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Services vs. Manufacturing – How Does Foreign and Domestic Sales Impact on their R&D?

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ABSTRACT

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JEL Code: D22, F14, F43, L60, L80, O14, O31, O33, O52

Keywords: Research and Development, Foreign and domestic sales, services, manufacturing

Services vs. Manufacturing – How Does Foreign and Domestic Sales Impact on their R&D?[1]

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Abstract

While the distinction between manufacturing and services becomes increasingly blurred to some observers, we find, using a panel of Swedish firms, clear evidence that foreign sales (exports) are more important than domestic sales for stimulating R&D. This is particularly clear for manufacturing and this importance of foreign sales has increased over time, simultaneous to an opening up of the Swedish economy. Even though service industries have seen an increase in both R&D and trade over time, it is thus mainly manufacturing that has benefited from increased possibilities for absorptive capacity. This result suggests a clear dichotomy between manufacturing and services in terms of how they react to trade and how they turn towards the foreign market vs. the domestic market to find stimuli for innovation.

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Introduction

A growing literature documents the rising importance of trade for learning. This literature has illuminated how rising exports affect research and development (R&D) on the firm level and vice versa, i.e. if further exports are stimulated by R&D. This relationship has been extensively studied for manufacturing. Less is known about the relative role of domestic vs. foreign sales (exports) and its effects on R&D, and about how these types of sales effects differ between manufacturing and service industries.

According to several influential papers on the relationship between the size of firms and its R&D-activities, the stylized fact that has emerged is that they are linked by a proportional relationship (Cohen 2010). The export-R&D literature assumes that sales signals convey information which is translated into a learning effect that can be used for R&D on how to develop new products and further signal if markets are unsaturated in terms of the product or potential variants that the firm develops. Thus the export-learning literature suggests that exports would have a stronger effect on R&D than domestic sales. This is because learning comes from market signals and for a small, open and relatively advanced economy such as the Swedish, foreign sales signals may be much more powerful in this respect relative to domestic sales.

Trade in services has grown tremendously over the last few decades (Breinlich and Criscuolo 2011). In addition, also R&D in services has grown. Thus one might wonder to what extent services differ from manufacturing. After all, some observers conclude that the distinction between manufacturing and services has become increasingly blurred, because of servitization of the manufacturing sector, making the distinction between manufacturing and services increasingly arbitrary (Baines et al. 2009; Lodefalk 2013).

Still, services and manufacturing are arguably different on several accounts. One important aspect concerns consumption and production, where traditional services, such as haircutting or restaurant meals, are consumed virtually at the same time as they are produced (Miles, 2005). Even though information technologies have decoupled the tight link between production and consumption for parts of services such as internet banking or booking systems, services tend to retain some of its ‘locality’. Another aspect concerns innovation development. Innovation scholars have noted how innovation is sometimes developed in close links with customers. One type of such firms are grouped under the heading specialized suppliers (Pavitt, 1984) which develop innovations embodied in products and services they offer. These suppliers need close interaction with their customers, i.e. other firms, and interaction requires accompanying services. Thus, these types of innovative activities related to services are formed by local interaction.

This paper aims to contribute in three ways to this literature. First, we investigate to what extent foreign sales are more important than domestic sales for R&D activities, suggesting that foreign sales may have a stronger effect. Second, the Swedish economy has undergone substantial liberalizations, opening up to trade and was subject to a massive depreciation in the early to mid 1990s, culminating in EU membership in 1995. We investigate whether this liberalization policy has altered the relative role of foreign and domestic sales. Third, we investigate whether exports impact differently on services relative to manufacturing firms. Our investigation is motivated by the fact that innovation sources are likely to differ for service firms so that we expect innovative activity in service firms to be more closely linked to domestic sales than for manufacturing firms.

In order to test these ideas, we take advantage of an encompassing panel dataset on Swedish firms for an extended period (1987-2009). We estimate Heckman selection models for cross-sections, and panel regression fixed effects models with instrumental variables, addressing issues of selection, endogeneity bias and unobserved heterogeneity.

Literature review

Several streams of literature are relevant for our study. These are i) the size-R&D literature, ii) the role of learning from exports and iii) trade and innovation in services.

