilökohtainen ja välitön kommunikaatio saattaa edelleen olla välttämätöntä.

Palveluyritysten sisäisiä haasteita ovat innovaatiotoiminnan ja osaamisen kehittämisen systematisointi ja liittäminen osaksi yrityksen strategiaa. Nähtäväksi jää, muodostuuko suurehkojen, osaamiseen perustuvien liike-elämän palveluyritysten T&K-toiminnasta samantyyppistä kuin teollisuuden toiminta on, vai tekevätkö näiden palvelujen osaamisintensiivisyys ja aineettomuus tuotekehityksestä luonteeltaan erilaista.

Tämän tutkimuksen perusteella innovaatiokyselyn aineistoa voisi kehittää palvelujen osalta selvittämällä mm. henkilöstökoulutuksen luonnetta ja merkitystä tarkemmin. Myös tiedon ja osaamisen omistettavuuskysymykset, palveluyritysten tietotekniikkainvestoinnit ja niiden vaikutukset innovaatiotoimintaan sekä innovaatioyhteistyön laajuus olisivat kiinnostavia ja ajankohtaisia laajennuksia. Tutkittavien alojen joukkoon voisi lisätä osaamisintensiivisiä liike-elämän palveluja, koska niiden merkitys taloudessa yleensä ja teollisuusyrityksille erityisesti kasvaa nopeasti.

1 Introduction and literature review

1.1 Services in national economies

The role of services has been steadily growing in the industrialized economies for the past two decades. Service industries account for about two-thirds of employment in OECD countries and continue to expand faster than other industries. According to the OECD data presented in a recent research report (Hauknes, 1998), seven out of the ten fastest growing industries in the OECD are service industries. Real estate and business services grow the fastest: employment in this industry more than doubled between 1970 and 1993 in the OECD area.

Despite their large and growing share in terms of GDP and employment, services account for only about 20% of world trade (Miles et al., 1995). At the same time, services' share of foreign direct investment is 50%. This reflects the spatially constrained nature of most services compared to manufacturing products. In order to compete in foreign markets service firms usually need to set up a foreign subsidiary instead of exporting their products.

Employment has grown rapidly in Finnish service industries as well over the past decades. Table 1 presents employment statistics for service industries excluding trade and public sector services. The employment share of "other" services, mainly real estate and business services, increased from 3.1% in 1980 to 9.2% in 1998. The employment share of this subsector was around 10% in most OECD countries in 1994. Some of the fastest growing service industries include information systems (software), management consulting, technical services and telecommunications. Financial services have undergone a major technological revolution reflected in the employment share.

The importance of services in terms of value added has been growing more slowly than in terms of employment. The share of real estate and business services in total value added grew from 11.7% in 1975 to 15.2% in 1998. Business services alone increased their share modestly, only 2% over the 23 year period. This reflects the high labor intensity of these services.

Table 1. Employment in service industries in Finland, 1980 and 1998

	1980	%	1998	%
Finance and insurance	128	5.8%	46	2.1%
Real estate	-		56	2.5%
Business services	-		148	6.7%
Other services	69	3.1%	-	-
Transportation, incl. telecommunications	169	7.7%	118	5.3%
of which telecommunications			51	2.3%
Total service industries	366	16.6%	368	16.6%
All industries	2203	100.0%	2222	100.0%

Source: Statistics Finland Employment statistics (Työvoimatilastot) 1980, 1998

Table 2. Value added in Finnish service industries, 1975 and 1998

Value added	1975	%	1998	%
Finance and insurance	11725	3.7%	24771	4.3%
Real estate	21151	6.7%	46939	8.2%
Business services	15850	5.0%	39967	7.0%
Transportation, incl. telecommunications	23096	7.4%	53547	9.4%
Total service industries	71822	22.9%	165224	28.9%
All industries	314211	100.0%	571665	100.0%

Source: ETLA database

Input – output tables offer yet another view on the importance of services for the Finnish national economy. The share of services (excluding construction) in intermediate consumption of all Finnish sectors was 38% in 1989 and increased to 43% in 1995. The share of real estate and business services as an input to all economic sectors rose only modestly in the same period, from 11.2% to 11.8%. Business services accounted for 7% of inputs used.[1]

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[1] Source: Input-output tables 1989 and 1995, Statistics Finland 1992 and 1999, respectively.

In comparison to the Finnish evidence, the OECD input-output data suggest far more rapid growth in the use of inputs from the knowledge-intensive services and higher intensity of their use. According to the studies reported in Miles and Boden (1999, forthcoming), in the United Kingdom the share of knowledge-intensive business services, KIBS, inputs used in the economy has risen from about 5% in 1970 to more than 25% in 1990. The rate of growth varies greatly across countries, though (see Tomlinson, 1999: 6). The reasons for Finland's different position have not been explored yet. One can only speculate that the small domestic market combined with the local nature of service production constrain the emergence of specialized business services.

In addition to the growing direct economic impact of business services on employment and sales, these services play an important indirect role as disseminators of knowledge. Therefore, the total economic impact of business services is likely to be much larger than the 10% suggested by the GDP share. Tomlinson (1999: 10) has provided some evidence on this. He investigated the productivity effects of using knowledge-intensive services as production inputs and found that the use of KIBS inputs is significantly and positively correlated with sectoral productivity and output. Similar results were obtained by Luukkainen and Niininen (2000) with data on Finnish industries.

Despite this indirect dynamism, the traditional perception of services themselves as laggards in productivity growth cannot be rejected for all industries. According to Statistics Finland, all measures of productivity have stagnated or even slightly decreased for business services between 1975 and 1997. In contrast, other services such as post and telecommunications and financial services have doubled or even tripled their labor productivity levels. Part of the weak performance of business services can be explained by the difficulties of measuring changes in quality and output. This leads to defining output as some linear function of labor hours in the productivity estimation, and the computation becomes confounded. Moreover, business services are based on human skills and therefore cannot benefit from new information and communication technologies to the same extent as for example financial services do. However, understanding of these issues would require more in-depth research.

All in all, from the foregoing it is clear that the economic impact of services is considerable and growing. In spite of this, the reasons underlying the dynamism of the sector, including innovation, have not been examined. This is the topic of this study. More specifically we ask what kinds of service firms innovate, and how service firms invest in and organize their development activities. Understanding how services contribute to growth of productivity and ultimately the whole economy requires studying innovation within the sector and interaction of services with other sectors of the economy.

1.2 Does the restructuring of industries create demand for business services?

According to a popular view, manufacturing firms increasingly outsource service functions. Thus part of the growth in business services described earlier would be rooted in the structural changes in the economy, whereby business services are being relocated outside the manufacturing sector. O'Farrell (1995) challenged this view by examining the movement of service activities into and out of manufacturing firms in the United Kingdom. He argued that most of service growth stems from pure demand growth instead of restructuring or relocating service functions. As externalization is more visible than internalization, it may be captured more easily by casual observation.

In O'Farrell's data on British firms, service functions move in both directions, that is, there are on-going processes of both internalization and externalization, and these more or less offset one another. It is interesting that some of the same functions that are most often externalized, are also internalized most often. These include training and computer software. In addition to these, firms are likely to shift around activities broadly related to marketing like graphic and product design, market research, advertising, and public relations. Instead, production planning and production engineering were being externalized less frequently. These results thus suggest that if there is any general pattern to the possibly intensified relocation activity, it must be studied at a more detailed level than has been the case so far. The evidence is most closely in line with the interpretation that there is rapid restructuring under way in both directions. Economic structures have perhaps become generally more fluid and flexible in the face of changing environments.

Whatever the ultimate cause of the growth of business services in the economy, performance of manufacturing firms depends increasingly on the competitiveness of business services. Even if there is no *net* externalization going on, business service supply is growing due to the demand growth, which gradually enables a higher degree of specialization of supply. Then it becomes more likely that manufacturing firms will find an external provider of a certain service function, which used not to be supplied in the markets. Growth of business services implies more interdependencies between the sectors. Larger markets for services followed by heightened competition and specialization therein have a positive effect on the competitiveness of manufacturing, eventually feeding back to the growth of demand for services.

From a global perspective, more external interactions among firms will lead to faster dissemination of knowledge, as knowledge is no longer locked inside corporate structures but flows more freely between organizations and sectors. However, this development unavoidably also brings new problems and questions to the fore, in particular related to intellectual property rights.

1.3 Services as users and disseminators of information technologies

One of the drivers of the current industrial dynamics and restructuring seems to be the growing use of information and communication technologies (ICT). Service sector is the largest user of ICT making 83% of the ICT investments in the United States (NIST, 1998, p. 20-21). ICT is a source of both benefits and problems. A content analysis of service trade journals in the U.S. during the 1990s revealed that by far the most frequently discussed issues in services were related to ICT (ibid.).

Recent research has proposed that business services complement the use of ICT. A European study on service innovation found that the use of knowledge-intensive business services (KIBS) and ICT are highly correlated. Certain business services help other firms in adopting and making use of ICT. Business services are thus both significant users and carriers of new information technologies. Antonelli (1998a) argues that business and communication services are becoming central in facilitating knowledge and information flows throughout the economy. Unfortunately, the Finnish innovation survey does not contain any explicit information about the use of IT in service innovation.

1.4 A review of some recent research concerning KIBS

Bilderbeek and others (1998) defined KIBS as private organizations relying heavily on professional knowledge or expertise and supplying intermediate products and services that are knowledge-based. This definition is problematic because it is not straightforward how to measure industries' reliance on professional knowledge. Miles et al. (1995) provided a list of industries where firms are likely to provide knowledge-intensive business services (see table below).

Table 3. KIBS industries

Accounting & bookkeeping	Management consulting
Technical engineering	R&D services, consulting
Design	Environmental
Computer- & IT-related	Legal
Marketing & advertising	Real estate
Training	Specific financial
Temporary labor recruitment	Press and news agencies (content)

(adapted from Miles & al., 1995)

It has often been argued that services are "special", that the operating logic somehow differs drastically from manufacturing industries. Some conspicuous characteristics of services, according to Miles et al. (1995), include client-intensity, i.e., importance of the user-supplier interaction, intangibility, "co-production" with customers, importance of ICT, and difficulties related to reaching the "minimum efficient scale." However, it can be argued that these features are not really specific to services, except for higher intangibility and co-production. Physical involvement of customers tends to be higher in many services. For instance, hair-dressing cannot be delivered unless the customer is present during the service production, and the productivity of on-the-job training depends to a great extent on the effort put forth by the customer. But then again, so does the productivity of newly adopted machinery in manufacturing firms.

It seems that the main difference between manufacturing and services is that in the case of service co-production, there is often a critical time- and site-specificity: the producer and the user of the service product need to be in the same place at the same time. However, some services, such as personal banking, have successfully reduced the time-specificity with the help of information technologies such as automatic teller machines (ATMs). Another example is training and teaching, which can be delivered via some audio-visual medium. Hence, generally speaking the arguments for the "special" nature of services are often not very tenable. Similar phenomena can be found in other sectors.

Recently, a few rather broad initiatives have been taken in Europe to study how service innovation takes place, and what the role of specialized knowledge-intensive services is in the innovation processes of their clients, notably manufacturing firms.[2] These mainly descriptive studies provide lists of important issues and a wealth of examples about service firm–manufacturing firm interaction, but they do not address concrete organizational questions or attempt to generalize.

Despite the recent Community Innovation Surveys (CIS) that were carried out in many member countries of the EU, research on business services is hampered by the fact that there are still not enough data about their evolution and impact on other economic sectors. Partly this arises from the immaterial nature of most services. Tracing the economic impact of intangible activities is difficult, and this has contributed to the "shadow" role of services in economic studies and policy alike (cf. Hauknes, 1998). Initiatives such as the CIS are therefore very important, as large-scale surveys provide interesting basic data on service activities. Thus far, most studies on business services rely on case studies, which makes it difficult to generalize the results across industries or even across firms in an industry.

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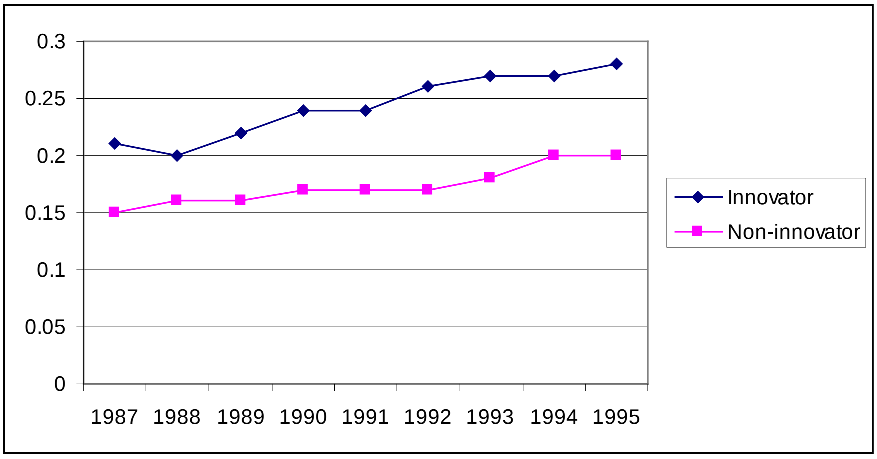
[2] EIMS – European Innovation Monitoring System, see Miles et al. 1995; SI4S – Services in Innovation, Innovation in Services, see Hauknes 1998; KISINN – Knowledge-intensive services and innovation/The Strategic Role of Knowledge-Intensive Services for the Transmission and Application of Technical and Management of Innovation, see Wood, 1998.

1.5 What is knowledge-intensity?

A notable omission in the study of knowledge-intensive business services is the lack of clear definitions of and measures for knowledge-intensity. How to study a field that has not even been defined and distinguished from other fields? For instance, relying on professional knowledge is suggested to be the fundamental feature of knowledge-intensive business services (KIBS) by the SI4S report (Hauknes, 1998). What exactly is professional knowledge? Does professional knowledge imply reliance on employees with higher degrees in scientific disciplines? This could be measured by the employees' educational attainments (see figure 1).[3]

Figure 1. "Knowledge-intensity" of 10 Finnish service industries measured by share of employees with higher education



Note: Innovators are firms reporting service innovations for 1994-96.

Figure 2. "Technology-intensity" of 10 Finnish service industries measured by share of employees with higher technical or natural scientific degree

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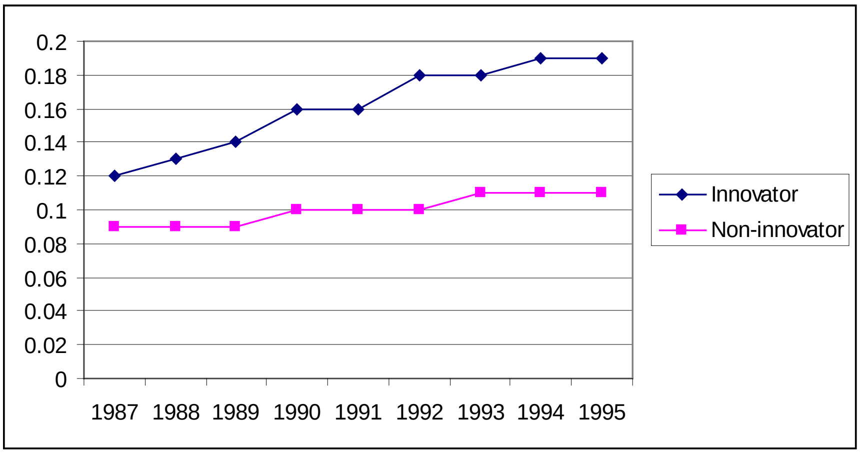
[3] See chapter 2 for more information about the dataset. In figures 1 and 2 only firms in the innovation survey were included in the sample, therefore N=387 in 1987, reaching gradually N=633 in 1995.



Measured by the share of employees with a higher degree in engineering or natural sciences, the technology intensity of services is quite high as well, and continues to grow fast (figure 2).

Both of these indicators have been steadily rising, but the increase has been faster in firms that innovated in 1994-96 than in non-innovating ones. In the manufacturing sector only 11% of employees had higher education degrees in 1995 and 8% had a higher technical education. Thus by these measures the service industries in the sample are considerably more knowledge intensive than the manufacturing sector.

1.6 Services for disseminating knowledge vs. information

Miles et al. (1995) propose the concept of *knowledge services* to distinguish services fostering knowledge development elsewhere in the economy from services such as telecommunications and broadcasting which are rather in the business of transferring data and information. This concept seems useful for examining those business services that are most closely associated with knowledge creation and dissemination in the economy, as opposed to information dissemination.

Creation and exchange of productive knowledge, which has a considerable tacit component, require very close interaction and take time to complete. As a consequence, some institutional setting within which to interact is necessary. At a minimum, interaction and exchange are based on a service contract specifying project goals and compensation for the service provider. The parties honor the contract because it is mutually beneficial, especially in a dynamic context: a successful project both improves the reputations of the parties and provides a basis for further collaboration later on.

The actual management and organization of collaboration between service and manufacturing firms is not assessed in the innovation survey, but we gain some understanding of the prevalence of collaborative innovation projects and study their determinants in chapter 4. Moreover, some issues in the management of collaboration are discussed in chapter 5. These aspects of knowledge-intensive services have not yet been much studied in the literature.

1.7 "Models" of service innovation

According to some scholars, innovation processes in service industries differ from those in manufacturing industries. For instance, Barras (1986) discovered a pattern of innovation in financial services that he called the reverse product cycle. In this model, product innovation in a service firm is triggered by technological change in processes. In banking for instance, adoption of information technologies brought about changes in information processing enabling the innovation of ATMs and eventually internet banking. Thus product innovation followed process innovation here, a reversal of the traditional product life cycle observed in manufacturing industries (Abernathy and Utterback, 1978).

Sundbo (1997), Gallouj (1991), and others have observed that innovation in services tends more often to be carried out in *ad hoc* organizations such as project teams or without any formal organization at all, following directly from people's ideas and observations or on the job learning. Even if formal R&D is very important in a few service industries, for others it is not. However, more recently Sundbo and Gallouj (1998) have observed a trend of systematizing product development in many service firms. Service product innovation thus increasingly resembles the manufacturing innovation process. Nevertheless, it can be argued that innovation in services depends (even) more on the individuals' effort, "intrapreneurship", than in manufacturing. This implies that individual employees' competencies and incentives are even more critical.

1.8 Technological regimes and trajectories in services

It is widely acknowledged that industries differ in their patterns of technological change. Innovation scholars have provided some useful taxonomies to characterize the main features of different patterns, Pavitt (1984) being a classical example. Soete and Miozzo (1989) attempted to extend Pavitt's work into the service sector. Instead of classifying all services as supplier-driven industries, they distinguished between supplier-dominated, scale intensive physical networks, scale intensive information networks, and specialized or science-based services. However, this is still a sectoral taxonomy.

In studies of manufacturing, technological environment has been suggested to have an impact on the incentives to invest in innovation (Cohen and Levinthal, 1989) and on market structure (Winter, 1984). Levin et al. (1987) and Klevorick et al. (1995) identified the presence of innovation opportunities and the appropriability of returns to innovation as the most important dimensions of the technological environment affecting firms' innovation behavior, mainly R&D intensity.

Miles and others (1995) argue that intellectual property is difficult to protect in services. Because innovation in services is often "embodied" in the production process, hence rather visible to customers and competitors, new ideas disseminate rapidly. Available strategies to protect them include embodying the service in a more tangible product like software, which can be more easily patented. A service can sometimes also be embedded in a delivery system, for instance telecommunications infrastructure, which has high barriers of entry. The more the service is based only on the production process, the more difficult it is to appropriate the innovation returns, even though trademarks and such tools provide some protection in many consulting services.

Another dimension of the technological regime is the cumulativeness of underlying knowledge, in other words, to what extent current innovation builds on existing knowledge. Accordingly, scholars in the Schumpeterian tradition (e.g., Audretsch, 1995, Malerba and Orsenigo, 1993) have characterized technological environments with the degree of technological turbulence (see also Tushman and Anderson, 1986). In an *entrepreneurial regime*, small and flexible firms will find it easier to innovate, while in a *routinized regime*, big corporations with large scale R&D activities may be in a better position to innovate. Basically this is a question of whether there are dynamic returns to scale in innovation or not.

In some fields, particularly science-intensive ones, it is necessary to possess considerable capabilities to be able to produce new valuable knowledge. In others, innovation depends more on pure imagination and less on previously accumulated capabilities. Cumulativeness of knowledge appears to be lower in services than in most manufacturing industries. This may reduce the returns to R&D investment and to formal organization of new product development. Externalization of technology development and innovation are more feasible in case the underlying knowledge base is not very cumulative. Technological trajectories along which innovation builds cumulatively on previous knowledge may be a source of increasing returns to learning, but they may also create rigidities as changing adopted trajectory is very costly. Lack of trajectory enables more flexible organization in general, as switching costs are not so high. Related concepts include competence-enhancing or competence-destroying innovation (Tushman and Anderson, 1986) and incremental or radical innovation (Arrow, 1962; see Henderson, 1993 for an excellent review).