Size and R&D

A natural starting point for explaining the R&D level of firms is its relationship to firm size. Schumpeter's work (1934, 1950), has led to what has become known as the two conflicting "Schumpeterian hypotheses" (Breschi et al. 2000). Theoretical arguments are ambiguous on whether large or small firms have advantages when it comes to the implementation of innovation processes in production. Large firm advantages include (i) scale economies in R&D, where higher returns from R&D arise as innovators can spread the fixed costs of R&D over larger volumes of sales, (ii) complementarities between R&D and other activities and (iii) fewer financial constraints due to capital market imperfections (Cohen 2010). These advantages also suggest that large firms may be inclined to direct their innovative efforts towards incremental, process-oriented innovations, which can be applied to large production volumes (Cohen and Klepper 1996a). The main reason why small firms should have an advantage stems from their larger natural flexibility from which they derive an advantage in doing R&D (Nelson and Winter 1982; Tidd et al. 2005; Cohen 2010).

Consistent with the theoretical ambiguity, size-advantages have also been difficult to establish empirically. Many studies examine the link between innovation and size (see e.g. Cohen and Klepper 1996b; Bound et al. 1984; Scherer 1965), where size is usually measured by sales or number of employees and innovation proxied for by R&D expenditures. The consensus view has become that R&D rises proportionately with firm size among R&D performers, with an elasticity of close to unity in cross-sections (Cohen 1995).[2] The first hypothesis is natural:

Hypothesis 1: R&D should be linked to size by a proportional relationship, with the combined elasticity of sales effects not significantly different from one in cross-sections.

R&D and foreign markets

The relationship between R&D and, especially foreign sales is a two-way street. Learning effects are dynamic in the sense that exports stimulate learning (Keller 2010) while R&D in turn makes future sales possible. Underlying these arguments is an assumption that competition abroad is fiercer, and that fierceness in competition is inductive to R&D. Recent evidence for Swedish firms, also supported by theory (Aghion et al. 2005), show that although competition has an inverse U-shaped relationship with the level of R&D, observed levels of competition indeed have generally pro-stimulating effects (Gustavsson Tingvall and Karpaty 2011).

[2] R&D is, however, an input into the innovation process, not necessarily linked to innovation (Smith 2005). Studies suggest that the number of innovations per employee declines with firm size (Acs and Audretsch 1990, 1991; Kleinknecht et al. 1993; Santarelli and Piergiovanni 1996; Pavitt et al. 1987).

Fors and Svensson (2002) examine how foreign sales affect R&D intensity (R&D/total sales) in Swedish multinationals and find a two-way relationship where a higher intensity of foreign sales increases the R&D intensity, and that a higher R&D intensity increases the foreign sales intensity. They also control for the size of the firm in terms of employment in one of their specifications and find a very small insignificant effect indicating a proportional relationship between size and R&D.

Several reasons suggest that foreign markets are different from domestic markets and give a stronger impetus to doing R&D. First, there are economies of scale in R&D. In a static product quality setting, process R&D can be seen as having a fixed cost part (e.g. lab equipment) and a variable part that cuts unit costs. As specified in a model by Cohen and Klepper (1996b), large-sales firms have the opportunity to spread their fixed costs of R&D. The marginal effect of an R&D dollar spent thus becomes higher than for smaller firms as a cost-cutting effect can be applied on more units sold. Thus, given that a firm has incurred a fixed cost of setting up an R&D lab it has an incentive to extend its market. Consider a simple model[3], where a firm's cost is given by (1) and the firm does not trade:

$$C = F + vX, \qquad (1)$$

where C represents the total cost, F is a fixed cost for R&D, v is a variable cost for production and X is the number of units produced. The average cost is

$$AC = \frac{C}{X} = \frac{F}{X} + v. \quad (2)$$

With larger production, average cost declines to reach the variable cost v in the limit. Consider now that the firm's initial strategy would include expanding into a new foreign country, which entails an additional fixed cost F_1. The market sales in the foreign country are X_1. In this case our equations become

$$C' = F + F_1 + v(X + X_1), \quad (1')$$

and

$$AC' = \frac{C'}{(X+X_1)} = \frac{F+F_1+v(X+X_1)}{(X+X_1)} = \frac{F+F_1}{(X+X_1)} + v \quad (2')$$

Total average costs will thus go down with a strategy of expanding to the foreign market if

$$\frac{F+F_1}{(X+X_1)} < \frac{F}{X} \quad \text{or} \quad \frac{F_1}{F} < \frac{X_1}{X} \qquad (3)$$

Thus, if the fixed cost of entering on the foreign market is small relative to the initial lab cost, and the foreign market is large relative to the home market, lower average costs are gained by entering.[4] Of course, the initial cost may be high, but the prospective market size may be very large. This seems to be a highly relevant case for a small open economy such as the Swedish one. There is certainly a dynamic element to this; if the firm can expect foreign sales to *become* larger, especially relative to that of the home market, condition (3) is more likely to be met in e.g. high-growth economies. The story does not end there; the size argument implies that large sales give a further stimulus to do more R&D, because of the cost-spreading effect (cf. Cohen and Klepper 1996b).

A related argument concerns the need to establish production activities in the foreign country to economize on transport costs. Transactions that take place to foreign affiliates within the larger multinational corporation tend, as in our data, to

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[3] The model disregards e.g. dynamic market effects from cost-cutting on demand and on competition, which is hence assumed to be constant.

[4] This result holds generally such that the average costs with an initial strategy of entering a second foreign market is lower compared to a strategy of just entering on one foreign market if $\frac{F_2}{F+F_1} < \frac{X_2}{X+X_1}$.

be recorded as exports. A firm may therefore keep R&D in the home country to exploit scale economies of R&D and apply production techniques overseas, which has the advantage of protecting R&D from easily spilling over to foreign competition through e.g. labor mobility. The extent to which R&D is kept in the home country is labeled a home bias effect (Belderbos et al. 2011), a path-dependency resulting from access to trained human capital and the need to transfer important (tacit) knowledge within the firm. These attributes render the location of R&D activities fairly stable over time. The home bias effect also relates to preferences, i.e. 'Swedes buy Volvos'. If the home market is small, and the preferences for such home-produced goods are saturated ('X' is small), going abroad is one way by which foreign markets might stimulate existing R&D further.

Second, again with special relevance to small economies, foreign markets provide opportunities to cater different segments of customers, each segment by itself potentially forming a large submarket abroad. Thus, foreign markets give an impetus towards product differentiation and in order to exploit economies of scope in R&D, firms may need to invest in complementary R&D to tailor its products to different submarkets. Again, if fixed costs of differentiation are small relative to potential market gains, economies of scope give rise to further R&D. Third, absorptive capacity arguments (e.g. Cohen and Levinthal 1989) hold that learning is facilitated by own R&D. As most knowledge is developed outside any individual country, large foreign markets should provide qualitatively superior information signals on how to improve the product, because a) small differences in quality may give rise to strong shifts in market shares and b) foreign sales give rise to a stronger learning effect through absorptive capacity.[5] Increased R&D is therefore a signal of learning induced by exposure to foreign markets.

Fourth, there is a self-selection argument according to which mainly firms with a higher ability choose to enter onto the foreign market. Ability can be expected to correlate with R&D, giving another reason for observing a higher level of R&D for firms that are active on the foreign market. The foreign market by virtue of its stronger competition necessitates more R&D in order for the firm to stay on the market. Similarly, foreign markets are different and a strong signal of product quality is that a firm is able to export it. For instance, Andersson and Ejermo (2008) show that Swedish regions tend to export goods with higher prices over longer distances.

We therefore state:

Hypothesis 2: R&D is stimulated to a higher extent by foreign rather than domestic sales.

Keller (2010) reports mixed evidence from a variety of approaches investigating the potential role of exports for learning, although later studies tend to find some effects on learning. It is well known that exporting firms are more productive than non-exporting firms, but the fundamental reason could well be that firms self-select into exporting. In other words, since they are already more productive than the average firm, they choose to enter the export market. Clerides et al. (1998) examine whether average costs, as an indicator of learning effects, are affected by exports among firms in Columbia, Morocco and Mexico. They control for the selection effect in a first-step equation but find no effect of starting to export. Similar to Clerides et al. (1998), van Biesebroeck (2005) investigates average cost effects of exporting for firms in nine African sub-Saharan countries and reveals a 25 percent productivity boost which is attributed to previous non-exploited scale effects. Hallward-Driemeier et al. (2002) find that South Asian firms that are planning to start exporting invest more resources to raise productivity and quality than non-exporters. Keller (2010), however, argues that such investments should be deducted from any learning effects as they consume real resources. De Loecker (2007) employs a matched

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[5] We are thankful to an anonymous reviewer for pointing out this absorptive capacity argument.

sample of Slovenian firms and finds that exporting firms become more productive after they start exporting. Damijan et al. (2010) investigate the two-way relationship between exporting and activity, as reported in the Slovenian innovation survey. They find no support that firms that engage in process or product innovation activity become first-time exporters, but do find evidence of productivity increases resulting from export activity.