Low cumulativeness of knowledge may be another reason for which manufacturing firms find it feasible to externalize service functions. Manufacturing firms sometimes outsource activities such as product design, which clearly is complementary with the highly strategic process of product development. However, firms often employ a dual strategy of internalizing the more cumulative and complementary activities and externalizing the more exploratory projects. For instance, the "core" design projects of Nokia Mobile Phones are highly secretive while a lot of other, seemingly more peripheral design works are outsourced at the same time. There is a need for a lot more research on these issues to understand what exactly differentiates the internal projects from the external ones.

Schmookler (1966) and many others have emphasized the importance of demand in creating incentives for innovation. Demand-induced innovation is economically less risky compared to "science-

“ or “technology-push” innovation in the sense that there already exist market opportunities, provided they can be combined with the technological opportunities. The strength of demand for innovation can be another important characteristic of the innovation environment.

Some researchers of service innovation suggest that the process is “peculiar”. However, we hypothesize that the organization of innovation in services is not so much an exception, but depends on the natures of accumulation and dissemination of knowledge. Appropriability, cumulativeness, science-intensity,[4] innovation opportunities, and demand for innovation are useful concepts borrowed from manufacturing innovation research to characterize the differences in technological change within different industries and sectors. These dimensions of the innovation regime may well apply in the service sector as well in explaining the determinants of the direction, locus, and organization of innovation. After all, the basic nature and implications of organizational knowledge are present as well in services as in other economic activities.

1.9 Interaction with customers

Miles et al. (1995) argue that KIBS innovations are distinguished from “traditional” innovation processes by high importance of interaction with clients. However, the intensity of client interaction may be largely a firm-specific and subindustry-specific characteristic. Firms that have adopted a customization strategy are likely to engage customers more tightly in their production and innovation processes than firms with standardized products. This should apply equally well to service and manufacturing firms, though. Client-intensity of innovation is not necessarily any more a characteristic of services than manufacturing.

Customization is one strategy to protect knowledge and appropriate returns to innovation, because it is not easy for competitors to observe the service process closely enough. On the other hand, a standardized product is more conducive to increasing returns to scale. This is a fundamental tradeoff that both service and manu-

[4] Science-intensity is likely to refer to social sciences more often within services than within manufacturing.

facturing firms have to deal with. Generation of scale returns, hence standardization of products, may be a prerequisite for profitable firm growth, but cannot necessarily be achieved in some markets or technological environments.

However, as the possibilities to appropriate the innovation returns tend to be weaker in service industries, customization may be a relatively more productive strategy there. In a dynamic perspective, the tradeoff is between the (dynamic) capabilities to innovate standardized as opposed to customized products. Standardization strategy requires constant and frequent product innovation – to stay ahead of competitors under rapid dissemination of knowledge – followed by efficient standardization, codification of underlying knowledge, and distribution. Customization strategy, in contrast, involves creative solutions to customers' problems. In this case the service firm needs to be innovative and create new knowledge in each project. Both of these strategies can be highly innovative, and both can be observed for instance in management consulting. They necessitate and develop different capabilities. Standardization enables larger scale of operation, but puts high pressure on the innovation capabilities, as the product will be imitated very rapidly. Sustainable competitive advantage can therefore only be based on constant innovation. Intellectual property is probably more easily appropriated with the customization strategy, but increasing returns to scale are difficult to realize, and the firm is likely to remain smaller.

Another reoccurring topic in the extant literature emphasizes that product innovation in services is closely associated with changes in processes and organization. This is not necessarily all that different from a lot of manufacturing innovation, but a service, its production process, and the way the process is organized may be even more tightly intertwined in services than in some manufacturing sectors. It has also been claimed that service innovations are more often social or organizational than manufacturing innovations are. However, to our knowledge there do not exist data on social or organizational innovations in manufacturing and there are no reliable quantitative comparisons.

1.10 Conclusion

The recurrent themes in the emerging literature on innovation in services include the use and implications of ICT and the "peculiarities" of services with respect to both the general operating logic and innovation processes. The drastic impact of ICT is hard to deny, and in some cases it leads to radical redefinitions of service products, innovation processes, and delivery. In contrast, it is still not clear how much services differ from other sectors in terms of the logic of the innovation process. Many of the arguments about the differences between services and other sectors can be mitigated by using and further developing the existing innovation concepts and results. A careful examination of the underlying drivers and tendencies should be able to illuminate the fundamental dynamics in both service and manufacturing sectors. In the best case, an insightful analysis of innovation in services may shed new light on some manufacturing phenomena, as well.

Chapters two and three in this report will compare the innovation patterns in Finnish service industries to those in manufacturing to assess the "exceptionality" hypothesis. The fourth chapter explores the implications of innovation regimes in the two major sectors to shed light on the determinants of innovation and its organization. There the roles of appropriability, cumulativeness, and other dimensions of the innovation regime are explicitly investigated. Finally, chapter five evaluates the statistical results in the light of three qualitative firm case studies from knowledge-intensive business service industries. This enables a more subtle understanding of innovation processes in the service sector.

2 Finnish survey data on innovation activities in services

2.1 General descriptive statistics

The following three chapters are based on our analysis of anonymous micro-data collected by Statistics Finland on Finnish service and manufacturing firms. Statistics Finland undertook the first survey on service innovation in 1997, simultaneously with the innovation survey of manufacturing industries. The survey concerns innovation in the period 1994-96, and the methodology was in accordance with the other Community Innovation Surveys (CIS) that have been carried out in several European countries. As this was the first time that services were investigated, there was not much information about how the questionnaire for manufacturing industries should be modified. Therefore the survey data may make most sense for service activities that most closely resemble manufacturing, such as energy utilities, telecommunications, and other information technology-related services. In contrast, investments in and organization of innovation in financial services, for instance, may be qualitatively different. Therefore there is a need for more detailed and qualitative research on innovation in services, especially in industries that are knowledge-intensive, in the sense of employing highly qualified people, but not necessarily R&D intensive.

The survey included 10 two-digit SIC level service industries. The response rate for services was 71%. The industries and the number of firms in each are shown in Table 4. Clearly these industries do not represent the whole service sector. Large industries such as construction (SIC class 45), motor vehicle and retail trade (SIC 50, 52), hotels and restaurants (SIC 55), auxiliary services for transportation (SIC 63), real estate (SIC 70), renting of machinery (SIC 71), and most of business services (SIC 74) are missing. Nevertheless, the sample can be used to describe innovation activities in these subsectors.

The last column in Table 4 shows the relation of the number of employees in the firms of the sample and the number of employees in the whole industry. This gives some idea of how well the sample represents the different industries. The large shares of employees included in the samples for some industries arise from the

Table 4. The survey sample breakdown by industry: Services (unweighted)

Industry	SIC	N	Share	Average number of employees	Employees in the sample/ employees in the industry
Energy utilities (electricity, gas and water supply)	40	54	9.0%	104	42.8%
Wholesale trade	51	231	38.5%	80	23.8%
Land transport	60	95	15.8%	191	30.2%
Water transport	61	22	3.7%	226	58.6%
Telecommunications	642	28	4.7%	473	80.3%
Financial intermediation	65	23	3.8%	835	61.3%
Insurance	66	20	3.3%	245	44.8%
Auxiliary financial	67	11	1.8%	35	18.0%
Computer and related	72	52	8.7%	136	42.8%
Technical services (architectural and engineering)	742	64	10.7%	65	20.3%
Total		600	100 %	173	37.4%

sampling frame that includes all large firms (more than 100 employees) and a random sample of the small ones. In the analyses that follow, differences in the representativeness across industries will be accounted for at least partially by using weights. In the manufacturing sample all SIC industries at the two-digit level were represented, albeit to a varying degree (see Table 5) and the response rate was 72%.

The innovation surveys contain information on the inputs into and outputs of innovation, collaborative innovation arrangements, knowledge sources used in and factors hampering innovation. The survey question on product innovation inquires simply whether the firm has introduced new products in the market within the past 3 years. On average, services are – surprisingly enough – about as innovative as manufacturing industries. 23% of the service firms in the sample reported service innovations, while 20% of manufacturing firms reported (technological) product innovations. Thus it is not fair to say that services as a group are not innovative. However, according to the Finnish data, differences in innovation behavior are large within the service sector. There appears to be more heterogeneity within services than within the manufacturing sector in

Table 5. The survey sample breakdown by industry: Manufacturing

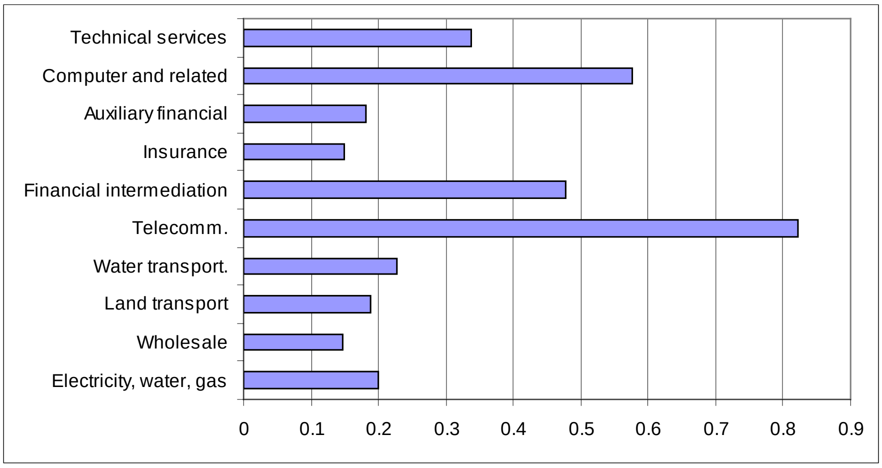
Industry	SIC	N	Share	Average number of employees	Employees in the sample/ employees in the industry
Food, tobacco	15-16	107	10.4%	242	57.3%
Textile, wearing apparel, leather, shoes	17-19	79	7.7%	98	43.4%
Wood	20	76	7.4%	143	40.8%
Pulp and paper	21	26	2.5%	205	12.6%
Printing, publishing	22	98	9.5%	143	47.5%
Coke, oil, chemical	23-24	43	4.2%	322	60.4%
Plastic, Rubber	25	47	4.6%	150	54.5%
Nonmetallic minerals	26	44	4.3%	127	45.0%
Primary (basic) metals	27	26	2.5%	459	67.1%
Metal products	28	97	9.4%	61	20.5%
Machinery, equipment	29	146	14.2%	191	50.6%
Electronics	30-33	133	12.9%	259	65.3%
Motor vehicles, ships	34-35	54	5.2%	253	73.8%
Furniture, other manufacturing	36	53	5.2%	91	33.5%
Total		1029	100.0 %	184	47.7%

this respect. For example, firms in telecommunications are more than four times more likely to innovate than transportation or wholesale firms (Figure 3).

Service innovation correlates with economic performance, though no causality is claimed in this descriptive study. Innovators are larger than non-innovators, and they also tend to be more export-oriented. Innovators tend to produce less revenue per employee, but this reflects the capital intensity of the industry more than profitability. Reliable information on profits was not available for most service firms, but the sparse data that exist indicate that innovators are more profitable than non-innovators.

Innovation expenditures in the innovation survey consist of investments in internal R&D, outsourced R&D, technology acquisitions (patents, licenses, trademarks, drawings, consulting services excluding R&D), process development and industrial design, and innovation-related training, marketing, and machinery. Contrary to

Figure 3. Shares of firms innovating in 10 service industries (N=600)



expectations, service innovators in the sample spend a larger share of their sales revenue on innovation activities than product innovating manufacturing firms (figure 4). Other innovation-related investments than R&D tend to be negligible for both sectors, although service firms invest more in these, as well. Training expenditures are underestimated though, since the cost of the employee time in training is not included.

Overall, collaboration in innovation activities is less common for innovating firms in the service sector than for those in manufacturing (Figure 5). Customers are the most important collaboration partners, and 42% of innovating service firms collaborate with them. 52% of product innovating manufacturing firms collaborate with customers. Process innovators, quite intuitively, collaborate more often with

Table 6. Means of some economic indicators of service innovators vs. non-innovators (weighted)

	Innovators	Non-innovators
Sales (M FIM)	137.4	84.4
Export share (%)	9.9	5.7
Employees	164.3	43.7
Market share (%)	0.5	0.2
Sales/employee (1000 FIM)	1137.9	1673.2

Figure 4. Total innovation expenditures and subclasses of expenditures of service and manufacturing product and process innovators, as % of sales (N=158, N=267, N=269 respectively)

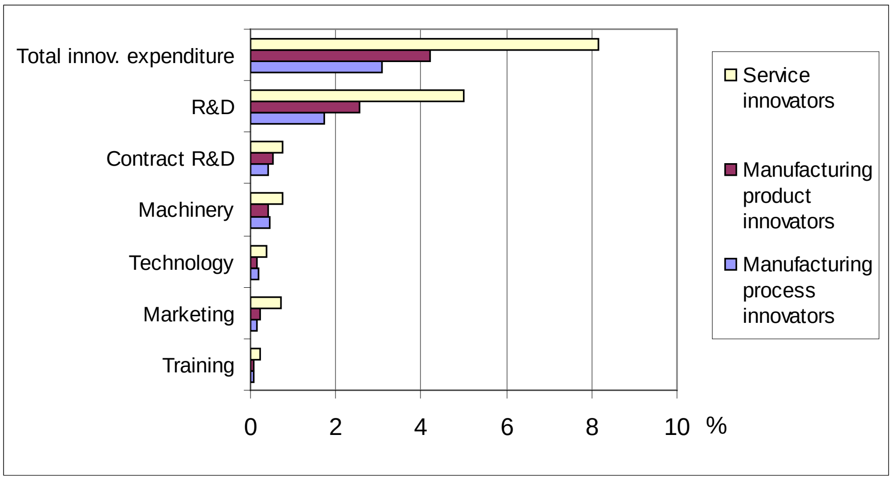
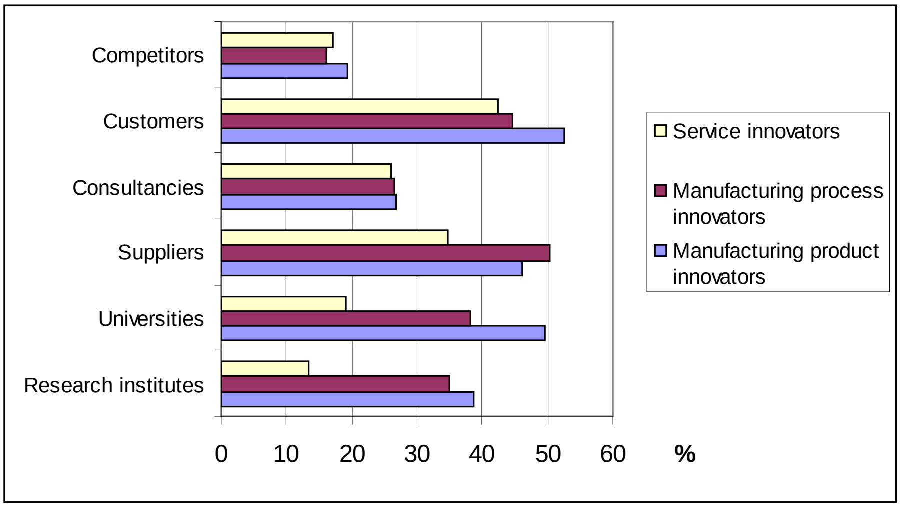


Figure 5. Innovation collaboration of service innovators, and manufacturing product and process innovators, % of firms (N=158, N=267, N=269 respectively)



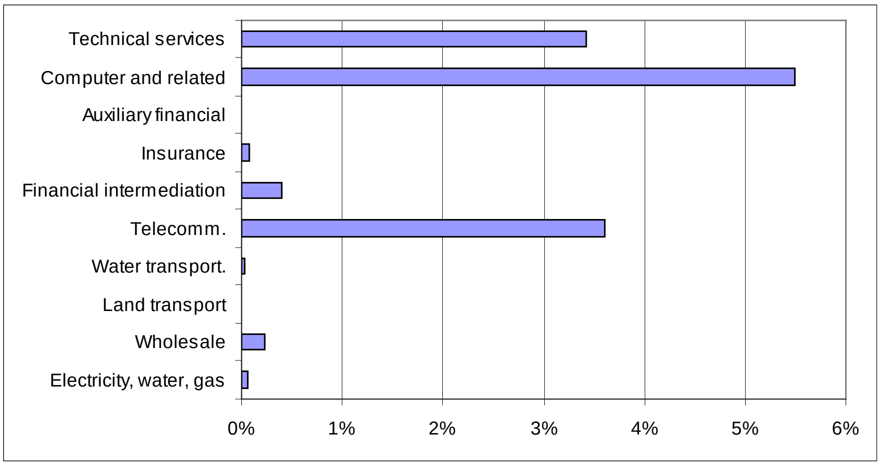
suppliers than with customers. The proportion of innovating service firms collaborating with suppliers is 35%, and 26% with consulting firms. The clearest difference compared to manufacturing innovators is with respect to collaboration with universities and research institutes. 50% of product innovating manufacturing firms collaborate with universities, while among service innovators only 19% engage in this activity. 39% of manufacturing product innovators collaborate with research institutes, against 13% of service innovators.

2.2 Service innovation by industry

The figure below illustrates the concentration of R&D activities in just few industries in the service sector. Telecommunications, computer services, and technical services account for a lion's share of R&D investment in the service industry sample. However, the data on financial services may be unreliable here, according to statistics Finland.[5]

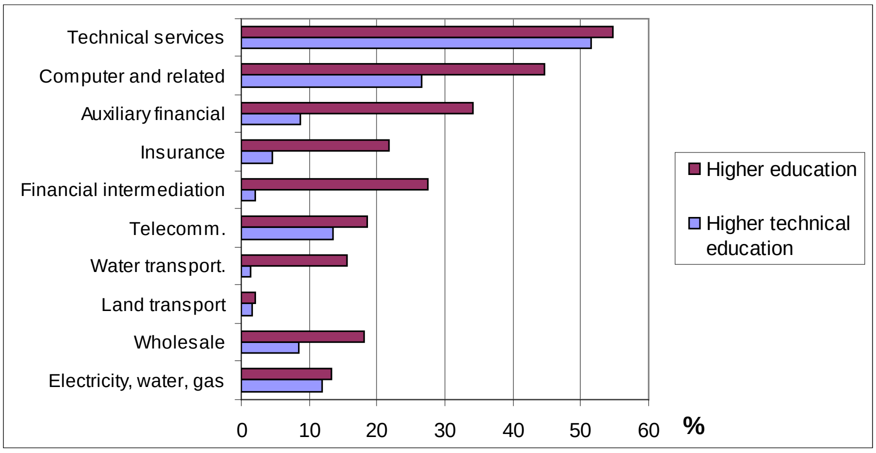
Despite its low R&D-intensity, the financial sector (financial intermediation, auxiliary financial services, insurance) is more knowledge-intensive than telecommunications, if measured by educational levels (Figure 9). The share of employees with a higher education degree varies between 22-35% in the financial industries, while in telecommunications the share is 19%. In manufacturing the share of higher

Figure 8. R&D intensity (expenditures/sales, %) in service industries



5 Mikael Åkerblom, personal communication.

Figure 9. Shares of employees with higher education and higher technical education by industry (N=600)



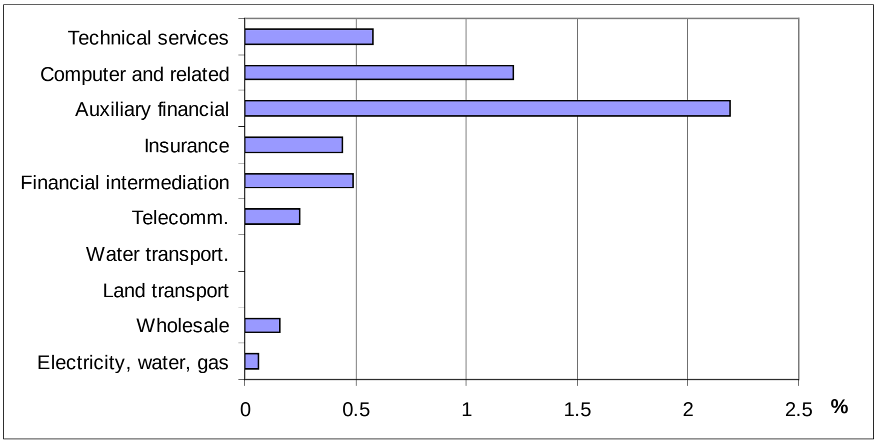
educated employees is 9% for all firms, and 15% for product innovators. One can conclude that these service industries tend to be very knowledge-intensive.

Technical knowledge-intensity is naturally the highest in technical services, where more than half of employees have a university degree in engineering or natural sciences. Computer and related services, telecommunications, and energy utilities are also relatively technology-intensive in this sense.

Research competencies are abundant in the auxiliary financial services industry, even though it is rather non-innovative according to the survey data (Figure 10). More than 2% of the employees in this industry have doctoral or licentiate degrees. This figure is higher than in any manufacturing industry. Research activities in financial services probably aim more often at creating knowledge about the economic environment to serve as inputs in the other activities of the firm, rather than innovating new products.

Computer and related services are also very research skill intensive by this measure. Moreover, technical services, finance and insurance are more research intensive than telecommunications. This measure thus supports a slightly different view of research-intensity than the usual R&D-based proxies. Financial services involve quite a lot of economic research, for example, but its results are not necessarily incorporated in new products or processes.

Figure 10. Research competencies by industry (% of employees with a doctoral or licentatiate degree)



Innovation collaboration with different kinds of partners of firms engaging in innovation activities is examined in Table 7. Firms in telecommunications are particularly active in various collaborative ventures, which reflects the technological dynamism in the sector – R&D-collaboration is often driven by radical technological change in the environment. About half of the innovating telecommunications firms in the sample collaborated with customers, consulting firms, and equipment suppliers. Horizontal collaborations are most common in computer services, about 19% of firms collaborate with competitors in this industry.

In the literature on service innovation it has been argued that customers are particularly important for services (see discussion in the first chapter in this report). According to the Finnish innovation survey data, however, there is no clear evidence of this. Manufacturing firms in fact collaborate more often with customers (54% of manufacturing product innovators against 37% of service innovators) and the two sectors cite customers as an equally important source of knowledge for innovation (average score of 2.1 for both manufacturing and services, see Tables 8 and 9 below). Among the sources of knowledge for innovation, only the importance of universities is clearly different for service firms than for manufacturing firms (average score 1.1 for manufacturing, 0.7 for services).

Table 7. Shares of innovating service firms collaborating with different partners by industry (those exceeding 0.30 in bold, N=158)

	Competitors	Customers	Consulting firms	Equipment suppliers	Universities	N
Electricity, gas, water	0.25	0.29	0.21	0.29	0.26	17
Wholesale	0.08	0.21	0.24	0.29	0.12	44
Land transport	0.18	**0.30**	0.11	**0.32**	0	23
Telecommunication	0.18	**0.51**	**0.60**	**0.45**	**0.30**	25
Financial intermediation	0.11	**0.33**	0.16	**0.33**	0.05	11
Computer and related	0.29	**0.61**	**0.37**	**0.31**	0.28	33
Technical	0.08	**0.41**	0.12	**0.36**	0.26	28
All industries	0.15	**0.37**	0.25	**0.32**	0.18	195

Note: Auxiliary financial services, insurance, and water transportation (14 firms) not included due to too few observations.

The importance of competitors as a source of knowledge for innovation can be interpreted as a proxy for the conditions for appropriating the returns to innovation. If competitors are an important source, appropriability is probably low as knowledge spills over easily within the industry. This interpretation suggests that among the service industries studied appropriability is particularly low in finance, telecommunications, and insurance, and high in land transportation and technical services (Table 8).

Customers as an important knowledge source highlights the importance of demand conditions for innovation. “Demand pull” is the strongest in computer and financial services, and telecommunications. Consulting firms do not play a very important direct role in innovation. They facilitate innovation mainly in water transportation, telecommunications, and energy utilities. The need for consulting may be linked to the dependence on technologies acquired from equipment suppliers. The most supplier-dominated innovators, to use Pavitt’s (1984) term, are telecommunications, energy utilities, and land transportation. Contrary to what has been suggested in the empirical literature, financial innovators in the Finnish sample report a low importance for suppliers as sources of knowledge for innovation. Financial product innovation appears here to be driven by customers' demand, that is, high market opportunities for innovation, and by knowledge spillovers from competitors.

Table 8. Importance of different sources of knowledge for innovation by service industry

	Competitors	Customers	Consulting firms	Suppliers	Universities	N
Electricity, gas, water	1.41	1.83	**1.25**	**1.78**	**1.19**	58
Wholesale	1.40	2.14	0.93	1.38	0.55	230
Land transport	1.17	1.71	0.63	**1.71**	0.58	96
Water transport	1.50	2.00	**1.33**	0.33	0.67	22
Telecommunication	**1.84**	**2.28**	**1.32**	**1.92**	**1.08**	28
Financial intermediation	**2.00**	**2.45**	1.09	0.82	0.45	19
Insurance	**1.80**	2.20	0.80	1.40	0.40	18
Computer and related	1.28	**2.63**	0.94	1.28	**1.06**	52
Technical	1.18	2.08	0.87	1.27	**1.13**	65
All	1.34	2.05	0.89	1.43	0.71	597

Note: Auxiliary financial services are not included because of too few valid observations. Industries with the highest intensities are highlighted. The survey question asks firms to rate the importance of the various knowledge sources on a scale of 0-3.

Perhaps surprisingly, energy utilities are the most intensive users of knowledge from universities, followed by technical services. On average the level of importance of universities for service innovation is quite low, however.

Telecommunications strikes as a sector that uses all knowledge sources very intensively. This probably reflects the high rate of innovation in this field, whereby all sources are relatively more important than for less innovative sectors such as retailing.

In manufacturing, few surprises emerge from the technological regime measures. Metals and minerals industries and motor vehicles depend most on knowledge from competitors; appropriability of innovation returns is thus lowest in these industries. Plastic and rubber industry features the highest appropriability by this measure, not surprisingly as patenting is rather efficient in many chemical industries. In addition to metal industries and furniture, textile firms are customer-driven innovators. Printing and publishing is the most intensive user of consulting services in innovation. Also non-metallic minerals and basic metals value high this source of information. Supplier-dominated industries in the manufacturing sector include food, textiles, wood, paper, printing and publishing, and furniture. Non-metallic minerals feature a particularly low dependence on suppliers, perhaps somewhat surprisingly. Another slight surprise is that among the highest users of knowledge from universities are food and primary metal industries. The fact that many Finnish firms in these sectors have adopted a relatively research-intensive strategy exploiting scientific inventions from biotechnology or metallurgy, may show up in these statistics. Chemical and machine industries also draw knowledge from universities and research institutes. In line with expectations, industries such as metal products and furniture do not rely very much on scientific knowledge.

Table 9. Importance of different sources of knowledge for innovation by manufacturing industry

	Competitors	Customers	Consulting firms	Suppliers	Universities	N
Food, tobacco	1.40	1.90	0.83	**1.67**	**1.29**	107
Textile, leather, apparel	1.65	**2.35**	0.77	**1.71**	1.13	81
Wood products	1.43	1.75	0.82	**1.68**	1.07	77
Pulp, paper	1.42	2.16	0.84	1.58	1.16	28
Printing, publishing	1.40	1.70	**1.17**	**1.93**	1.13	103
Oil, chemical	1.46	2.29	0.61	1.39	**1.39**	44
Plastic, rubber	1.31	2.10	0.90	1.38	1.03	48
Nonmetallic minerals	**1.74**	2.26	**1.11**	1.21	1.16	46
Basic metals	**1.71**	2.14	**1.00**	1.50	**1.71**	26
Metal products	1.49	2.14	0.81	1.30	0.95	99
Machinery, equipment	**1.72**	**2.47**	0.88	1.35	1.33	153
Electronics	1.56	**2.35**	0.75	1.42	1.25	136
Motor vehicles	**1.76**	**2.38**	0.79	1.41	1.07	56
Furniture, other	1.41	2.35	0.65	**1.88**	0.94	56
All firms	1.46	2.14	0.84	1.45	1.06	1060

2.3 Conclusion

Formal service innovation activities as investigated in the Finnish innovation survey tend to concentrate strongly to a few industries. As expected, computer and telecommunication services are "high tech" among service industries. However, financial services (finance, insurance, auxiliary services for finance) appear to be innovative as well, even though their investments in formal R&D and other innovation activities are low. In contrast, they are highly knowledge-intensive measured by education levels. Comparative research on innovation in these innovative but apparently not R&D-intensive industries on the one hand, and R&D-intensive services on the other hand should yield interesting insights.

Innovating service firms collaborate most often with their customers, but equipment suppliers and consulting firms are important partners, too. On the whole, collaborative innovation is less frequent within services than manufacturing, and particularly universities and research institutes are less relevant partners for service firms. The evidence here does not indicate that interaction with customers is more important for service innovation than for manufacturing innovation, as has been argued in the literature. Customers are equally important as a source of knowledge for innovation in the two sectors, and innovating manufacturing firms collaborate with customers more often than innovative service firms do. Overall the patterns of innovation behavior and knowledge sources do not differ dramatically between manufacturing and services.

Interpreting the data on knowledge sources as innovation regimes, appropriability is lowest in financial services. Computer-related and financial services are the most demand-driven service industries, while telecommunications and energy utilities are the most supplier-dominated industries. Energy utilities are the most science-intensive service industry.

3 Correlation and principal component analyses of the service innovation data

3.1 "Innovator profiles"

First we will construct simple contingency tables of the innovation survey indicators. Variables are defined in Table 10. Tables 11 and 12 present the "innovator profiles", or means for other variables, when the variable on top of the column equals one, that is, when the firm is engaged in that activity.

The data for service industries indicate that generally engagement in one type of innovation-related activity increases the likelihood of engaging in other activities. For example, compare the column "COL_cus" presenting the statistics for firms that had innovation projects (successful or not) and collaborated with their customers, to the "All innovators" column, which shows the means for all firms that had innovation projects. 34% of innovating firms that collaborate with customers also collaborate with competitors (compared to 15% of all innovators), 57% collaborate with suppliers (32%), and 37% with universities (18%). The share of firms with research competencies (RES_dum) among COL_cus firms is more than double that among all innovators, and the R&D investments are almost double as well. The table also shows the close connection between the various other innovation-related activities and investments. Notably, innovating firms that collaborate with universities tend to have extremely high shares of RES and TECH employees, and R&D investments. If the firm is engaged in one of the activities, it is likely to invest in knowledge creation in many different ways.

Service firms investing in the various innovation-related activities tend to be larger than average firms in the sample measured by sales. Especially those firms collaborating with competitors and suppliers are larger than the average firm is.

Table 10. Variables

Variable	Explanation
SALES	Sales turnover, million FIM
PROFIT%	Net profit margin, %
INNO	Dummy for service innovation
PROD	Dummy for new products introduced (manufacturing)
PROC	Dummy for process innovation (manufacturing)
COL_com	Dummy for collaboration with competitors
COL_cus	-- with customers
COL_sup	-- with equipment suppliers
COL_uni	-- with universities
TECH	Share of employees with higher technical or scientific degree (Masters level in engineering or natural sciences)
RES	Share of employees with postgraduate (licentiate or doctoral) degree
RES_dum	Dummy for RES > 0
RD_inv	R&D investment/sales
RD_dum	Dummy for R&D investment > 0
OUTRD_inv	Outsourced R&D investment/sales
OUTRD_dum	Dummy for outsourced R&D investment > 0
PAT	Domestic patent applications
PAT_dum	Dummy for PAT > 0
TRAIN_inv	Investments in training/sales
TECH_inv	-- technology
PROCDES	-- industrial design, other process transformations
MARK_inv	-- marketing
MACH_inv	-- machinery and equipment
SOUR_com	Importance of competitors as a source of knowledge for innovation, on a scale of 0 - 3.
SOUR_cus	-- customers
SOUR_con	-- consulting firms
SOUR_sup	-- equipment suppliers
SOUR_uni	-- universities
SCHUMP	Share of small firms among innovating firms in the industry
EXPORT	Exports/sales

Table 11. "Innovation profiles" for service firms (N=600, weighted)

	COL_com	COL_cus	COL_con	COL_sup	COL_uni	RES_dum	RD_dum	OUTRD_dum	All innovators	All firms
SALES (M)	294	179	272	210	146	98	130	166	144	97
EXPORT	0.20	0.19	0.13	0.16	0.19	0.24	0.13	0.09	0.09	0.07
COL_com	1	0.34	0.45	0.34	0.48	0.39	0.19	0.22	0.15	0.04
COL_cus	0.84	1	0.67	0.65	0.77	0.89	0.47	0.42	0.37	0.10
COL_con	0.74	0.45	1	0.45	0.62	0.46	0.29	0.35	0.25	0.07
COL_sup	0.74	0.57	0.59	1	0.56	0.68	0.37	0.41	0.32	0.09
COL_uni	0.57	0.37	0.45	0.31	1	0.60	0.23	0.29	0.18	0.05
RES_dum	0.22	0.21	0.16	0.18	0.28	1	0.11	0.07	0.09	0.05
TECH	0.25	0.29	0.25	0.28	0.36	0.38	0.30	0.24	0.23	0.14
RES	0.017	0.019	0.011	0.015	0.021	0.082	0.011	0.003	0.007	0.003
RD_inv	0.114	0.082	0.086	0.063	0.122	0.191	0.078	0.040	0.048	0.013
RD_dum	0.79	0.78	0.70	0.69	0.81	0.83	1	0.84	0.62	0.17
OUTRD_inv	0.025	0.014	0.017	0.006	0.012	0.008	0.009	0.014	0.007	0.002
OUTRD_dum	0.61	0.48	0.59	0.53	0.67	0.34	0.57	1	0.42	0.12
TRAIN_inv	0.004	0.004	0.003	0.003	0.003	0.011	0.003	0.001	0.002	0.001
N	35	75	56	70	40	19	122	88	195	600

Note: Columns show means for the variables in the first column when the top row variable equals one and the firm has had innovation projects. Only the "All firms" column contains the whole sample.

Table 12. "Innovation profiles" for manufacturing firms (N=1029, weighted)

	COL_com	COL_cus	COL_con	COL_sup	COL_uni	RES_dum	RD_dum	OUTRD_dum	All innovators	All firms
SALES (M)	577	378	497	453	474	1067	285	309	240	102
PROFIT%	5.49	6.81	6.64	6.42	6.45	8.54	7.11	6.59	6.93	6.77
EXPORT	0.28	0.35	0.33	0.34	0.39	0.45	0.32	0.33	0.30	0.19
COL_com	1	0.30	0.33	0.27	0.27	0.27	0.18	0.21	0.16	0.06
COL_cus	0.79	1	0.80	0.71	0.71	0.65	0.46	0.49	0.43	0.15
COL_con	0.49	0.45	1	0.49	0.45	0.28	0.27	0.32	0.24	0.09
COL_sup	0.67	0.66	0.83	1	0.71	0.63	0.45	0.50	0.40	0.15
COL_uni	0.67	0.66	0.74	0.70	1	0.76	0.45	0.54	0.40	0.14
PAT	1.12	1.43	2.14	1.52	1.72	4.07	0.90	0.79	0.75	0.26
PAT_dum	0.14	0.17	0.17	0.15	0.18	0.34	0.13	0.14	0.12	0.05
RES_dum	0.26	0.24	0.18	0.25	0.30	1	0.18	0.20	0.16	0.06
TECH	0.10	0.12	0.11	0.11	0.12	0.16	0.10	0.10	0.10	0.06
RES	0.003	0.003	0.002	0.003	0.004	0.014	0.002	0.003	0.002	0.001
RD_inv	0.029	0.025	0.021	0.021	0.026	0.036	0.024	0.024	0.020	0.007
RD_dum	0.91	0.87	0.90	0.90	0.93	0.93	1	0.92	0.81	0.29
OUTRD_inv	0.009	0.006	0.006	0.005	0.006	0.004	0.005	0.008	0.005	0.002
OUTRD_dum	0.77	0.68	0.81	0.76	0.82	0.76	0.68	1	0.60	0.21
TRAIN_inv	0.002	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.0003
N	83	219	115	206	214	105	369	276	430	1029

Note: Columns show means for the variables in the first column when the top row variable equals one and the firm has had innovation projects. Only the "All firms" column contains the whole sample.

Compared to manufacturing firms, innovating service firms in the sample tend to collaborate and invest in internal or external R&D less often. In contrast, innovating service firms have higher levels of research and technical competencies. This is true for all service firms compared to manufacturing ones: the average share of TECH employees is 14% for the service sample and 6% for the manufacturing sample. Even more drastic is the difference between innovating and collaborating firms in the two sectors. 36% of employees in service firms collaborating with universities have TECH degrees, as opposed to 12% in manufacturing, and among service firms that invest in internal R&D, 30% have this level of education, compared with 10% of firms in manufacturing. Thus the Finnish data support the argument that compared to manufacturing, innovation in services draws more from individuals' skills and capabilities than from formally organized innovation activities. However, one has to bear in mind that the service sample does not represent the whole sector, because only 10 industries are included.

3.2 Correlations among continuous variables

This section constructs simple correlation tables for the continuous variables in the two samples. Table 13 shows the results for the service sample and Table 14 for the manufacturing sample. Focusing first on the innovation-related investments and knowledge sources, we see that export intensity is strongly associated with R&D activities and technical skills in the two sectors. In the service sector also research competencies correlate with a high export share. In both sectors, internal R&D-intensity correlates highly with external R&D, research and technical skills, and investments in marketing. Additionally, in services R&D investments correlate with investments in design and process transformation.

In services, high training investments are observed in research-intensive firms (RES). Training is also very closely associated with investments in technology acquisition, marketing, and design/process transformation. In contrast, manufacturing firms combine training with internal and external R&D, rather than with research and technology acquisition. Knowledge creation through in-house training is more research-intensive and more highly correlated with other innovation-related investments in the service sector than in the manufacturing sector.

Table 13. Correlations among service innovation variables (N=600)

	SALES	EXPORT	EMPL	SALES EMP	RD_ inv	OUTRD_ inv	RES	TECH	TRAIN _ inv	MARK_ inv	TECH_ inv	MACH_ inv	PROC DES	SOUR_ com	SOUR_ cus	SOUR_ con	SOUR_ sup	SOUR_ uni
SALES	1																	
EXPORT	-0.09	1																
EMPL	0.63	-0.07	1															
SALESEMP	0.47	-0.05	-0.02	1														
RD_ inv	-0.10	0.25	-0.06	-0.10	1													
OUTRD_ inv	-0.06	0.15	-0.04	-0.05	0.29	1												
RES	-0.07	0.22	-0.05	-0.06	0.37	0.02	1											
TECH	-0.15	0.38	-0.11	-0.09	0.41	0.17	0.26	1										
TRAIN_ inv	-0.07	0.10	-0.03	-0.07	0.16	-0.01	0.29	0.10	1									
MARK_ inv	-0.07	0.13	-0.05	-0.06	0.28	0.02	0.35	0.15	0.56	1								
TECH_ inv	-0.07	0.04	-0.04	-0.07	0.14	0.03	0.04	0.02	0.68	0.02	1							
MACH_ inv	-0.01	0.00	0.15	-0.05	0.03	0.00	-0.03	-0.08	0.09	0.02	0.14	1						
PROCDES	-0.05	0.11	0.01	-0.06	0.20	-0.02	0.28	0.08	0.75	0.91	0.29	0.07	1					
SOUR_ com	0.18	0.08	0.23	-0.03	0.03	0.07	0.04	-0.17	0.06	-0.04	0.16	0.02	0.01	1				
SOUR_ cus	0.15	0.02	0.13	0.05	0.07	0.03	0.17	0.04	0.06	0.07	0.03	-0.08	0.03	0.47	1			
SOUR_ con	0.05	0.03	0.05	0.01	0.00	0.12	0.02	0.00	0.06	-0.13	0.09	0.06	-0.07	0.32	0.21	1		
SOUR_ sup	0.11	0.04	0.07	-0.04	-0.11	-0.01	-0.05	-0.08	0.07	-0.13	0.12	0.11	-0.06	0.18	-0.02	0.28	1	
SOUR_ uni	0.12	0.15	0.10	0.03	0.12	0.10	0.17	0.24	0.02	-0.05	0.04	-0.04	-0.06	0.24	0.30	0.39	0.15	1

Table 14. Correlations among manufacturing innovation variables (N=1029)

	SALES	EXPORT	EMPL	SALES EMP	RD_inv	OUTRD_ inv	RES	TECH	TRAIN _ inv	MARK_ inv	TECH_ inv	MACH_ inv	PROC DES	SOUR_ com	SOUR_ cus	SOUR_ con	SOUR_ sup	SOUR_ uni
SALES	1																	
EXPORT	0.12	1																
EMPL	0.77	0.20	1															
SALESEMP	0.38	0.10	0.17	1														
RD_inv	0.05	0.21	0.11	-0.08	1													
OUTRD_inv	0.05	0.16	0.03	-0.01	0.43	1												
RES	0.11	0.09	0.08	0.19	0.36	0.04	1											
TECH	0.12	0.24	0.14	0.15	0.53	0.25	0.30	1										
TRAIN_inv	-0.05	0.02	-0.04	-0.08	0.27	0.36	0.00	-0.01	1									
MARK_inv	-0.05	0.12	-0.06	-0.08	0.30	0.27	0.19	0.13	0.32	1								
TECH_inv	-0.04	-0.01	-0.05	-0.06	0.05	0.08	0.00	-0.04	0.13	0.09	1							
MACH_inv	-0.03	-0.07	-0.04	-0.04	-0.05	-0.04	-0.04	-0.06	0.01	-0.04	0.05	1						
PROCDES	-0.03	-0.01	-0.04	0.01	0.06	0.06	-0.02	0.01	0.02	0.07	0.48	-0.01	1					
SOUR_com	0.08	0.21	0.16	0.01	0.06	-0.03	0.06	0.04	0.01	0.13	0.01	-0.02	-0.09	1				
SOUR_cus	0.06	0.22	0.11	0.04	0.15	0.11	0.10	0.17	0.05	0.09	0.01	-0.01	-0.10	0.47	1			
SOUR_con	0.05	0.01	0.07	-0.01	0.01	0.10	-0.02	0.00	0.14	0.02	0.13	0.05	0.12	0.11	0.11	1		
SOUR_sup	0.03	0.03	0.07	-0.02	-0.04	-0.04	-0.05	-0.09	0.04	0.03	0.00	0.01	0.09	0.11	0.14	0.22	1	
SOUR_uni	0.08	0.17	0.13	0.11	0.11	0.12	0.21	0.15	0.00	0.12	-0.06	-0.09	-0.08	0.18	0.27	0.23	0.18	1

Finally, the knowledge source measures feature quite similar patterns in the two samples. However, research competencies correlate with sourcing of knowledge from universities in manufacturing, while in services, technical competencies correlate with this source. The knowledge sources themselves correlate quite highly with one another, except suppliers. Firms relying on suppliers as a source of knowledge also tend to rely on consulting firms, but not customers or competitors.