Andersson and Lööf (2009) differentiate between small and large exporters (in terms of export intensity), and between temporary and persistent exporters among Swedish firms. They find that learning effects require persistent export activity for small and large firms, while large firms also need a high export intensity to be effective. Fryges and Wagner (2010) construct profitability measures rather than productivity measures for German firms, which enables them to distinguish productivity effects from those of rising wages. They find a small statistically significant productivity premium for exporting firms which is not absorbed by higher wages.

Innovation and trade in services

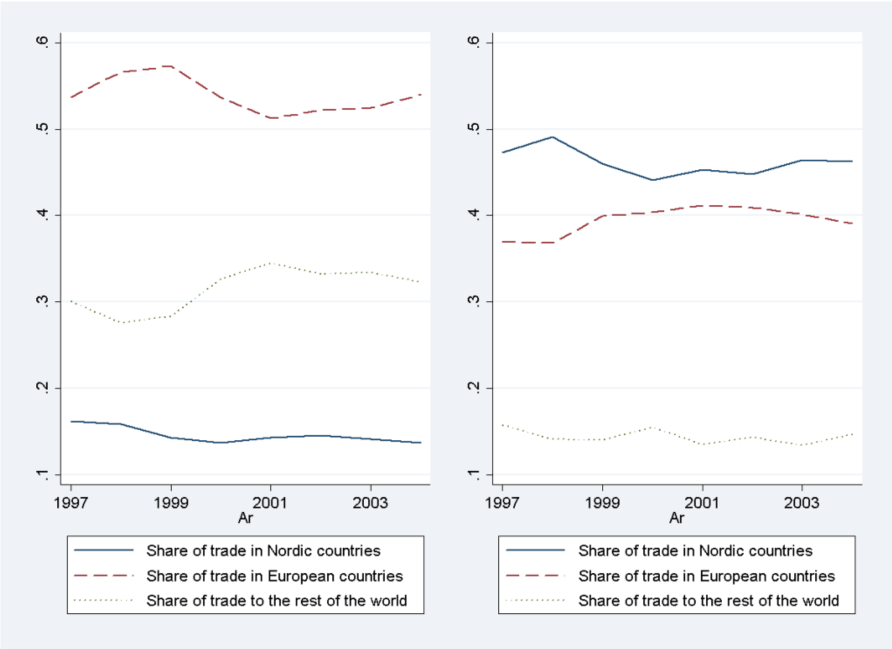
Service production arguably needs to be tailored more directly to users, necessitating arms-length relationships between R&D and production. In the famous Pavitt (1984) taxonomy, the author distinguishes two types of sectors which affect and are affected by innovation development. These are specialized suppliers and supplier-dominated firms. One side of this coin consists of firms that through intense interaction with demanders of new technology provide services in the form of consultancy, expertise and so on. From the other side, we find firms that receive new technology. Services also reside here. For instance, advanced information technology solutions may be developed by service firms in IT, which are demanded by banks and travel agencies. Nevertheless, new such solutions are not unique for services and specialized suppliers exist also among manufacturers. Are services then different from manufacturing in terms of how they develop innovation? One view, which characterizes more traditional services, is that production and consumption takes place simultaneously, since services cannot be stored (Hill 1977). Some services behave more like manufacturing, however. They may for instance be highly technology intensive and work with materials (Miles 2005). Thus, while some services are non-tradable, others have tradable products and behave more like manufacturing, and may host R&D labs.