3.3 Principal component analysis

Principal component analysis (PCA) is a useful way to describe multivariate data with highly correlated variables. The idea is to find a linear combination, that is, weights for the variables of interest that explain as much of the variation in the data as possible. This computation produces the first principal component. The second component is required to be orthogonal to the first one and capture as much of variation in the data as possible in that dimension. The third component is required to be orthogonal to both of the earlier components and again maximize the explanation of remaining variation, and so on. The components can be interpreted as strategies. Observations (firms) in the sample receive scores for each of the strategies, and they are likely to score high in some strategies and low in others. The ones in which they score high represent the firm's "strategic orientation" the best (for more detailed description of the method, see Mardia, Kent and Bibby, 1979).

The output of PCA includes, first, a set of principal components or strategies, which reveal the groups of variables that tend to be observed together. Second, observations can be sorted in the order of the firms' scores in each of the principal components. This provides information on which firms or which industries tend to score high in certain strategies.

PCA is used here to describe the innovation and competence variables in the datasets. These kinds of survey data often give rise to considerable correlation among variables, partly because the variables used are incomplete proxies for some unobservable variables, which we would ideally like to measure but cannot. Examples of these kinds of unobservables are the concepts of organizational knowledge and innovative capability. For categorical survey data, a better method of analysis would be multiple correspondence analysis (MCA). However, MCA is less intuitively appealing without graphical display, and it is not possible to create graphical representations of binary data. Hence PCA is used here instead of MCA.

Table 12. Services: First five principal components of the innovation and competence variables

	"Customer-oriented formal innovators"	"Competence and process investors"	"Supplier-driven technology buyers"	"Research-intensive, external knowledge"	"Technically competent exporters"
INNO	**0.29**	-0.06	0.19	0.09	-0.04
COL_com	**0.28**	-0.17	0.04	-0.12	-0.11
COL_cus	**0.35**	-0.08	0.01	0.00	-0.11
COL_con	**0.30**	-0.18	0.08	0.00	-0.14
COL_sup	**0.31**	-0.14	0.14	-0.05	0.01
COL_uni	**0.30**	-0.17	-0.19	0.01	-0.12
COL_res	**0.27**	-0.16	**-0.22**	-0.18	-0.11
RES	0.16	0.18	**-0.35**	**0.24**	0.10
TECH	0.15	0.00	**-0.36**	-0.10	**0.33**
RD_inv	0.19	0.07	**-0.34**	-0.05	0.03
OUTRD_inv	0.12	-0.07	-0.14	-0.18	0.03
PAT	0.13	-0.11	-0.02	-0.19	-0.06
TRAIN_inv	**0.20**	**0.46**	0.17	-0.10	0.04
TECH_inv	0.17	**0.22**	**0.31**	**-0.28**	0.17
PROCDES	0.17	**0.53**	0.01	0.04	-0.13
MARK_inv	0.15	**0.49**	-0.14	0.11	-0.19
MACH_inv	0.10	0.04	**0.23**	-0.19	**0.24**
SOUR_com	0.12	-0.04	**0.20**	**0.35**	**0.23**
SOUR_cus	**0.26**	-0.06	0.04	**0.35**	-0.06
SOUR_con	0.07	-0.07	0.12	**0.43**	0.15
SOUR_sup	0.14	-0.02	**0.39**	-0.09	**0.27**
SOUR_uni	0.07	-0.03	-0.05	**0.44**	**0.27**
SCHUMP	0.04	-0.01	0.14	0.08	**-0.47**
EXPORT	0.10	0.01	-0.19	-0.17	**0.46**
Cumulative	0.22	0.33	0.40	0.46	0.51

Note: loadings of 0.20 or higher are highlighted

Table 12 presents the first five principal components for the service and manufacturing samples. For both datasets, these five components account for about 50% of the variation in the data (cumulative explanation). The first components are strikingly similar for services and manufacturing. The strategy that explains most of the variation for both samples is labeled "Customer-oriented innovators," and it has high loadings for product innovation, all types of collaboration, and customers as a source of knowledge. In addition, service firms emphasize training investments, while manufacturing firms emphasize internal and outsourced R&D investments in this strategy. Training appears to replace R&D as the critical knowledge creation investment in many service industries.

The second component combines training and marketing with technology acquisition and design/process transformation investments in service firms. Manufacturing firms complement training and marketing with research competencies and both types of R&D investments. Acquiring technologies is an important knowledge creation investment for services. Another interesting feature is that in the manufacturing sample, internal and outsourced R&D investments tend to be closely associated. This points to a complementary, rather than substitutable, relationship between internal and external R&D.

According to the third component for services, the so-called "Supplier-driven technology buyers," investments in technology and machinery are associated with relying particularly on suppliers as a knowledge source. Supplier-driven strategy is associated here with low levels of competence and R&D. The fact that competitors are a relatively important source of knowledge as well suggests that in these fields it is difficult to appropriate innovations. This may weaken the incentives to invest in own R&D. The third component for manufacturing, "Consulting-driven technology buyers," loads consulting firms even more than suppliers as an important source of knowledge. The strategy is associated with rather low competencies in both sectors, while investments in process transformation and technology acquisition are emphasized.

The "Research-intensive, external knowledge" strategy for services loads research competencies rather strongly and combines them with external knowledge sources, especially universities. This strategy is not very closely associated with innovation output, however. In manufacturing the "low-tech spillover-driven" component also loads high the external sources of competitors and customers.

Table 13. Manufacturing: First five principal components of the innovation and competence variables

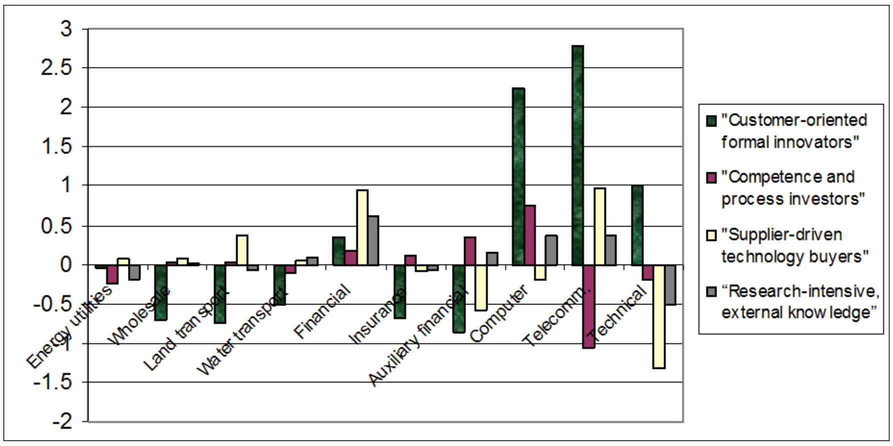
	"Customer-oriented innovators"	"Research-intensive non-innovators"	"Consulting –driven technology buyers"	"Competitor-driven technical exporters"	"Low-tech spillover-driven"
PROD	**0.31**	-0.10	-0.02	0.08	0.00
PROC	**0.24**	-0.15	0.09	0.00	0.10
COL_com	**0.21**	-0.10	-0.08	**-0.21**	0.02
COL_cus	**0.32**	-0.17	-0.08	-0.04	-0.04
COL_con	**0.24**	-0.19	0.04	**-0.22**	-0.14
COL_sup	**0.30**	-0.19	0.01	**-0.20**	-0.06
COL_uni	**0.33**	-0.13	-0.12	-0.08	-0.08
COL_res	**0.30**	-0.12	-0.09	-0.16	-0.07
RES	0.18	**0.35**	-0.06	0.00	0.02
TECH	0.19	0.10	-0.15	**0.27**	**-0.22**
RD_inv	**0.22**	**0.42**	-0.01	0.04	0.01
OUTRD_inv	**0.21**	**0.44**	0.03	-0.05	0.03
PAT	0.09	0.00	-0.09	**0.25**	0.13
TRAIN_inv	0.16	**0.33**	0.12	-0.07	0.14
TECH_inv	0.09	-0.01	**0.54**	0.20	-0.09
PROCDES	0.07	0.00	**0.54**	0.14	**-0.25**
MARK_inv	0.16	**0.40**	0.03	-0.09	0.03
MACH_inv	-0.03	0.02	0.08	-0.13	**0.48**
SOUR_com	0.13	-0.10	0.00	**0.39**	**0.48**
SOUR_cus	**0.23**	-0.13	-0.01	**0.24**	**0.29**
SOUR_con	0.05	-0.06	**0.48**	-0.01	0.01
SOUR_sup	0.08	-0.10	**0.22**	-0.15	0.13
SOUR_uni	0.13	0.04	-0.01	**-0.26**	-0.07
SCHUMP	0.05	0.03	-0.13	**0.37**	**-0.48**
EXPORT	0.15	-0.07	-0.10	**0.41**	0.06
Cumulative	0.23	0.35	0.42	0.48	0.52

Note: loadings higher than 0.20 are highlighted

Finally, the remaining strategies, "Technically competent exporters" for services and "Competitor-driven technical exporters" for manufacturing both load strongly and positively export share, technical competencies, and competitors as a source of knowledge. In services, this strategy is associated with machinery investments as well as suppliers and universities as knowledge sources. For manufacturing firms aligned with this strategy, competitors and customers are relevant knowledge sources. These firms often patent their innovations to protect the innovation returns in an environment of high spillovers, that is, high loading of SOUR_com. In contrast, existing evidence from other studies (Miles and others) suggests that patents are not effective means for protecting service innovations. Patents are indeed not associated with intensive knowledge flows among competitors in services.

Next we will study which strategies different industries tend to adopt. Figure 13 shows the average scores in each service industry. The "*Customer-oriented innovators*" concentrate mainly in industries already previously found to be innovative and engaged in formal innovation activities including R&D investment and collaboration. Among these industries are telecommunications, computer, and technical services. Auxiliary financial services, insurance, wholesale and transportation score particularly low here. Firms providing auxiliary financial services tend to be "*Competence and process investors*," together with certain computer service providers. Telecommunications firms do not behave according to the competence and process investment strategy at all. Instead, they are relatively strong in the "*Supplier-driven technology buyers*" group. This is also the most prevalent strategy for financial intermediation, quite in line with the existing studies on technological change and innovation patterns in fi-

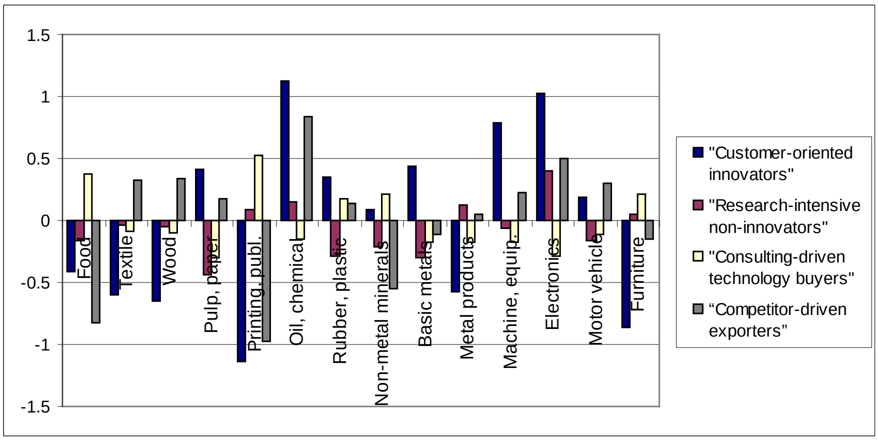
Figure 13. Average principal component scores for service industries (N=609)



nancial services (notably Barras, 1986). Technical services are not at all technology- and supplier-driven. Their main innovation pattern is the high-tech strategy, that is, customer-oriented formal innovation. The fourth strategy, "*Research-intensive, external knowledge*" is strongest in financial, computer, and telecom services.

In manufacturing, *Customer-oriented formal innovation* is found to be strongest in high technology sectors including chemical, electronic, and machine industries. Many firms in the "medium tech" industries of paper and basic metals (non-ferrous metals and steel) have also adopted this strategy. This behavior is the least common in printing and publishing, furniture, wood, textiles and metal products, that is, what is traditionally thought of as "low tech". Food, printing and publishing, and furniture, together with non-metallic minerals, rather tend to be "*Consulting-driven technology buyers*." Large differences in average scores among industries are also found in respect of the strategy of "*Competitor-driven exporters*." It is prevalent especially in oil and chemical, and electronics, and to a lesser extent in textiles, wood products and automotive industry. Food, printing and publishing, and non-metallic minerals tend to be oriented towards domestic markets and thus do not apply this strategy. Some electronics firms are also "*Research-intensive non-innovators*." Other industries do not score high in this strategy.

Figure 14. Average principal component scores for manufacturing industries (N=1025)



3.4 Conclusion

This section provides evidence on the clustering of innovation activities and competence investments. Firms that engage in some innovation-related activity have a high propensity to expand also to other activities of this sort. A necessary condition may be a sufficient level of general capabilities, partially reflected in skill levels and firm size. A possible interpretation is that once firms set out on an innovative trajectory, they start accumulating certain types of dynamic capabilities, which make additional knowledge creation activities more productive.

The correlation analysis suggests that training and R&D investments play different roles in services and manufacturing. Training is more important for service firms trying to benefit from research, technology acquisitions, and investments in design or process changes. Moreover, internal and external R&D feature less of a scale effect within the service sector. In the manufacturing sector, in contrast, internal and outsourced R&D are associated with large firm size and high export intensity.

Principal component analysis yields strikingly similar results for the two samples. The most general innovation strategy in both samples features collaboration with various partners, successful innovation, and sourcing of knowledge inputs from customers. In manufacturing this orientation is also associated with high internal and outsourced R&D investments, while services emphasize training investments. This lends further support to the argument that training substitutes for R&D in some services as the key knowledge creation activity. Moreover, the fact that high internal and external R&D tend to be observed together in manufacturing firms suggests that outsourced R&D needs to be complemented by internal R&D. It is not a viable option to substitute internal R&D with the external one.

According to the third most prevalent strategy in both samples, technology acquisition, training, and sourcing of information from equipment suppliers and consulting firms tend to be observed together. This is intuitive: benefiting from new technologies necessitates organizational learning that technology suppliers and consulting firms can facilitate.

Industry-level indicators on the importance of different knowledge sources are interpreted here as measures for the innovation environment. Principal component analysis produces some intuitive associations between these and firms' innovation strategies. For instance, high importance of competitors as a source of knowledge, which was argued to reflect a regime of low appropriability of innovation returns, is associated with patenting in the manufacturing dataset. Thus the patterns of interacting with the external environment seem to have implications for the internal strategies of knowledge management.

The clusters of behaviors revealed by the principal component analysis accord nicely with intuition and previously documented patterns of technological change in different industries. The first component for both manufacturing and services is most closely in line with innovation theories and is strongest in the high technology sectors of computer and related services, telecommunications, and technical services, and chemical, machine and electronics industries. In contrast, "medium-" or "low-tech" industries such as financial intermediation, land transportation, food, and printing and publishing appear to behave according to the supplier- or consulting firm-dominated technology buying strategy.

Note, however, that even within the high tech sectors there coexist other strategies. Notably, telecommunication services have a strong presence of the strategy based on suppliers' and consulting firms' capabilities and technology acquisition. Similarly, chemical and electronics industries feature both the less innovative competitor-driven export-oriented strategy and the highly innovative high-tech strategy.

The fact that wholesale trade, energy utilities, water transportation, and insurance services get few positive scores (on average) on the principal components calls for a critical assessment of the data. These industries do not have many positive entries on any of the innovation activities or competence investments. This implies that either these industries truly do not invest in knowledge creation or else the data do not capture their knowledge investments.

4 Technological regimes and the determinants of innovation activities and performance

4.1 Introduction

This chapter examines the determinants of R&D and training investments, innovation collaboration, and innovation using slightly more rigorous econometric techniques. First, we are interested in characterizing those firms in the service sector that invest in innovation activities. These are compared and contrasted with those in the manufacturing sector. The goal is to assess the relative importance of various knowledge creation activities in different sectors, and the impact of different technological regimes within the sectors. Second, we saw in previous chapters that innovation collaboration is often observed together with service innovations or successful new product introductions. Here we study how collaboration is determined, focusing in particular on competence requirements and the effects of the technological environment. Third, factors contributing to service or product innovation in the two sectors are compared. Again, competencies and the incentives created by technological regimes are of interest. The final section of this chapter examines R&D, collaborative arrangements, and product innovation jointly. The idea is that firms may decide simultaneously about engaging in a product development project, investing in R&D, and organizing the project. Therefore, studying these separately may give rise to biased estimates. Especially the effects of R&D investment on the propensity to collaborate and introduce new products or services are potentially biased without taking the interdependence of the activities into account.

Determinants and effects of innovation are topics of intense research interest, particularly since the fundamental relationship between economic and technological change has become widely acknowledged. As a result, contributions of research and development activities (R&D) to innovation and industrial evolution, especially in manufacturing industries, are well appreciated. However, in many economic studies, R&D is conceptualized as an innovation production function. Such treatment may be a useful first approximation of the innovation process within a linear model of innovation. However, in qualitative empirical studies over the past 20 years it has been observed that the *organization* of the firm, and R&D in particular, is a critical determinant of both innovation (e.g. Mowery, 1983) and economic performance (e.g. Teece, 1986). Informal models of innovation emphasize feed-backs and complementarities among a firm's activities and knowledge bases (Kline and Rosenberg, 1986, Rothwell, 1994). Organizational choices, for instance whether to organize knowledge creation activities (e.g., R&D, training, employing qualified workers) internally or outsource them, have a considerable impact on the strength of the interactions between various sources of knowledge.

Services have been described as supplier-dominated industries adopting technologies from outside. Service innovation is argued to happen mainly as a by-product of technology adoption, as in the case of innovation induced by information technology in financial services (Barras, 1986). Other empirical studies emphasize the informal nature and organization of service innovation (e.g., Sundbo, 1997). These studies seem to suggest, first, that service firms do not innovate as frequently as manufacturing firms, since innovation is not a result of deliberate efforts, and second, that the innovation process in services is very different from that in manufacturing. However, according to the descriptive analysis in the previous chapters, the first conclusion is clearly not true – innovation is about as frequent in the service sample as in the manufacturing sample – and the second holds only for some services. Principal component analysis revealed that the structures of the two datasets do not differ drastically: the first five principal components were strikingly similar for the two sectors. Moreover, at least in the "high tech" services, firms do engage in formal R&D and innovate very frequently. The service innovation process is not necessarily very different from that within manufacturing.

This chapter differs from most earlier literature by incorporating some organizational aspects into the empirical analysis of innovation. Innovation is modeled as based on a system of activities; internal R&D, R&D collaboration with outside partners, and outsourcing of R&D. It is argued that this system is complemented by competencies and skills of the firm. Competencies are hypothesized to be prerequisites for success in the three forms of R&D activities.

As discussed in Chapter 1, industries are characterized by different patterns of technological change (see e.g. Pavitt, 1984). The effects of these sectoral differences on R&D investment (Cohen and Levinthal, 1989) and industrial structure (Winter, 1984 has a theoretical model) have been studied. In this chapter we also assess how sectoral differences affect firms' organizational choices applied to R&D and, ultimately, innovation.

The Finnish innovation survey data are used to analyze the determinants of external R&D arrangements in firms, i.e., collaboration with various partners and outsourcing. The main research questions are the following. (1) Are the determinants of innovation-related investments, R&D collaboration, and innovation in the service sector different from those in the manufacturing sector? (2) How do competencies affect the organization of innovation activities? (3) How does the technological environment impact on innovation and patterns of knowledge accumulation?

4.2 Conceptual framework

4.2.1 R&D collaboration

As technological change has become more rapid and complex, and dissemination and sourcing of information have become easier due to new technologies, many firms decide not to create all knowledge internally. Some information can be acquired in the "markets". For certain important kinds of knowledge there are no markets, however. In particular, a significant part of firms' productive knowledge is tacit or collective and therefore not easily transferable, and other parts are firm-specific or strategic, and thus not for sale. Nevertheless, through intensive collaboration within an R&D alliance, even some of this "stickier" knowledge can be shared and jointly utilized. Collaborative R&D can be viewed as a transaction in organizational knowledge. Indeed, collaborative arrangements like R&D alliances, joint ventures, and research consortia are becoming increasingly common in modern economies. However, in order to make use of another firm's knowledge, a firm needs to possess sufficient internal competencies, in other words, absorptive capacity.

As collaborative arrangements between firms have proliferated over the past two decades, various explanations for their occurrence have been offered in the academic literature (see e.g. Contractor and Lorange, 1988). The benefits of collaboration are usually emphasized in these studies, partly due to the sampling bias: generally only collaborating firms are examined (e.g. Hagedoorn and Schakenraad, 1992; Powell, Koput and Smith-Doerr, 1996)[6]. Few studies assess the reasons for *not* collaborating. The cross-sectional approach with random sampling in this chapter reduces this bias.

One of the few more critical views on collaborative arrangements comes from the transaction cost approach, which suggests that R&D collaboration can lead to unintended leakage of strategic information to the firm's competitors (Pisano, 1989; Oxley, 1997). Other studies argue that external organization of R&D may reduce the possibilities to innovate profitably as externally sourced knowledge may be more difficult to integrate tightly with the other activities of the firm. In such a situation, the potential complementarities related to innovation may remain only partially exploited (Mowery and Rosenberg, 1989; Leiponen, 1999). External organization of R&D may be associated with a trade-off between lower costs of developing new internal capabilities, on the one hand, and the transactional hazards stemming from the leakage of knowledge-based assets and missed opportunities for complementarity among knowledge resources, on the other. Moreover, firms lacking complementary internal competencies will find it less profitable to engage in collaborative innovation.

According to Hagedoorn (1993), the main reasons behind strategic R&D alliances include i) technological complexity and complementarities, ii) reduction of the uncertainty and costs of R&D, iii) interest in capturing partners' knowledge, and iv) reduction of product development times. However, the kinds of partners with which firms do and do not collaborate has not been empirically examined. The literature generally focuses on collaboration with competitors, perhaps as an outgrowth of economists' interest in organizational changes related to degradation of competition. Do motivations for forming alliances with customers differ from those associated with partnering with competitors or universities? The transaction point of view implies that the logic and cost structures support-

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6 However, Contractor and Lorange (1988) in their introductory chapter discuss both benefits and costs of cooperative ventures.

ing "vertical" alliances might be different from those of "horizontal" ones.

Beyond analyzing patterns of collaboration, this study seeks to examine possible interactions between collaboration and internal competence accumulation. Using the Finnish survey data, we can compare the skill characteristics of firms entering collaborative arrangements with those of non-collaborating firms.

4.2.2 Hypotheses

This chapter focuses on the determination of innovation-related investments, R&D collaboration decisions, and product innovation. These decisions may be highly intertwined. When the firm decides to pursue innovation, it will also choose whether to carry out formal R&D, and how to organize such a project (internally, outsource, and/or collaborate).

The main hypotheses are, first, that skill and competence investments, measured by fields and levels of education of employees, complement firms' investments in internal R&D and collaboration in innovation. Second, different types of skills complement collaboration with different types of partners. For instance, research cooperation with universities and other research organizations necessitates relatively high internal research skills due to the absorptive capacity requirement. Collaboration with universities is thus expected to be associated with high research competencies. In contrast, collaboration with suppliers is expected to be associated with relatively low research competence requirements. Third, the technological regime affects the innovation behavior of firms as measured by their propensity to engage in R&D, collaborate in innovation, and innovate. Finally, the determinants of innovation and investments in knowledge creation are qualitatively the same in the manufacturing and service sectors.

The proxies for technological regime include industry averages of the importance of various external sources of knowledge to the firm's innovation process. The Finnish innovation survey does not contain direct information about the appropriability of innovation returns. However, data on competitors as knowledge sources can serve as an indication of appropriability: when competitors are important sources of knowledge in an industry, it is likely that secrets are difficult to maintain, and thus appropriability is fairly low. On this basis, low appropriability is expected to discourage collaboration and outsourcing of R&D due to the transaction hazards. Its effect on R&D investment is ambiguous, however, as R&D supports both internal innovation and absorption of spillover knowledge. The effect of low appropriability on innovation is hypothesized to be negative because of the disincentives to innovate created by spillovers.

Industry averages of the importance of the other external knowledge sources – customers, suppliers, and universities – are also treated as indicators of particular technological environments. Even if within each industry there may be different strategies, as we found in the previous chapter, firms face more or less the same technological conditions. For instance, where universities are important knowledge sources, the regime is considered to be science-intensive. According to Klevorick et al. (1995), science-intensive regimes are higher in innovation opportunities. Thus, firms in science-intensive industries are expected to be more likely to invest in R&D, collaborate with universities, and innovate, relative to firms in industries of low science-intensity.

The importance of customers as a knowledge source represents the demand for innovation and the need to be in touch with users, both of which bode well for profitable innovation. Therefore, firms operating in an environment in which customers frequently provide ideas and opportunities for innovation both invest more in innovative activities and succeed in innovation more often. They are also highly likely to collaborate with customers in R&D.

Finally, industries in which suppliers represent important sources of knowledge are treated as supplier dominated regimes (Pavitt, 1984). Supplier domination implies that a considerable part of technological development is delegated upstream for example to equipment suppliers. Consequently, innovations become embodied in production equipment, machinery, and service technicians. Firms in supplier dominated regimes are often oriented toward process improvement through incremental learning in their operations and do not necessarily introduce new products frequently. On this basis, outside of their close relations with suppliers, they are not expected to collaborate in innovation.

The "Schumpeterian" regime is hypothesized to affect the propensity of firms to externalize R&D. Firms can share innovation risks by collaborating instead of developing the complementary capabilities internally. In a rapidly changing environment, expected returns to internally developed capabilities are lower, *ceteris paribus*, because of the higher risk that the capabilities will soon become obsolete due to some other firm's radical innovation. Therefore it is expected that a more turbulent, or *entrepreneurial*, environment is associated with more frequent outsourcing of and collaboration in R&D.

In addition, the level of competition in the industry characterizes the firms' economic operating environment. Because of the small size of the Finnish economy, we use measures of international competition: the firm's export share and import intensity of its industry.[7] Export and import competition is expected to encourage innovative activities.

4.3 Variables and estimation results

As in previous chapters, the data originate from the innovation survey of 1996 and the employment register for 1995. The list of variables is in Table 14 below. Most of them have already been discussed and used in the earlier analyses. New variables include GROUP, a dummy for firms that belong to a business group or a concern, and LPROD, an additional industry control variable for services. Membership in an enterprise group may provide firms with access to additional resources facilitating their own innovation activities. The data are weighted to represent the Finnish economy.

4.3.1 Determinants of investments in knowledge creation

First we investigate factors associated with investments in various knowledge creation activities. Tables 15-19 show the results of simple Tobit-estimations of the determinants of these investments for firms engaged in some innovation activity: either successful product

[7] The traditional variables of industry concentration and market share were originally included as well, but they did not capture statistically significantly the aspects of competition in Finnish manufacturing, perhaps due to the too high level of aggregation and the small open economy environment.

Table 14. Variables

Innovation activities	RD_inv	Internal R&D investments/sales
	TRAIN_inv	Innovation related training investments/sales
	TECH_inv	Innovation related technology acquisition/sales
	MACH_inv	Innovation related machinery investments/sales
	MARK_inv	Innovation related marketing investments/sales
	OUTRD_inv	Outsourced R&D investments/sales
	RD_dum	Dummy for R&D_inv > 0
	COLLAB	Dummy for R&D collaboration with any partner
	COL_com	Dummy for R&D collaboration with competitors
	COL_cus	Dummy for R&D collaboration with customers
	COL_sup	Dummy for R&D collaboration with suppliers
	COL_uni	Dummy for R&D collaboration with universities
	OUTRD	Dummy for outsourced R&D investment > 0
	INNO	Dummy for successful service or product innovation (sales revenue from the commercialized new product >0)
COMPETENCIES	RES	Share of employees with a post-graduate degree (doctoral or licentiate)
	TECH	Share of employees with a higher technical or natural scientific degree (e.g., university engineer, Master of science in chemistry)
FIRM	EMPL	Number of employees, in thousands
	GROUP	The firm is a member in a group
TECHNOLOGICAL REGIME	REG_com	Industry average for the importance of competitors as sources of knowledge
	REG_cus	Industry average for the importance of customers as sources of knowledge
	REG_sup	Industry average for the importance of suppliers as sources of knowledge
	REG_uni	Industry average for the importance of universities as sources of knowledge
	SCHUMP	Share of small firms (EMPL<100) among innovating firms in the industry
COMPETITION	EXPORT	Firm's exports/sales
	IMPORT	Total imports in the product category/domestic industry sales
	LPROD	Average labor productivity in the industry (SALES/EMPL); additional industry control for service industries due to missing information on imports

Table 15. Determinants of R&D intensity (dependent variable: RD_inv)

Services	N=185		Manufacturing	N=468	
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-0.25**	-2.63	Constant	-0.04*	-1.90
RES	1.12**	3.42	RES	1.03**	5.40
TECH	0.17**	3.22	TECH	0.14**	7.74
COLLAB	0.01	0.49	COLLAB	0.01*	1.74
OUTRD_inv	0.98**	2.79	OUTRD_inv	1.06**	7.14
EMPL	0.01	0.74	EMPL	0.0032	1.54
GROUP	-0.01	-0.72	GROUP	-0.003	-0.82
EXPORT	0.04	0.85	EXPORT	0.01*	1.93
REG_com	0.08	0.82	REG_com	-0.02	-1.35
REG_cus	0.04	0.89	REG_cus	0.02**	2.12
REG_con	-0.09	-0.84	REG_con	0.001	0.07
REG_sup	0.01	0.25	REG_sup	0.002	0.23
REG_uni	0.09	1.25	REG_uni	0.01	0.86
Sigma	0.12**	15.04	Sigma	0.03**	27.26

Note: ** denotes statistical significance at the 5% level, * denotes significance at the 10% level.

or process innovation, or innovation projects that were not yet completed. Thus a considerable share of the total variance is excluded. These results are therefore not directly comparable to those in the following section, where the whole datasets are used in the multivariate analysis. Financial industries are excluded here because of the unreliability of the data obtained from them. Tobit-estimation is preferred to least squares methods, because the underlying distributions are censored on the left (negative investments are not possible).

Each of the tables presents regression results for both service and manufacturing firms that pursue innovation in one way or another. Table 15 presents the factors that contribute to R&D intensity. It suggests that in both sectors, high research and technical competencies correlate strongly with high R&D intensity. External innovation activities also tend to encourage internal R&D investments. High investments in outsourced R&D, in particular, is associated with higher internal R&D. In manufacturing, innovation collaboration is weakly associated as well. Export intensity is correlated with R&D

in manufacturing, but not in services. Further, manufacturing firms in regimes of high market opportunities for innovation (high REG_cus) tend to be more R&D intensive. In services, regimes do not have any significant effects: R&D intensity of innovating firms seems driven mainly by firms' strategic capabilities and activities. Innovation regimes may contribute more significantly to the choice of engaging in innovation activities in the first place.

The estimated determinants of investments in in-house training support the argument that competence strategies differ between the two sectors (Table 16). In service industries, high training intensity is associated with a high level of research competencies, while in manufacturing competencies are not correlated with training. In services training intensity is also observed in regimes of high science-intensity and low dependence on consulting firms for knowledge. In manufacturing, in contrast, low science-intensity and high dependence on consulting tend to accompany high training investments. For both sectors, collaborative innovation supports higher training investments, in manufacturing outsourced R&D does that as well. Internalization of knowledge from external innovation activities seems to require efforts in the form of employee training.

Table 16. Determinants of training investments (dependent variable: TRAIN_inv)

Services	N=185		Manufacturing	N=468	
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-0.01	-1.34	Constant	-0.002	-0.69
RES	0.07**	2.12	RES	0.03	0.99
TECH	-0.01*	-1.72	TECH	-0.002	-0.77
COLLAB	0.005**	2.32	COLLAB	0.002**	3.65
OUTRD_inv	-0.07	-0.86	OUTRD_inv	0.13**	6.49
EMPL	0.001	0.74	EMPL	0.0001	0.48
GROUP	0.0004	0.23	GROUP	0.0001	0.28
EXPORT	0.01	1.09	EXPORT	0.0002	0.21
REG_com	0.01	1.56	REG_com	-0.001	-0.45
REG_cus	0.001	0.29	REG_cus	0.001	0.39
REG_con	-0.02**	-2.39	REG_con	0.004*	1.69
REG_sup	-0.01	-1.47	REG_sup	-0.0003	-0.32
REG_uni	0.02**	2.18	REG_uni	-0.004**	-2.62

Sigma	0.01**	12.03	Sigma	0.004**	17.64

Table 17. Determinants of technology acquisitions (dependent variable: TECH_inv)

Services	N=185		Manufacturing	N=468	
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-0.02	-1.39	Constant	-0.03**	-2.95
RES	-0.06	-0.78	RES	0.08	1.26
TECH	-0.01	-1.26	TECH	-0.002	-0.35
COLLAB	0.01*	1.81	COLLAB	0.004**	2.75
OUTRD_inv	-0.030	-0.36	OUTRD_inv	0.06	0.96
EMPL	-0.0002	-0.82	EMPL	0.0003	0.45
GROUP	0.004	1.02	GROUP	-0.001	-0.95
EXPORT	0.009	0.87	EXPORT	-0.00005	-0.02
REG_com	0.03*	1.88	REG_com	-0.01	-1.14
REG_cus	0.004	0.55	REG_cus	0.01**	2.21
REG_con	-0.04**	-2.17	REG_con	0.01*	1.71
REG_sup	-0.01**	-2.00	REG_sup	0.001	0.39
REG_uni	0.02*	1.78	REG_uni	-0.003	-0.78
Sigma	0.02**	13.41	Sigma	0.01**	13.93

Table 17b. Determinants of technology acquisitions (dependent variable: TECH_inv)

Services	N=185		Manufacturing	N=468	
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-0.02	-1.30	Constant	-0.03**	-3.13
RES	-0.07	-0.91	RES	0.09	1.31
TECH	-0.01	-1.19	TECH	-0.003	-0.48
COL_com	-0.001	-0.10	COL_com	0.001	0.62
COL_cus	0.002	0.32	COL_cus	0.001	0.70
COL_sup	**0.01****	**3.16**	**COL_sup**	**0.004****	**2.61**
COL_uni	-0.001	-0.17	COL_uni	0.000	-0.15
OUTRD_inv	-0.01	-0.17	OUTRD_inv	0.06	0.99
EMPL	-0.0002	-0.97	EMPL	0.0001	0.16
GROUP	0.003	0.74	GROUP	-0.001	-0.97
EXPORT	0.01	0.59	EXPORT	0.0003	0.16
REG_com	0.03	1.70	REG_com	-0.007	-1.36
REG_cus	0.004	0.59	REG_cus	0.01**	2.43
REG_con	-0.04	-1.98	REG_con	0.01*	1.81
REG_sup	-0.01	-2.08	REG_sup	0.001	0.49

REG_uni	0.02	1.62	REG_uni	-0.002	-0.54
Sigma	0.02**	13.47	Sigma	0.01**	13.88

Table 17 displays the results on the intensity of technology acquisition. Again, the impact of consulting intensive regimes is different in the two sectors. In services, firms not dependent on consulting firms or suppliers invest a lot in technology. In manufacturing it is the opposite case: consulting services and technology acquisition correlate positively. For service firms, high spillovers and science-intensity are also significant at the 10% level. In manufacturing high innovation demand regimes drive technology investments.

Competence measures do not correlate significantly with technology investments in either sector. Collaborative innovation, on the other hand, is associated with technology investments in both sectors. Further analysis in Table 17b shows that particularly collaboration with suppliers drives this result. These results imply that within manufacturing, technology acquisition tends to be a relatively low-skill strategy supported by consulting services and knowledge derived from equipment suppliers. In services, in contrast, technology acquisition seems to be observed in relatively more knowledge-intensive regimes.

High investments in machinery and equipment do not depend on competencies, either (Table 18). In services machine investments tend

Table 18. **Determinants of machine and equipment investments (dependent variable: MACH_inv)**

Services	N=185		Manufacturing	N=468	
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-0.02	-0.65	Constant	-0.03**	-2.22
RES	-0.07	-0.52	RES	0.06	0.62
TECH	-0.03	-1.64	TECH	-0.003	-0.26
COLLAB	-0.01	-1.13	COLLAB	0.002	1.00
OUTRD_inv	-0.01	-0.05	OUTRD_inv	-0.10	-1.07
EMPL	0.006**	2.01	EMPL	-0.0001	-0.10
GROUP	-0.01	-1.20	GROUP	0.0003	0.15
EXPORT	0.03*	1.76	EXPORT	-0.001	-0.44
REG_com	-0.02	-0.72	REG_com	0.001	0.12
REG_cus	0.01	0.59	REG_cus	0.001	0.25
REG_con	0.002	0.06	REG_con	0.01	1.09

REG_sup	0.01	0.92	REG_sup	0.01**	2.09
REG_uni	0.02	0.77	REG_uni	0.001	0.23
Sigma	0.04**	13.31	Sigma	0.02**	22.73

Table 19. Determinants of marketing investments (dependent variable: MARK_inv)

Services	N=185		Manufacturing	N=475	
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-0.10**	-2.83	Constant	-0.01	-1.43
RES	0.21**	2.07	RES	0.15**	3.06
TECH	0.02	0.96	TECH	0.001	0.12
COLLAB	0.004	0.57	COLLAB	0.004**	3.45
OUTRD_inv	-0.10	-0.62	OUTRD_inv	0.14**	3.61
EMPL	0.005*	1.69	EMPL	-0.001	-0.83
GROUP	-0.01*	-1.90	GROUP	-0.001	-1.46
EXPORT	0.02	1.41	EXPORT	0.002	1.61
REG_com	0.01	0.44	REG_com	0.001	0.18
REG_cus	0.04**	2.90	REG_cus	0.002	0.79
REG_con	-0.03	-0.93	REG_con	0.001	0.33
REG_sup	0.01	0.42	REG_sup	-0.003	-1.53
REG_uni	-0.01	-0.63	REG_uni	-0.001	-0.20
Sigma	0.03**	11.00	Sigma	0.01**	16.25

to be higher in larger firms with some export orientation. Manufacturing firms in supplier-dominated industries invest more in machines and equipment, quite intuitively.

Investments related to market introduction of new products correlate strongly with high research competencies in both sectors (Table 19). In other words, highly research-oriented firms tend to invest a lot in the marketing of new products. Also, manufacturing firms engaging in external innovation invest heavily in marketing. In the service sector, demand for innovation is driving marketing investments as well.