Tether (2005) describes an emerging view, *the synthesis approach*, suggesting that services and manufacturers do not follow entirely different approaches to innovation, because of an increased co-mingling of the two types of activities, e.g. servitization of manufacturing. One key aspect of service innovation concerns their intangible and interactive nature. Because of this, innovation is often continuous rather than occasional and discrete. Thus, while manufacturing may rely on discrete innovation steps applied on distinct models that can be mass-produced, services tend to alter products more continuously, with less standardization going on. Tether (2005) reports results from a survey of innovation patterns, the Innobarometer 2002, which interviewed managers in 3,014 European firms employing at least 20 people. Three types of firms are compared: i) manufacturing firms that focus on product and/or process innovation (PPI), ii) service firms that focus on PPI, and iii) service firms that focus on organizational innovation. One of the results reported is that service firms rely significantly more on cooperation with suppliers and/or customers as sources of advanced technologies, even after controlling for firm age and size. This difference was particularly noticeable among organizationally innovating firms, but also among PPI service firms.

Rising trade in services has resulted in part thanks to the development of information technologies. At the same time, manufacturing firms have outsourced parts of their R&D to knowledge-intensive business services to make to them more flexible in managing their innovation development, with the effect of dramatically increasing service sectors' R&D

(Miozzo and Soete 2001; Tether 2003). We believe that even though services to some extent behave more like manufacturing firms, its very nature impinges a closer interaction with customers and therefore domestic sales should have a greater impact on R&D. One piece of evidence to support this is provided by Figure 1, which depicts the share of trade with i) Nordic countries, ii) other European countries and iii) the rest of the world. The trade data are from Statistics Sweden on the firm level aggregated to the two broad groups manufacturing and services based on value of exports.[6] The figure clearly shows that service firms have their trading partners much closer to Sweden, since the share of trade to Nordic countries is higher and the share of the rest of the world trade is markedly lower than for manufacturing firms. This is suggestive that service firms' important sources of new information are found closer by.

Figure 1. Share of trade in three regions. Left panel = manufacturing firms, right panel = service firms.



The argumentation above thus suggests that the sales-R&D relationship is different for services firms compared to manufacturing firms, because for services the relevant impetus to R&D more frequently comes from arms-length business relationships. For manufacturing firms, production and innovation may more easily be decoupled, and relevant sources of learning are less frequently local. We thus formulate two related hypotheses:

Hypothesis 3: A stronger foreign sales effect pertains in particular to manufacturing firms.

and

Hypothesis 4: Domestic sales have a stronger R&D effect on service firms than on manufacturing firms.

R&D and trade in Sweden

Sweden's research and development (R&D) expenditures, as a share of GDP, is among the highest in the world with business R&D being the most important constituent. The trend towards such a high business R&D ratio originated in the

[6] The same type of trade data are later used in the regressions.

mid-1980s (Table 1) and continued at least throughout the 1990s. Other countries, especially among the Nordic, have seen similar upward trends, but this trend has been more pronounced in Sweden than elsewhere.

Parallel with this rising trend, a shift has taken place in terms of the Swedish economy’s dependence on trade. Trade has always been important and for decades Sweden has had an unusually high concentration of multinationals. Out of 12 European countries Sweden actually had the highest share of large firms in 1988-91 (Henrekson and Jakobsson 2001; Henrekson and Johansson 1999). From 1950 until the mid-1970s exports as a share of GDP were stable at 20-25 percent. After a series of devaluations in the 1970s and early 1980s, exports temporarily rose above 30 percent. An increasing problem of high domestic inflation forced the government to float the currency in 1992, and the Swedish krona immediately lost 25 percent in value, which seems to have become permanent. At the same time Sweden experienced a permanent shift towards higher levels of trade, in part stimulated by the depreciation, and EU membership in 1995. Export and import levels are now firmly established above 40 percent as a share of GDP (Statistics Sweden 2011).