4.3.2 Determinants of collaborative arrangements to innovate

Here we test for the relevance of internal competencies in collaborating with outside partners. It was argued in section 4.2 that firms need absorptive capacity to benefit from external arrangements, external collaboration thus being a complement rather than a substitute for internal knowledge creation. Secondly, we are interested

Table 20. Determinants of collaboration with competitors (dependent variable: COL_com)

Services	N=175		Manufacturing	N=475	
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-5.39*	-1.84	Constant	-1.19	-1.01
RES	-1.20	-0.25	RES	5.51	0.61
TECH	-1.06	-1.37	TECH	-0.67	-0.78
TRAIN_inv	-1.12	-0.07	TRAIN_inv	63.71**	1.97
RD_inv	2.57**	2.29	RD_inv	2.10	0.86
EMPL	0.09	0.85	EMPL	0.24**	2.21
GROUP	0.47*	1.70	GROUP	0.34**	2.17
EXPORT	0.63	0.91	EXPORT	-0.31	-1.23
REG_com	-1.37	-1.11	REG_com	1.02	1.55
REG_cus	2.00	0.96	REG_cus	-0.49	-1.06
REG_sup	2.50	1.02	REG_sup	-0.60*	-1.67
REG_uni	0.45	0.31	REG_uni	0.11	0.26
SCHUMP	-3.30	-0.48	SCHUMP	0.44	0.67
Log Likelihood	-71.8		Log Likelihood	-217.2	
R^2 for ML	0.12		R^2 for ML	0.03	
% correct	83		% correct	82	
d.f.	165		d.f.	464	

	Predicted				Predicted		
Actual	0	1	Total	Actual	0	1	Total
0	139	3	142	0	385	4	389
1	27	5	32	1	81	5	86
Total	166	8	174	Total	466	9	475

in the effects of the technological regime on the collaboration behavior of firms.

Table 20 presents the estimation results of collaboration with competitors. This dependent variable is binary, and for this reason the method is probit maximum likelihood estimation. Thus we estimate the factors influencing the probability that a firm engages in a collaborative arrangement. Marginal effects are reported in the appendix, because the coefficients obtained with probit cannot be directly interpreted as elasticities. The datasets contain again only firms that engage in some innovation activity, as in the previous section.

Table 21. Determinants of collaboration with customers (dependent variable: COL_cus)

Services			Manufacturing		
Variable	Coeff.	t-stat	Variable	Coeff.	t-stat
Constant	-4.09**	-3.37	Constant	-0.91	-0.89
RES	51.09*	1.88	RES	4.13	0.47
TECH	-0.54	-0.82	TECH	1.48**	2.02
TRAIN_inv	164.33*	1.91	TRAIN_inv	-0.27	-0.01
RD_inv	2.14	1.37	RD_inv	0.58	0.26
EMPL	-0.02	-0.17	EMPL	0.31*	1.87
GROUP	0.45*	1.80	GROUP	0.54**	4.05
EXPORT	0.91	1.33	EXPORT	0.17	0.82
REG_com	-0.38	-0.37	REG_com	-0.12	-0.22
REG_cus	-0.14	-0.15	REG_cus	0.77**	1.99
REG_sup	-0.08	-0.10	REG_sup	-0.73**	-2.46
REG_uni	1.41*	1.69	REG_uni	0.13	0.37
SCHUMP	4.33	0.96	SCHUMP	-0.68	-1.14
Log Likelihood	-92.7		Log Likelihood	-293.0	
R^2 for ML	0.24		R^2 for ML	0.14	
% correct	75		% correct	65	
d.f.	165		d.f.	464	

	Predicted				Predicted		
Actual	0	1	Total	Actual	0	1	Total
0	94	11	105	0	182	63	245
1	33	36	69	1	101	129	230
Total	127	47	174	Total	283	192	475

According to the results, none of the technological regime measures has a significant effect on collaboration with competitors.

For service firms, R&D intensity and membership in a group increase the probability of collaboration. Interestingly in manufacturing, firms that invest more in training are more likely to collaborate with competitors. Also size and group membership increase the collaboration probability. For both sectors the results suggest that this type of collaboration is not particularly competence intensive. Overall, the model does not identify the firms engaging in collaboration with competitors that well. Comparing the predicted and actual outcomes shows that among the 32 service firms and 86 manufacturing firms

Table 22. Determinants of collaboration with suppliers (dependent variable: COL_sup)

Services				Manufacturing			
Variable	Coeff.	t-stat		Variable	Coeff.	t-stat	
Constant	-1.42	-1.25		Constant	1.42	1.40	
RES	2.30	0.59		RES	0.84	0.10	
TECH	0.38	0.66		TECH	0.89	1.25	
TRAIN_inv	22.81	1.36		TRAIN_inv	13.00	0.59	
RD_inv	0.76	0.70		RD_inv	-1.12	-0.51	
EMPL	0.03	0.30		EMPL	0.81**	3.08	
GROUP	0.18	0.78		GROUP	0.30**	2.24	
EXPORT	0.73	1.29		EXPORT	0.24	1.16	
REG_com	0.53	0.55		REG_com	-1.00*	-1.79	
REG_cus	-0.58	-0.65		REG_cus	0.31	0.83	
REG_sup	-0.08	-0.12		REG_sup	-0.30	-1.04	
REG_uni	0.68	0.90		REG_uni	-0.02	-0.05	
SCHUMP	1.16	0.28		SCHUMP	-1.36**	-2.31	
Log Likelihood	-107.05			Log Likelihood	-306.20		
R^2 for ML	0.08			R^2 for ML	0.09		
% correct	69			% correct	63		
d.f.	165			d.f.	464		
	Predicted				Predicted		
Actual	0	1	Total	Actual	0	1	Total
0	103	7	110	0	198	55	253
1	47	17	64	1	119	103	222
Total	150	24	174	Total	317	158	475

that actually collaborated, only 5 firms in each dataset were predicted to do so by the model. Consequently the explanatory powers of the models are very weak. This problem will be alleviated to some degree in the section 4.4 where we control for the endogeneity of R&D.

Estimation of the factors behind collaboration with customers yields more significant results (Table 21). Competencies affect collaboration probabilities positively. In services, research competencies are important whereas in manufacturing collaborating firms tend to have high technical competencies in particular. In the service sector, training investments have a weak effect as well. Business group membership supports customer collaboration in both datasets.

Table 23. Determinants of collaboration with universities (dependent variable: COL_uni)

Services			Manufacturing		
Variable	Coeff.	t-stat	Variable	Coeff.	t-stat
Constant	-7.05**	-1.98	Constant	-2.58**	-2.43
RES	5.64	1.42	RES	20.72**	2.12
TECH	0.73	1.12	TECH	0.68	0.91
TRAIN_inv	-17.04	-0.80	TRAIN_inv	-22.21	-0.83
RD_inv	1.97*	1.67	RD_inv	1.39	0.61
EMPL	0.27	1.46	EMPL	1.08**	3.65
GROUP	0.32	1.13	GROUP	0.50**	3.54
EXPORT	0.46	0.77	EXPORT	0.34	1.58
REG_com	5.40	1.28	REG_com	0.54	0.86
REG_cus	3.61	1.07	REG_cus	0.33	0.80
REG_sup	1.29	0.85	REG_sup	-0.75**	-2.35
REG_uni	0.16	0.10	REG_uni	1.04**	2.76
SCHUMP	-16.82	-1.09	SCHUMP	-0.03	-0.05
Log Likelihood	-72.16		Log Likelihood	-267.3	
R^2 for ML	0.21		R^2 for ML	0.22	
% correct	82		% correct	71	
d.f.	165		d.f.	464	

	Predicted				Predicted		
Actual	0	1	Total	Actual	0	1	Total
0	130	5	135	0	206	51	257
1	27	12	39	1	85	133	218
Total	157	17	174	Total	291	184	475

According to the manufacturing sample results, firms in regimes with high demand for innovation and low supplier-domination are more likely to engage in collaboration with customers. In contrast, service firms in science-intensive regimes where universities are an important source of knowledge are most likely to collaborate.

Next we turn to collaboration with suppliers (Table 22). This type of collaboration is not skill intensive in either sector. None of the explanatory factors used here increase the propensity to collaborate significantly in services. Again, the size of the firm is an important determinant of collaboration for manufacturing firms. Scale of operations is relevant there in relation to most innovation-related activities, while in services these scale effects are rather rarely observed. Membership in a group is again a positive factor of collaboration for manufacturing firms. As regards technological regimes, however, supplier-domination in fact discourages collaboration with suppliers in manufacturing. High spillovers are also a discouraging factor.

Table 24. Determinants of outsourced R&D (dependent variable: OUTRD_inv, Tobit-estimation)

Services	N=175			Manufacturing	N=475	
Variable	Coeff.	t-stat		Variable	Coeff.	t-stat
Constant	-0.11**	-2.98		Constant	-0.005	-0.45
RES	-0.36*	-1.85		RES	-0.17**	-2.10
TECH	-0.004	-0.19		TECH	-0.002	-0.28
RD_inv	0.09**	2.57		RD_inv	0.13**	6.56
COLLAB	0.01	1.37		COLLAB	0.01**	3.24
EMPL	0.001	0.32		EMPL	-0.001	-1.00
GROUP	0.008	1.07		GROUP	0.001	0.95
EXPORT	0.02	0.99		EXPORT	0.004*	1.78
REG_com	0.01	0.42		REG_com	0.002	0.36
REG_cus	0.01	0.90		REG_cus	-0.001	-0.25
REG_con	-0.009	-0.24		REG_con	-0.002	-0.28
REG_sup	0.01	0.93		REG_sup	-0.01*	-1.74
REG_uni	0.03	1.09		REG_uni	0.005	1.21
Sigma	0.04**	12.40		Sigma	0.01**	22.98

Collaboration with universities is not very common among service firms (Table 23). Partly for this reason it is easy to “predict” collaboration (percentage of correct predictions is 94% for the service sample). However, only R&D intensity is a significant explanatory factor, and weakly so. In contrast, manufacturing firms with high research competencies are clearly more likely to collaborate. The effect is very strong, too. Moreover, in line with expectations, larger firms with a group linkage, operating in regimes with high science-content (high REG_uni) and low supplier-domination are more likely to collaborate. These effects are not observed in the service sample.

The last type of external innovation arrangement is contract R&D, that is, R&D sourced through contractual relations rather than joint projects (Table 24). Here we use a measure for the extent of outsourcing: share of outsourced R&D investments in sales revenue. Thus the estimation method is again tobit. However, tobit and probit results for the probability of outsourced R&D were qualitatively very similar.

Internal R&D investments strongly complement externally sourced R&D. Endogeneities related to R&D, however, may bias the results on competencies, for instance. Also, manufacturing firms that collaborate in innovation tend to invest more in contract R&D.

4.3.3 Determinants of innovation output

In this section we compare the factors affecting product innovation outcomes in the two sectors, services and manufacturing. For the manufacturing dataset the dependent variable is derived from the survey question on how much of the firm's sales revenue comes from products introduced within the past three years. If the firm reports positive sales revenue for new products, it is classified as a product innovator. In services the dependent variable is the direct binary survey question about whether the firm has introduced new products to the market or not.

Table 25 presents the estimation results for the two samples. The most interesting result is that training is very strongly correlated with service innovation but not with successful product innovation in manufacturing. However, the relationship cannot be interepreted as that of causality. R&D investments are important for innovation in both sectors, although its marginal effects are stronger for manufacturing (see appendix). The competence variables do not seem to be very important for successful innovation, but this is probably caused by the endogeneities of R&D and training investments suppressing the coefficients of other related variables. Competence variables were found to correlate with R&D training investments in section 4.3.2. The question of endogeneities is discussed in more detail in the following section.

An intriguing result in Table 25 is that the appropriability regime has an opposite impact in the two sectors. In particular, low appropriability supports service innovation. This means that high incoming knowledge spillovers increase the productivity of innovation processes there. Additionally, strong innovation demand supports innovation in both sectors, but supplier domination reduces innovativeness only in manufacturing.

Table 25. Determinants of successful product innovation (dependent variable: INNO, probit estimation)

Services	N=540			Manufacturing	N=1029		
Variable	Coeff.	t-stat		Variable	Coeff.	t-stat	
Constant	-5.15**	-5.83		Constant	-1.29*	-1.72	
RES	3.03	0.71		RES	16.54	1.49	
TECH	0.05	0.11		TECH	1.05*	1.68	
TRAIN_inv	824.14**	5.67		TRAIN_inv	-16.24	-0.68	
RD_inv	4.16**	2.90		RD_inv	18.08**	6.24	
EMPL	0.90**	2.30		EMPL	1.14**	4.64	
GROUP	-0.03	-0.20		GROUP	0.12	1.00	
EXPORT	-0.22	-0.53		EXPORT	0.41**	2.24	
REG_com	1.81**	3.37		REG_com	-0.70	-1.49	
REG_cus	0.76**	2.29		REG_cus	0.49	1.58	
REG_sup	0.39	1.59		REG_sup	-0.44**	-1.99	
REG_uni	0.06	0.18		REG_uni	0.38	1.42	
LPROD	0.00**	-3.41		IMPORT	0.43*	1.89	
Log Likelihood	-227.11			Log Likelihood	-445.46		
R^2 for ML	0.26			R^2 for ML	0.24		
% correct	83			% correct	81		
d.f.	528			d.f.	1017		
	Predicted				Predicted		
Actual	0	1	Total	Actual	0	1	Total
0	386	14	400	0	734	28	762
1	80	60	140	1	170	97	267
Total	466	74	540	Total	904	125	1029

4.4 Joint determination of R&D, training, collaboration, and innovation

4.4.1 Econometric method

Now we attempt to control for the possibility that R&D investment is endogenous. R&D may be affected by the same factors as decisions to engage in collaboration and pursue innovation: capabilities possessed by the firm and environment in which it operates. To take this into account, we allow R&D investment, collaboration, and innovation to be simultaneously determined:

(1)

$$\begin{cases} RD\_inv_i = f(COMPETENCIES_{1,i}, FIRM_{1,i}, REGIME_{1,I}, COMPETITION_{1,I}) \\ COLLAB_i = g(COMPETENCIES_{2,i}, FIRM_{2,i}, REGIME_{2,I}, COMPETITION_{2,I}) \\ INNO_i = h(COMPETENCIES_{3,i}, FIRM_{3,i}, REGIME_{3,I}, COMPETITION_{3,I}) \end{cases}$$

In the equations above, $i = 1,\ldots,N$ refers to the individual firms and I to industries. *RD_inv* is the share of R&D investment in sales revenue, *COMPETENCIES* is a vector of skills and knowledge, *FIRM* is a vector of firm-specific variables, *REGIME* refers to a set of measures for the technological regime, and *COMPETITION* obviously consists of the measures for the competitive environment. The other dependent variables are binary, and they refer to R&D collaboration (*COLLAB*) and service or product or service innovation (*INNO*).

However, since a system with two binary dependent variables and one continuous but censored dependent variable cannot be subjected to a standard estimation procedure, it is modified into a system of three probit equations: RD_dum =1 if RD_inv>0, otherwise RD_dum=0.

(2)

$$\begin{cases} RD\_dum_i = f^*(COMPETENCIES_{1,i}, FIRM_{1,i}, REGIME_{1,I}, COMPETITION_{1,I}) \\ COLLAB_i = g(COMPETENCIES_{2,i}, FIRM_{2,i}, REGIME_{2,I}, COMPETITION_{2,I}) \\ INNO_i = h(COMPETENCIES_{3,i}, FIRM_{3,i}, REGIME_{3,I}, COMPETITION_{3,I}) \end{cases}$$

This approach enables us to account for the simultaneities and perform estimation with a standard procedure. Other approaches inlude the kind of two-stage methods suggested by Maddala (1983). However, this possibility is not pursued here due to the complexities involved in deriving the covariance matrix.

The estimation method is thus trivariate probit, where the decisions to engage in R&D, to collaborate in R&D with other organizations, and to introduce new products are simultaneously estimated. Collaboration data is binary but has several "dimensions": did the firm collaborate with rivals, customers, or suppliers etc., or not. The choices are of course not mutually exclusive. In the last section we also explore the joint determination of R&D, training, and innovation. Ideally, one would estimate the simultaneous determination of all types of collaboration and innovation-related investments, but due to lack of reasonable methods we settle for the trivariate approach.

4.4.2 Estimation results

Table 26 shows the results for collaboration with competitors as the dependent variable in the second equation. The first equation has a dummy variable for investing in R&D as the dependent variable. No strikingly different results are obtained compared to those for the tobit-estimation of R&D intensity carried out in section 4.3.1, except for the regime variables. For both samples, competence measures affect positively the probability of investing in R&D. Size and group membership remain important factors within manufacturing. Now due to difficulties of identification, the regime variables are replaced by industry dummies for telecommunications, IT services, and technical services in the first equation for the service sector. There is apparently not enough variation in the dataset to identify a three-dimensional system because of the small number of industries and large number of non-investing firms.

As regards the determinants of collaboration with *competitors*, firm size in manufacturing and group membership in both sectors are the only significant factors, now that we control for the endogeneity of R&D. Product innovation, instead, is now positively associated with internal research and technical competencies. Competencies thus influence both the likelihood of investing in R&D and the probability of succeeding in innovation.

Residual correlation coefficients between the three equations suggest that the dependent variables are indeed closely associated with one another. This justifies the assumption that the dependent variables are drawn from the "same" multivariate distribution.

The results for collaboration with *customers* as the second dependent variable are displayed in Table 27. The R&D and innovation equations remain the same, and their results change only marginally for the rest of the analysis. Hence from now on we focus on the determinants of collaboration. In manufacturing, customer collaboration is associated with both competencies, particularly technical. With the system of equations approach, R&D investment does not any more affect collaboration significantly, although the high residual correlations suggest a close association between R&D investment and innovation collaboration. In the case of services, research competencies strongly increase the probability of collaboration with customers.

Table 26. Collaboration with competitors (N=1029), 3-variate probit system

Services	N=540						Manufacturing	N=1029					
Dependent variable	RD_dum	t-stat	COL_ com	t-stat	INNO	t-stat	Dependent variable	RD_dum	t-stat	COL_ com	t-stat	INNO	t-stat
Constant	-1.59**	-11.99	-9.25**	-2.54	-6.14**	-5.87	Constant	-0.88	-1.33	-1.77*	-1.77	-1.48**	-2.07
RESEARCH	10.92	0.85	3.80	0.73	8.00**	2.20	RESEARCH	18.98*	1.84	9.99	1.21	22.09**	2.14
TECHNIC	1.49**	3.32	-0.21	-0.26	0.74	1.64	TECHNIC	2.00**	3.74	0.01	0.01	2.06**	3.61
RD_inv			1.90	1.39	-0.49	-0.46	RD_inv			2.42	1.25	2.77*	1.70
EMPL	0.82	1.14	0.15	0.83	0.72	0.96	EMPL	1.38**	9.76	0.29**	4.09	1.13**	5.03
GROUP	-0.002	-0.01	0.63*	1.74			GROUP	0.16**	5.53	0.38**	2.52		
EXPORT			0.59	0.73	0.21	0.34	EXPORT	0.94**	-2.39	0.33	1.15	0.64**	3.40
Telecom	1.58**	4.35											
Computer	1.18**	4.80											
Technical	0.41	1.35											
REG_com			-2.04	-1.45	1.43**	2.16	REG_com	-0.98**	2.27	0.38	0.60	-0.75*	-1.74
REG_cus			1.68	0.66	1.64**	4.65	REG_cus	0.60**	-2.87	-0.26	-0.57	0.55*	1.71
REG_sup			2.18	0.69	0.45	1.32	REG_sup	-0.63**	3.18	-0.57	-1.65	-0.45*	-1.88
REG_uni			0.99	0.61	-0.28	-0.91	REG_uni	0.81*	1.82	0.31	0.74	0.53*	1.85
SCHUMP			3.17	0.37			SCHUMP			0.61	1.09		
LPROD					-0.0004**	-4.30	IMPORT					0.51**	2.68
Correlation coefficients							Correlation coefficients						
R(01,02)	0.60**	2.80					R(01,02)	0.66**	8.56				
R(01,03)	0.89**	26.30					R(01,03)	0.82**	24.73				
R(02,03)	0.69**	3.82					R(02,03)	0.53**	6.55				
Log L.	-413.5						Log L.	-964.23					

Note: ** indicates 95% level significance, * indicates 90% level.

Technical competencies remain significant for collaborating with *suppliers* for both datasets (Table 28). Interestingly, in the service sample supplier collaboration is also strongly associated with high research competencies. Collaboration with suppliers is thus a relatively more research competence-intensive activity within services than manufacturing. Also, firms in science-intensive service regimes are more likely to collaborate, and firms in regimes with high innovative entry (variable SCHUMP). In manufacturing, high spillovers appear to hamper supplier collaboration.

Collaboration with *universities* is now associated with high internal research competencies, although only weakly in service industries (Table 29). Manufacturing firms in supplier dominated manufacturing industries are clearly not likely to collaborate with universities, but, quite intuitively, those in science-intensive regimes are. In contrast, technological regime variables do not explain the service firms' choice of collaborating with universities. This type of collaboration is rather unusual among service firms, and it is not as closely associated with R&D and product innovation, reflected in the lower residual correlation coefficients for the equations 1 and 2 (58%) and equations 2 and 3 (54%). In the manufacturing sample, these correlation coefficients are 78% and 72%, respectively.

The final type of external R&D arrangement is contract R&D. The difference in the results in Table 30 compared to the single equation tobit estimations earlier is that R&D outsourcing is now strongly associated with research competencies in manufacturing and technical competencies in services. The endogeneity of R&D no longer suppresses the competence coefficients. Outsourcing is also most common in highly science-intensive regimes. These results suggest that R&D outsourcing is a high competence strategy employed especially by firms in high innovation opportunity regimes.

The last multivariate model examines the simultaneous determination of R&D, training and product innovation (Table 31). The idea of training investments *causing* product innovation is somewhat problematic in respect of the current datasets, because the training question in the survey inquires about investments into innovation-related training. Thus firms may report both training leading to innovation and training following innovation. However,

Table 27. Collaboration with customers, 3-variate probit, weighted

Services	N=540					
Dependent variable	RD_dum	t-stat	COL_cus	t-stat	INNO	t-stat
Constant	-1.59**	-12.15	-6.83**	-5.51	-5.91**	-5.69
RESEARCH	11.06	1.01	30.10**	2.33	6.13**	2.62
TECHNIC	1.56**	3.51	0.54	0.83	0.77*	1.70
RD_inv			0.51	0.31	-0.37	-0.35
EMPL	0.78	1.18	0.12	0.49	0.67	1.02
GROUP	-0.01	-0.08	0.33*	1.78		
EXPORT			1.02*	1.80	0.24	0.42
Telecom	1.61**	4.46				
Computer	1.16**	4.73				
Technical	0.37	1.25				
REG_com			-1.57**	-1.99	1.50**	2.26
REG_cus			-0.89	-1.02	1.55**	4.35
REG_sup			-1.20	-1.35	0.39	1.15
REG_uni			2.50**	3.49	-0.35	-1.08
SCHUMP			12.78**	3.24		
LPROD					-0.0004**	-4.28
Correlation coefficients						
R(01,02)	0.73**	7.59				
R(01,03)	0.88**	24.38				
R(02,03)	0.88**	14.34				
Log L.	-437.8					

Manufacturing	N=1029					
Dependent variable	RD_dum	t-stat	COL_cus	t-stat	INNO	t-stat
Constant	-0.79	-1.22	-1.93**	-2.37	-1.42**	-2.01
RESEARCH	20.00**	2.08	16.82*	1.82	24.32**	2.16
TECHNIC	2.04**	3.81	2.18**	3.69	2.05**	3.52
RD_inv			-0.46	-0.25	2.87*	1.78
EMPL	1.27**	8.34	0.64**	6.04	1.06**	5.15
GROUP	0.17*	1.93	0.43**	3.85		
EXPORT	0.99**	5.84	0.78**	4.04	0.66**	3.56
REG_com	-1.03**	-2.48	-0.54	-1.14	-0.83*	-1.87
REG_cus	0.61**	2.32	0.72**	2.03	0.60*	1.90
REG_sup	-0.62**	-2.87	-0.60**	-2.35	-0.46*	-1.88
REG_uni	0.76**	3.00	0.34	1.17	0.48*	1.69
SCHUMP			0.09	0.18		
IMPORT					0.50**	2.63
Correlation coefficients						
R(01,02)	0.74**	15.79				
R(01,03)	0.82**	24.17				
R(02,03)	0.69**	14.42				
Log L.	-1064.06					

Table 28. Collaboration with suppliers, 3-variate probits, weighted

Services	N=540						Manufacturing	N=1029					
Dependent variable	RD_dum	t-stat	COL_sup	t-stat	INNO	t-stat	Dependent variable	RD_dum	t-stat	COL_sup	t-stat	INNO	t-stat
Constant	-1.59**	-13.76	-5.02**	-4.02	-6.00**	-5.85	Constant	-0.90	-1.38	-0.37	-0.46	-1.45**	-2.02
RESEARCH	11.92	0.98	10.49**	2.27	7.98**	2.33	RESEARCH	19.09*	1.78	10.80	1.34	20.48	1.63
TECHNIC	1.46**	3.04	1.32**	2.71	0.75*	1.72	TECHNIC	1.89**	3.44	1.74**	2.93	2.02**	3.53
RD_inv			-0.48	-0.37	-0.56	-0.52	RD_inv			-2.31	-1.26	2.69	1.61
EMPL	0.73	1.01	0.15	0.85	0.64	0.95	EMPL	1.46**	9.64	1.12**	4.77	1.26**	5.90
GROUP			0.31*	1.72			GROUP	0.15*	1.74	0.33**	2.95		
EXPORT			0.56	1.11	0.14	0.24	EXPORT	0.95**	5.61	0.76**	3.89	0.65**	3.44
Telecom	1.60**	4.46					Telecom						
Computer	1.19**	4.86					Computer						
Technical	0.42	1.35					Technical						
REG_com			-0.16	-0.19	1.42**	2.19	REG_com	-0.98**	-2.35	-1.13**	-2.62	-0.80*	-1.76
REG_cus			-1.19	-1.49	1.61**	4.60	REG_cus	0.63**	2.40	0.42	1.33	0.59*	1.80
REG_sup			-0.93	-1.17	0.42	1.27	REG_sup	-0.63**	-2.99	-0.35	-1.46	-0.49**	-2.02
REG_uni			1.55**	2.45	-0.29	-0.95	REG_uni	0.79**	3.08	0.28	0.92	0.51*	1.75
SCHUMP			8.72**	2.26			SCHUMP			-0.39	-0.82		
LPROD					-0.0004**	-4.51	IMPORT					0.52**	2.73
Correlation coefficients							Correlation coefficients						
R(01,02)	0.62**	6.30					R(01,02)	0.77**	18.87				
R(01,03)	0.89**	26.37					R(01,03)	0.81**	24.29				
R(02,03)	0.80**	11.68					R(02,03)	0.60**	11.50				
Log L.	-457.7						Log L.	-1078.73					

Table 29. Collaboration with universities, 3-variate probits, weighted

Services	N=540						Manufacturing	N=1029					
Dependent variable	RD_dum	t-stat	COL_uni	t-stat	INNO	t-stat	Dependent variable	RD_dum	t-stat	COL_uni	t-stat	INNO	t-stat
Constant	-1.58**	-12.07	-8.09*	-1.76	-6.19**	-5.86	Constant	-0.84	-1.29	-3.11**	-3.35	-1.30*	-1.84
RESEARCH	10.66	0.91	6.09*	1.72	6.40*	1.79	RESEARCH	21.53**	2.05	30.03**	2.14	21.70	1.10
TECHNIC	1.53**	3.44	0.98	1.37	0.80*	1.78	TECHNIC	1.93**	3.56	1.68**	2.82	1.91**	3.35
RD_inv			1.55	0.92	-0.39	-0.27	RD_inv			-1.61	-0.75	3.17**	1.97
EMPL	0.78	1.04	0.32	1.02	0.64	0.90	EMPL	1.45**	9.10	1.29**	5.36	1.23**	5.89
GROUP	-0.02	-0.13	0.18	0.66			GROUP	0.16*	1.85	0.40**	3.61		
EXPORT			0.33	0.50	0.24	0.41	EXPORT	0.98**	5.74	0.88**	4.68	0.64**	3.38
Telecom	1.59**	4.43					Telecom						
Computer	1.16**	4.76					Computer						
Technical	0.38	1.23					Technical						
REG_com			3.56	0.60	1.52**	2.26	REG_com	-1.03**	-2.47	0.01	0.01	-0.80*	-1.88
REG_cus			2.32	0.51	1.61**	4.47	REG_cus	0.64**	2.41	0.33	0.87	0.54*	1.71
REG_sup			0.54	0.26	0.47	1.38	REG_sup	-0.64**	-2.96	-0.72**	-2.49	-0.49**	-2.03
REG_uni			0.57	0.30	-0.35	-1.15	REG_uni	0.78**	3.04	1.13**	3.24	0.48*	1.70
SCHUMP			-7.42	-0.35			SCHUMP			0.68	1.25		
LPROD					-0.0004**	-4.30	IMPORT					0.54**	2.84
Correlation coefficients							Correlation coefficients						
R(01,02)	0.50**	3.05					R(01,02)	0.80**	17.58				
R(01,03)	0.89**	24.75					R(01,03)	0.81**	23.20				
R(02,03)	0.63**	4.40					R(02,03)	0.71**	13.21				
Log L.	-426.0						Log L.	-1009.10					

Table 30. R&D outsourcing, 3-variate probits, weighted

Services	N=540						Manufacturing	N=1029					
Dependent variable	RD_dum	t-stat	OUTRD_dum	t-stat	INNO	t-stat	Dependent variable	RD_dum	t-stat	OUTRD_dum	t-stat	INNO	t-stat
Constant	-1.60**	-11.20	-6.14**	-5.28	-5.93**	-5.69	Constant	-0.83	-1.30	-1.68**	-2.25	-1.36*	-1.91
RESEARCH	10.57	0.83	-1.53	-0.27	7.43**	2.35	RESEARCH	12.77	1.40	13.82**	2.05	17.47*	1.74
TECHNIC	1.48**	3.19	1.06**	2.28	0.74	1.65	TECHNIC	1.82**	3.40	0.87	1.53	2.02**	3.40
RD_inv			-1.31	-1.39	-0.72	-0.62	RD_inv			0.19	0.13	2.77	1.63
EMPL	1.19**	2.07	0.33	0.49	1.01	1.51	EMPL	1.02**	5.76	0.23**	4.98	0.86**	4.18
GROUP	-0.05	-0.34	0.07	0.41			GROUP	0.19**	2.19	0.30**	3.16		
EXPORT	0.28	0.35	0.27	0.48	0.38	0.62	EXPORT	0.99**	5.86	0.96**	5.70	0.65**	3.45
Telecom	1.41**	3.99					Telecom						
Computer	1.17**	4.81					Computer						
Technical	0.33	1.01					Technical						
REG_com			0.41	0.53	1.31**	1.99	REG_com	-1.01**	-2.45	-0.15	-0.33	-0.78*	-1.80
REG_cus			-0.29	-0.38	1.63**	4.50	REG_cus	0.61**	2.30	0.22	0.80	0.52*	1.69
REG_sup			-0.34	-0.51	0.50	1.43	REG_sup	-0.64**	-2.94	-0.49**	-2.32	-0.47**	-1.99
REG_uni			1.56**	2.71	-0.43	-1.40	REG_uni	0.83**	3.25	0.66**	2.52	0.55*	1.95
SCHUMP			5.87*	1.73			SCHUMP			0.35	1.09		
LPROD					-0.0004**	-4.42	IMPORT					0.53**	2.80
Correlation coefficients							Correlation coefficients						
R(01,02)	0.91**	27.73					R(01,02)	0.91**	47.83				
R(01,03)	0.89**	24.38					R(01,03)	0.81**	24.60				
R(02,03)	0.77**	11.83					R(02,03)	0.73**	18.35				
Log L.	-459.0						Log L.	-1063.27					

there is evidence from the interviews discussed in the next chapter that knowledge-intensive service firms use in-house training as a forum for improving existing products and developing new product ideas. In any case, both the qualitative interview evidence and the statistical data here suggest that the knowledge-creating role of training in services should be further researched.

With the multivariate approach we are able to control to some extent for the endogeneity of training investments. Comparing the results in Table 31 with those in Table 16 on the determinants of training investments, we find that the connection between training and research competencies loses some significance in services. Nevertheless, service firms in science-intensive regimes are more likely to invest in training. Training may be one way to internalize scientific knowledge from the environment. Manufacturing firms with high technical competencies are now more likely to invest in training. However, the coefficients of training intensity in the innovation equations are not significant. Higher levels of training do not seem to increase the chances of successful innovation, even if training tends to be observed together with innovation, as indicated by the high residual correlations.

Here we obtain another interesting result concerning R&D investments. Now the regime variables are used in the first equation also for the service dataset, and supplier-domination is found to be positively associated with the probability of R&D. In manufacturing, R&D likelihood is significantly reduced by supplier-domination. This again highlights the different roles suppliers play in the two sectors.

Overall, the multivariate results differ slightly from the single equation probit results reported earlier. The main difference is that the coefficients on competence measures are larger and more significant in explaining the probability of collaboration and innovation, when the endogeneity of being an R&D firm is taken into account. Competencies appear to support both firms' decision to invest in R&D and their capability to make successful innovations. They are also significant factors in most forms of collaborative innovation. The multivariate model works reasonably well in explaining how the three innovation-related activities are jointly determined. High correlations between the three equations in all specifications indicate that it is warranted to assume a joint distribution for the dependent variables and that it makes sense to estimate their determination simultaneously.

Table 31. R&D, training, and innovation, 3-variate probits, weighted

Services	N=540						Manufacturing N=1029						
Dependent variable	RD_dum	t-stat	TRAIN_dum	t-stat	INNO	t-stat	Dependent variable	RD_dum	t-stat	TRAIN_dum	t-stat	INNO	t-stat
Constant	-5.80**	-5.89	-3.17**	-2.85	-1.32**	-7.03	Constant	-0.76	-1.15	-0.98	-1.24	-1.29*	-1.80
RESEARCH	11.12	0.87	5.42*	1.75	7.25**	2.11	RESEARCH	22.19**	2.38	15.79	1.52	24.35**	2.36
TECHNIC	1.29**	2.99	0.54	1.21	0.58	1.02	TECHNIC	1.87**	3.53	1.23**	1.98	1.85**	3.10
RD_inv					-0.15	-0.14	RD_inv					3.99**	2.23
TRAIN_inv					67.39	0.38	TRAIN_inv					-38.00	-1.36
EMPL	1.04	1.32	0.84	1.36	0.75	1.04	EMPL	1.14**	6.82	0.27**	5.33	1.02**	4.84
GROUP	-0.10	-0.67	-0.07	-0.44				0.17*	1.95	0.20*	1.91		
EXPORT	0.35	0.49	0.69	1.60	0.24	0.35	EXPORT	1.00**	6.05	0.85**	4.44	0.67**	3.60
Telecom					1.54**	4.33	Telecom						
Computer					1.23**	4.43	Infotech						
Technical					0.27	0.72	Technical						
REG_com	0.16	0.30	-0.20	-0.35			REG_com	-0.91**	-2.19	-1.00**	-2.48	-0.73	-1.58
REG_cus	1.22**	3.51	0.31	0.77			REG_cus	0.56**	2.13	0.42	1.46	0.53	1.65
REG_sup	0.69**	2.38	0.50	1.31			REG_sup	-0.68**	-3.13	-0.09	-0.35	-0.49**	-2.03
REG_uni	0.93**	2.82	0.83**	2.27			REG_uni	0.77**	2.98	0.12	0.41	0.44	1.56
LPROD					0.0001	1.19	IMPORT					0.46**	2.49
Correlation coefficients							Correlation coefficients						
R(01,02)	0.78**	11.89					R(01,02)	0.87**	25.74				
R(01,03)	0.87**	22.36					R(01,03)	0.81**	24.57				
R(02,03)	0.79**	10.47					R(02,03)	0.70**	14.28				
Log L.	-473.68						Log L.	-1032.37					

4.5 Discussion and conclusion

This chapter examines the factors behind various innovation-related investments, R&D collaboration, and product innovation. To summarize the results, in both services and manufacturing, investments in R&D are increasing in research and technical competencies, and contract R&D. Investments in the marketing of new products are higher in firms with high research competencies. A research-intensive strategy may need to be complemented by considerable marketing efforts. Collaborative innovation creates incentives to invest in training in order to internalize and diffuse the results.

Collaborative R&D itself is an important activity for adopting new knowledge, and it is closely associated with internal R&D investments and product innovation. Collaborative arrangements with competitors are found to be determined differently from those with customers, suppliers and universities. Neither competencies nor technological regimes are significant explanatory factors for collaboration with competitors in the multivariate estimation approach. In contrast, collaborative arrangements with customers and suppliers are associated with high research and technical competencies. In particular, to be able to collaborate with universities it is important to have high internal research competencies.

The results thus suggest that skills and competencies are important covariates in the firms' "systems of innovation" as defined by the various innovation activities (R&D, collaboration, outsourcing). This finding highlights the important role of absorptive capacity. Without internal capabilities the firm is not likely to be an attractive partner in collaborative arrangements or to benefit fully from externally sourced knowledge. Estimation results here support the interpretation that high internal skills and competencies, in addition to internal R&D, help build absorptive capacity and enhance firms' ability to engage in collaborative arrangements. Naturally, competencies and internal R&D have very important roles in innovation itself.

It is important to distinguish patterns of collaboration among different kinds of partners. First, this chapter demonstrates that competence requirements vary somewhat with the type of collaboration: research competencies are identified as much more important for university collaboration than for the other types of collaboration, particularly in the manufacturing sector. Supplier collaboration instead is most strongly associated with both types of competencies in the service sector. Second, collaboration with competitor firms is not so prevalent as the extant literature on research joint ventures between rivals would seem to imply. From a market structure or competition point of view, it is highly relevant to study the implications of and reasons for cooperation among rivals. However, to understand innovation, technological change, and the evolution of firms and industries, it is equally important that we assess the knowledge transactions firms carry out with differently positioned actors in production systems.

Product innovation correlates strongly with research competencies, but technical competencies are consistently associated with innovation only in the manufacturing sample. R&D investments, firm size, and export intensity are also significantly associated with innovation in manufacturing firms only. In general, firm size and group membership do not play much of a role in services. Scale of operations is a less important determinant of innovation activity and performance in that sector.

The analysis accounted for industry differences by using a set of proxies for the technological environment to understand how industries and sectors differ. According to the results, a technological regime with high demand for innovation increases investments in innovation activities and innovation output in both sectors. Appropriability of innovation returns generates interesting results: low appropriability decreases the probability of innovation in manufacturing industries and increases it in services. In other words, knowledge spillovers support service innovation and hamper manufacturing innovation. The underlying reasons are unclear, however. It is possible that spillovers enhance the productivity of innovation activities more in service firms. Finally, suppliers are found to play different roles in innovation in the two sectors. In the service sector, high supplier-domination is associated with high likelihood of R&D, while it reduces the likelihood of R&D for manufacturing firms. Moreover, research and technical competencies are strongly correlated with supplier collaboration in services. Relying on suppliers for technology and knowledge inputs requires thus high internal competencies in services, but in manufacturing this strategy can be characterized as relatively low-competence.

It seems that using and further developing measures for technological regimes is a worthwhile endeavor. Current measures capture significant industry differences, so we are able to see *how* industries differ in addition to controlling for these differences in empirical analyses. Understanding industry-specificities is highly relevant from the perspective of policy analysis. For instance, technological regimes may have a bearing on the issues of antitrust and intellectual property rights. If patterns of cooperation in knowledge creation among firms depend on the technological environment, competition policies concerned with collusive behavior need to take this into account – cooperation may be beneficial in some environments, in others it may be an indication of collusion. Relatedly, firms' willingness to collaborate and thus the rate and nature of innovation may depend on intellectual property rights legislation and enforcement. Fruitful cooperation may be hindered by excessive spillover hazards. Finally, technology policy emphasizing participation in collaborative innovation arrangements may be inefficient in high spillover regimes, because firms are reluctant to engage with full effort in collaboration under the hazard of knowledge leakage.

The simultaneous equations approach is useful in controlling for some of the endogeneities related to innovation strategies. Innovation research using survey datasets would benefit from new econometric methods to utilize multivariate or instrumental variable techniques for limited-dependent variable models.

The research approach here may not be as suitable for the heterogeneous service sample as it is for the manufacturing sample, but it represents a way to begin the analysis of service innovation within a more explicit and formal framework. Service innovation is not necessarily such a "peculiar" phenomenon as has been argued in the extant literature. More work needs to be done to improve the measurement of innovation activities and regimes in services.

4.6 Appendix

Table A1. Marginal effects for collaboration with competitors (dependent variable: COL_com)

Services	N=540		Manufacturing		N=1029
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-1.20**	-2.19	Constant	-0.26	-1.02
RES	-0.27	-0.25	RES	1.22	0.61
TECH	-0.24	-1.29	TECH	-0.15	-0.78
TRAININV	-0.25	-0.07	TRAININV	14.06*	1.94
RD_INV	0.57**	2.17	RD_INV	0.46	0.86
EMPL	0.02	0.84	EMPL	0.05**	2.20
GROUP	0.11*	1.70	GROUP	0.08**	2.19
EXPORT	0.14	0.91	EXPORT	-0.07	-1.23
REGCOM	-0.31	-1.16	REGCOM	0.22	1.56
REGCUS	0.45	1.03	REGCUS	-0.11	-1.06
REGSUP	0.56	1.12	REGSUP	-0.13	-1.68
REGUNI	0.10	0.31	REGUNI	0.02	0.26
SCHUMP	-0.74	-0.50	SCHUMP	0.10	0.67

Table A2. Marginal effects for collaboration with customers (dependent variable: COL_cus)

Services			Manufacturing		
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-1.63**	-3.36	Constant	-0.35	-0.89
RES	20.32*	1.92	RES	1.59	0.47
TECH	-0.21	-0.82	TECH	0.57**	2.02
TRAININV	65.37*	1.94	TRAININV	-0.11	-0.01
RD_INV	0.85	1.38	RD_INV	0.22	0.26
EMPL	-0.01	-0.17	EMPL	0.12*	1.87
GROUP	0.18*	1.80	GROUP	0.21**	4.05
EXPORT	0.36	1.33	EXPORT	0.07	0.82
REGCOM	-0.15	-0.37	REGCOM	-0.05	-0.22
REGCUS	-0.06	-0.15	REGCUS	0.30**	2.00
REGSUP	-0.03	-0.10	REGSUP	-0.28**	-2.46
REGUNI	0.56*	1.68	REGUNI	0.05	0.37
SCHUMP	1.72	0.96	SCHUMP	-0.26	-1.14

Table A3. Marginal effects for collaboration with suppliers (dependent variable: COL_sup)

Services			Manufacturing		
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-0.53	-1.26	Constant	0.55	1.40
RES	0.86	0.59	RES	0.32	0.10
TECH	0.14	0.66	TECH	0.34	1.25
TRAININV	8.56	1.36	TRAININV	5.02	0.59
RD_INV	0.28	0.70	RD_INV	-0.43	-0.51
EMPL	0.01	0.30	EMPL	0.31**	3.05
GROUP	0.07	0.78	GROUP	0.12**	2.24
EXPORT	0.27	1.29	EXPORT	0.09	1.16
REGCOM	0.20	0.55	REGCOM	-0.39*	-1.79
REGCUS	-0.22	-0.65	REGCUS	0.12	0.83
REGSUP	-0.03	-0.12	REGSUP	-0.12	-1.04
REGUNI	0.25	0.90	REGUNI	-0.01	-0.05
SCHUMP	0.43	0.28	SCHUMP	-0.53**	-2.32

Table A4. Marginal effects for collaboration with universities (dependent variable: COL_uni)

Services			Manufacturing		
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-1.47**	-3.39	Constant	-0.96**	-2.44
RES	1.17	1.30	RES	7.69**	2.11
TECH	0.15	1.18	TECH	0.25	0.91
TRAININV	-3.55	-0.79	TRAININV	-8.25	-0.83
RD_INV	0.41	1.48	RD_INV	0.52	0.61
EMPL	0.06*	1.78	EMPL	0.40**	3.56
GROUP	0.07	1.04	GROUP	0.19**	3.57
EXPORT	0.10	0.77	EXPORT	0.13	1.58
REGCOM	1.13*	1.81	REGCOM	0.20	0.86
REGCUS	0.75	1.41	REGCUS	0.12	0.80
REGSUP	0.27	1.01	REGSUP	-0.28**	-2.36
REGUNI	0.03	0.10	REGUNI	0.39**	2.77
SCHUMP	-3.50	-1.45	SCHUMP	-0.01	-0.05

Table A5. Marginal effects for product innovation (dependent variable: INNO)

Services			Manufacturing		
Variable	Coefficient	t-stat	Variable	Coefficient	t-stat
Constant	-1.88*	-5.69	Constant	-0.32*	-1.73
RES	1.11	0.71	RES	4.13	1.48
TECH	0.02	0.11	TECH	0.26*	1.67
TRAININV	301.19**	4.99	TRAININV	-4.06	-0.68
RD_INV	1.52**	2.85	RD_INV	4.51**	5.92
EMPL	0.33**	2.27	EMPL	0.28**	4.51
GROUP	-0.01	-0.20	GROUP	0.03	1.00
EXPORT	-0.08	-0.53	EXPORT	0.10**	2.24
REGCOM	0.66**	3.33	REGCOM	-0.17	-1.49
REGCUS	0.28**	2.28	REGCUS	0.12	1.58
REGSUP	0.14	1.58	REGSUP	-0.11**	-2.00
REGUNI	0.02	0.18	REGUNI	0.09	1.42
LPROD	-0.0001**	-3.41	IMPORT	0.11*	1.89

5 Business services as innovation catalysts: organization of knowledge creation in Finnish business service firms

5.1 Introduction

This chapter examines more qualitatively some research questions raised in this study, particularly those concerning knowledge-intensive business services (KIBS), in the light of extant theories of innovation and the firm. KIBS have recently been studied by several European scholars (Hauknes, 1998, Miles *et al.*, 1995 and 1999, Antonelli, 1998b). However, certain interesting issues have not yet been addressed including the nature of learning processes within KIBS firms, their incentive structures, and the role of KIBS firms in the larger innovation system.

Underlying the case studies is the "integrated model of innovation" (cf. Kline and Rosenberg, 1986, Rothwell, 1994), according to which the interactions between sources of competence within the firm and between the firm and its environment are critical in the creation and utilization of knowledge. The relative importance of different sources varies by industry, but customers, equipment suppliers, and competitors are likely to be important external knowledge bases in which most firms need to tap. Internally, R&D department, manufacturing or production process, and marketing are some essential basic units of competence. Integration of these knowledge bases is possible through collaboration and open knowledge exchange, but it requires that participants be motivated to collaborate, the organizational setting support cooperation and communication, and that means to protect intellectual property exist when collaborating with external partners. These are the main focus of this chapter. Additionally, some strategic issues related to growth and knowledge creation of service firms are explored.

The discussion here builds on in-depth interviews with three Finnish business service firms. These firms are engaged in management consulting, process engineering, and industrial design. To maintain confidentiality, they will not be identified by name. Semi-structured interviews with top managers were carried out, focusing on knowledge and innovation strategies of the companies, with an eye toward identification of commonalities in their experience.

The choice of industries in these case studies reflects interest in KIBS as disseminators of knowledge and facilitators of three kinds of innovation. Management consulting promotes *organizational change*. Industrial design firms support clients' *product innovation* processes. Process engineering services facilitate technology adoption and *process innovation*. Thus, these three industries are interesting examples of interaction between service and manufacturing firms as related to the three classic forms of innovation.

The three KIBS industries can be described as providers of consulting services in that they are all in the business of transferring knowledge. In most cases this knowledge has a considerable tacit component, and the success of transfer depends on the interaction capabilities of the consultant and the client organization. For instance, it is usually not possible to sell, deliver, or apply a new organizational design in a codified form. Organizational tools such as "knowledge management" or "self-managing teams" can be outlined in a management bestseller, but to implement them effectively requires that the firm learn and fine-tune internally. Consultants can usefully support such adaptive processes. This leads to a high degree of customization of consulting services. The consultant needs broad professional skills and a diverse "toolkit" to be able to adapt his or her knowledge to the particular needs, capabilities, and organizational configuration of the customer. On the other hand, we do observe one-size-fits-all type consulting services in those settings where the problem is standardized. Even then, however, the consultant must participate in the client's learning process because of the organizational (systemic) nature of this process. A change in one element of the firm requires a broader adaptive effort.

In the following sections seven research issues related to innovation in KIBS firms are discussed. Perceptions of respondents will be evaluated in relation to the current literature.

5.2 Specialization vs. flexibility

How do service firms grow?

Growth of firms is not well understood in general. In particular, what determines the size of service firms is a challenging question.

The largest industrial design firm in the Nordic countries employs less than 30 people. In contrast, global strategic management consulting firms employ thousands of people. What accounts for this difference?

According to one argument, growth is related to the "minimum efficient scale" of operations, i.e. the technological dimension determines the size of production units. Other modes of explanation such as the transaction cost theory focus on the determination of firm boundaries (Williamson, 1985, 1996). In that framework, transaction costs define which operations are carried out internally and which are carried out externally. Penrose (1959) suggested a knowledge-based explanation: growth of firms depends on the generation of "excess" resources, such as managerial capacity, that can be more efficiently exploited within the firm than by selling the resources to outsiders. This is in fact a combination of the technological and transaction arguments. Excess capacity characterized by high transaction costs, for example a knowledge resource, is more efficiently utilized internally. These ideas are variants of the argument that firm growth is based on increasing returns to scale, rendering larger firms more efficient. One classic way to achieve returns to scale is to increase the degree of standardization of the service to promote lower cost delivery or higher quality. However, part of the reason for growth of firms being hard to explain by economic theories is that it depends on strategic choice. Some firms choose to remain small, and some attempt to grow rapidly for instance by diversification, even at the expense of profitability. The choice depends to a large degree on individuals' risk preferences and time horizons.

Managers of the three KIBS firms interviewed expressed interest in introducing a finer division of tasks. Such specialization could be achieved by the growth of the service firm, as growth makes it more profitable to employ specialists. Consulting service providers usually need to work with people from very diverse backgrounds and across functional boundaries. This requires a high capacity to communicate with a variety of people and to understand the conceptual frameworks and the relevant problems of organizational subgroups. However, the understanding developed by consultants is often superficial. As one of the respondents said, the consultant needs to be bold enough to draw conclusions on rather limited and impressionistic knowledge of the situation.

Managers emphasized that in addition to the client's value chain, its organizational setup and culture must be addressed in designing the service. This creates a need for diverse competencies within the consulting service provider. For instance, industrial designers are usually educated in design institutes, but in the workplace, artistic vision needs to be complemented by skills in psychology, business strategy, industrial economics, even philosophy. Internal specialization of the employees of service firms would enable the construction of consulting teams matched with the customers' knowledge needs. However, more extensive division of work may reduce firms' flexibility as jobs become more rigidly defined and special education and skills are required. Thus there is a tradeoff between the breadth and depth of consulting knowledge. The "optimal" choices of both the ideal competencies of an employee and aggregate competencies of the firm's workforce are likely to depend to a great extent on the (in)stability of the environment in which their customers compete (see Aoki, 1986, Aoki, 1990). The faster and more radical the changes, the less useful it is to build rigid knowledge structures.

5.3 Incentives governing client-consultant interaction

What are the implications of performance-based compensation schemes and under what conditions are these useful?

The literature on asymmetric information (see Holmström, 1979 for an early contribution) suggests that agency costs are likely to arise in a situation where the agent possesses more information about the job to be carried out and his own effort than the principal. In the case of KIBS service provision, the agent is the KIBS firm and the principal is the client firm. Agency costs can in theory be mitigated by using contracts that link compensation to performance.

KIBS respondents were aware of this issue, but most commonly project compensation is based on hours worked rather than more complex profit sharing schemes. Partly this seemed to depend on clients getting used to a new type of a contract: clients are often unfamiliar with incentive-based payments and therefore prefer to avoid the associated uncertainty as service budgets are fixed. Clearly there are instances where project outcomes could be productively coupled with the compensation of service providers. For example, if an organizational change facilitated by a management consulting firm is expected to improve the productivity of a business unit, the service firm's pay could be conditioned on productivity change over a specified period of time.

However, in projects where the output depends to a large extent on the effort by the client itself it may be difficult or even counter-productive to tie the service firm's compensation to performance. Another fundamental problem with profit sharing schemes is that it is often very difficult or even impossible to identify the change in performance caused by the consulting effort.

5.4 Incentives to collaborate

How to structure incentives within service firms?

Two of the three service providers interviewed were using department- or firm-level bonuses. The fact that compensation is structured in this way rather than through project-level profit sharing is at odds with agency theory in economics. However, the reason for the "failure" of these firms to follow the teachings of economic theory lies probably in the weaknesses of the theory rather than in poor judgment of the firms. The theory fails to acknowledge, first, how important teamwork is in business organizations, and second, how cooperation is sustained in the long term. One of the firms had experimented with project bonuses but had shifted to incentives focused at higher levels of organization (department and firm) as the atmosphere for cooperation among project groups deteriorated drastically. Holmström and Milgrom (1994) have discussed the tradeoff between the intensity of informal cooperation among individuals and strong individual-level incentives. Compensation based on the performance of the individual employee creates competition among employees thus discouraging cooperation.

In contrast, the third service firm reported extremely strong incentives for individuals' performance. Individual consultants are responsible for carrying out projects and receive most of the profits themselves. Even internal collaboration is based on contracts: consultants are paid to participate in their colleagues' projects. In the absence of complementary management mechanisms this entrepreneurial incentive system could impede informal (uncompensated) cooperation, especially knowledge sharing. Such mechanisms were in fact observed as the firm complements individuals' performance incentives with substantial investments in cooperation. For example, employees spend up to 40 days per year in various firm-level or group-level training and development events. Through frequent and extensive communication and joint learning in these competence and cooperation development events, employees form the requisite social relationships for open knowledge exchange.

5.5 Knowledge creation and innovation in KIBS firms

How does learning and innovation occur in KIBS firms?

Barras (1986) posited a model in which technology adoption induces product innovation in the service firm. In essence, the model implies that product innovation follows process innovation, a notion opposite to that describing innovation in manufacturing firms (Abernathy and Utterback, 1978). This conceptualization has been criticized for privileging financial services at the expense of the larger and more diverse service sector. Thus, the extant literature does not allow us to distinguish between the natures of service and manufacturing innovation. For instance, the "integrated innovation" model in which internal and external sources of knowledge are combined through multiple feedbacks between the stages of the innovation process (Rothwell, 1994) may well apply to both services and manufacturing. The analysis based on the Finnish innovation survey data for manufacturing and services carried out in the previous chapters demonstrated that innovating service firms' investments in training and R&D and their patterns of collaboration with R&D partners are not radically different from those of manufacturing firms. Interesting differences between the sectors are identified, but these do not necessarily undermine the conception of innovation as a process of integrating relevant sources of knowledge both within and outside the firm.

The literature on innovation in service industries emphasizes the informal nature and organization of the service innovation process. Service firms do not necessarily invest in formal R&D, and even highly innovative firms may not have an R&D department. As regards knowledge creation in Finnish KIBS firms, all of the firms interviewed have a long tradition of providing extensive in-house training to their employees. In fact, training is sometimes used as an organizational setup for product improvement and even new product development. Moreover, the firms were in the process of developing more systematic routines and formal organizational structures for product and process innovation, apart from training. It remains to be seen how these strategies will work in practice.

As regards product development, KIBS have traditionally provided rather customized services. Their professional expertise and capabilities are used to solve the particular problems of the client, rather than supplying narrowly defined and standardized products. While complete standardization may not be desirable, the experience of the service firms interviewed suggests that it is useful to define the service products clearly, and even more importantly, the competencies and organizational capabilities on which they are based. In order to enhance capabilities cumulatively and exploit potential complementarities, the firm needs to define its "core" services, how these can be improved, and how the supporting competencies are to be built. It would seem that focusing, rather than engaging in dispersed, non-cumulative learning within unrelated activities, is an important strategic challenge.

Even if the service must be modified to fit the needs of each client, a clear conceptualization of service products can guide decisions about possible development trajectories of the firm. Further, well defined products or methods (processes) can sometimes be standardized and licensed to other service providers. Surprisingly, such licensing arrangements are common in management consulting despite the rather amorphous nature of the consulting process itself. Significant returns to scale in knowledge creation can be realized only through some degree of standardization and focusing of efforts.

Overall, it seems that the process of service innovation and product development does not necessarily differ dramatically from that in manufacturing industries. Moreover, even though formal scientific research plays a less important role, it is not unheard of for firms in service industries to collaborate with university researchers. All three firms interviewed were engaged in a more or less formal dialogue with universities. Service firms also collaborate frequently with specialized technology firms in order to develop tools and processes to participate in the information technology revolution. These firms tend to outsource the necessary IT skills.

5.6 Management of intellectual property

How is knowledge safeguarded in KIBS?

How do KIBS firms and their clients manage knowledge flows between them?

In contrast to manufacturing, in service industries low appropriability of innovation returns, that is high knowledge spillovers, is associated with higher probability of successful product innovation (see the statistical analysis in Chapter 4). This finding merits further research, as it has fundamental implications for policies concerning intellectual property rights in the service sector.

Appropriability issues have an effect not only on incentives to invest in R&D (see Cohen and Levinthal, 1990), but also on the organizational choices made by firms. Teece (1986) has argued that under low appropriability "make," that is internal organization, has advantages over "buy," or externalization. Results in the previous chapter also support this observation.

Joint R&D among rival service firms is not common according to the Finnish survey data or the interviews with the three KIBS firms. The interviewed firms believed that benefits from collaboration generally do not outweigh costs associated with leaking strategic information to rivals. Moreover, according to the industrial design manager, there are few specialized jobs or competencies that the firm itself could not hire or develop internally in a reasonable time. This suggests, first, that knowledge is not very cumulative (i.e., creation of a particular competence does not require a long tenure). Second, this observation is in accord with the literature arguing that appropriability tends to be low in services, sometimes prohibiting collaborative innovation.

In those cases where service products and processes are sufficiently well defined, it is possible to contract and trade in "service designs" or methods. As mentioned earlier, licenses for particular service products can be exchanged among firms and collaborative (joint) service arrangements can be supported. In general, however, intellectual property rights protecting service products are difficult to define and enforce. For instance, trade secrets protect process drawings in engineering in principle. However, the engineering firm respondent reported that it is not unheard of for clients to request proposals from one engineering firm and then pass the designs on to a second firm who will take on the project at a lower cost. This illegal behavior is possible because rights associated with trade secrets are difficult to enforce. Even in cases where firms learn that their secrets have been infringed upon, prosecution is usually not pursued. While there are gaps in legal protection, some informal codes of conduct or norms of "proper" behavior have developed. For example, in engineering services it is not considered to be "ethically" correct to use the same drawings for two different clients.

5.7 Information and communication technologies (ICT)

How do new communication technologies affect the interaction between service providers and their clients?

What is the role of face-to-face interaction in the circulation of tacit knowledge?

Scholars have examined how tacit knowledge is created and exchanged within organizations. Nonaka (1994), as well as the innovation systems literature (e.g. Johnson, 1992) emphasize the role of personal communication, frequent and sustained interaction, extended planning horizons, and appropriate governance structures. Nonaka's concept of socialization, i.e., transmission of tacit knowledge between individuals is viewed as a central aspect of knowledge production. Thus, it appears that face-to-face interaction is important for effective learning. At the same time, the ICT revolution is widely expected to accelerate exchange of knowledge at a distance and expand the potential range of operation of KIBS firms. It is not clear how these differing perspectives on the geography of service provision can be reconciled. It seems that personal relationships, preferably face-to-face contact, are necessary to create the codes and dedicated communication channels through which tacit knowledge is continuously exchanged.

Each of the three firms interviewed are currently making significant investments in information and communication technologies. These investments are made in the expectation that virtual interfaces can substitute for face to face interaction. But, in light of the literature discussed above these expectations may need to be tempered. Intranets, extranets, and virtual "workdesks" which allow several people to simultaneously participate in projects will surely change the service process. It is not clear whether these communication media are sufficiently powerful to overcome barriers to transmission and incorporation of sticky knowledge. New technologies may not be able to completely replace face-to-face communication.

5.8 Concluding remarks

The purpose of this chapter has been to assess the validity of the innovation survey data on service industries on the one hand, and examine some new issues in service innovation on the other. However, it must be kept in mind that the number of observations is very small. Therefore generalizability is very limited, and the results must be interpreted critically.

Generally speaking, the interview results obtained do not support any drastically different conceptualization of innovation. The integrated model of innovation and knowledge creation appears to be a reasonable starting point for the study of service innovation as well.

However, several issues require further research. First, the role of training as a key knowledge creation activity in services is not well understood. Incremental product innovation can to some extent be carried out through in-house training. Therefore, it seems that the nature of training processes and their links with product development should be examined in more detail.

Second, intellectual property rights in service industries are a relatively unexplored area. Service firms do use these rights and trade with them, contrary to what is argued in a lot of extant literature. At the same time, knowledge spillovers appear to prohibit horizontal collaboration. Nevertheless, the result from the econometric analysis in Chapter 4 that spillovers support service innovation implies that strengthening these rights might be counterproductive from the social point of view.

Third, how "knowledge integration" is achieved, that is, how the potential complementarities among relevant sources of knowledge are realized through cooperation and knowledge sharing is poorly understood in innovation studies in general. Incentives to cooperate and communicate, and organizational structures within which this happens should be investigated in both the service and the manufacturing context.

Finally, the potential expansion of the geographic area of operation of knowledge-intensive service firms by use of new communication technologies needs to be assessed. A new balance is likely to emerge between face-to-face communication and knowledge transfer with new electronic media. Tacit knowledge may remain hard to communicate with the new media, however.

The implications of this chapter for the current European innovation survey approach are that the roles of training, suppliers, knowledge spillovers, and ICT should be investigated in more detail in future surveys of service innovation. Moreover, some key KIBS industries currently missing from the survey sample, such as media and advertising agencies, management consulting firms, and industrial design, should be included in the survey, and their participation in clients' innovation processes should be investigated.

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