TABLE 1. Business R&D as a share of GDP 1981-2008 in selected OECD countries, percent

	1981	1985	1989	1993	1997	2001	2005	2008
Denmark	0.5	0.7	0.8	1.0	1.2	1.6	1.7	2.0
Finland	0.6	0.9	1.1	1.2	1.8	2.4	2.5	2.8
France	1.1	1.3	1.3	1.5	1.4	1.4	1.3	1.3
Germany	1.6	1.9	2.0	1.5	1.5	1.7	1.7	1.9
Israel	..	..	..	1.4	1.9	3.5	3.4	3.8
Japan	1.4	1.8	2.0	1.9	2.1	2.3	2.5	2.7
Netherlands	0.9	1.1	1.2	0.9	1.1	1.1	1.0	0.9
Norway	0.6	0.9	0.9	0.9	0.9	0.9	0.8	0.9
Sweden	1.4	1.9	1.8	2.2	2.6	3.2	2.6	2.7
Switzerland	1.6	..	2.0	..	..	..	..	2.2
United Kingdom	1.5	1.4	1.5	1.3	1.2	1.2	1.1	1.1
United States	1.6	2.0	1.8	1.7	1.9	2.0	1.8	2.0
OECD Total	1.2	1.5	1.5	1.4	1.4	1.6	1.5	1.6

Source: OECD (2010) and own calculations. ‘..’ denotes missing data.

As Sweden has continuously increased its trade dependence, we investigate whether the effect of foreign sales on R&D has increased in importance over time. This gives us Hypothesis 5:

Hypothesis 5: The dependence of Swedish R&D on foreign trade has increased over time.

Empirical analysis

Data and variables

The data for our analysis consists of firm-level observations from different databases compiled by Statistics Sweden. With respect to R&D we have had the choice of two sources of data. One source is the Swedish firm register (Structural Business Statistics – SBS) that has annual R&D data between 1985 and 2002 and other types of data until 2009, but data on R&D are only given for an interval for firms with R&D expenditures less than 10 MSEK. Another source is the data that forms the foundation for the Swedish official R&D statistics used in reports to the OECD. These data on R&D expenditures are collected from a biennial R&D survey which is more specific. It covers the period 1987-2009 and includes all firms with reported R&D expenditures over 5 MSEK and a sample of firms reporting less than 5 MSEK. Because the quality of the data from the R&D statistics is higher and more comprehensive, we have chosen this source of data. The sales variables come from the Structural Business Statistics. The foreign sales variable is exports, which is the sum of sales to foreign firms within the corporate group and sales to other foreign customers.

We also include a number of control variables. Since the level of R&D is likely to be affected by the education level at the firm, we have gathered information on the share of employees with any type of tertiary education at each firm. Capital intensity, measured as the book value of capital divided by total sales, is also included on the basis that technological progress is usually interlinked with capital investments.

The nature of R&D and innovation can be expected to differ between sectors, and technological opportunities differ as well. We include industry dummies to pick up some of these differences as well as possible differences in the market structure (Breschi et al. 2000). Following Ejermo and Kander (2011), firms have been classified as belonging to one of ten sectors. Sectors 1-7 belong to manufacturing, while sectors 8-10 are in services. The logic behind this division is based on different R&D intensities following OECD:s division into low, medium and high tech sectors. Because of different classification schemes over time, we had to 'translate' some sectors over time. A full list of sectors with corresponding Swedish SIC codes is provided in the Appendix.

As discussed, we expect R&D in manufacturing firms to be more strongly linked to foreign sales, and therefore conduct estimations for manufacturing and service industries separately.

Another aspect of the organization of R&D activities concerns the possibility of a differential effect between Swedish vs. foreign owned firms. As mentioned earlier, home bias effects in terms of the localization of R&D might induce foreign owned firms active in Sweden to reduce their R&D levels in Sweden relative to sales. All nominal variables are deflated using an index of civil engineering wages (Ljungberg 1990), and are expressed in 1985-year prices. Table 2 shows summary statistics for R&D performing firms in 1997, which is representative for all years between 1987 and 2009.

TABLE 2 Descriptive statistics of variables for 1997 for R&D performing firms.

	Variable	Obs.	Mean	Sd.	Min	Max
All sectors	R&D	446	52.76	214.65	0.07	2607.32
	Foreign sales	446	497.49	1656.95	0.03	20150.20
	Domestic sales	446	334.15	1156.62	0.65	18903.91
	Capital intensity	446	0.23	0.39	0.00	6.93
	Highly educated, share	446	0.27	0.20	0.02	0.92
	Foreign ownership	446	0.36	0.48	0.00	1.00
Manufacturing sectors	R&D	375	53.31	224.98	0.07	2607.32
	Foreign sales	375	569.63	1791.17	0.03	20150.20
	Domestic sales	375	268.10	538.54	0.65	5784.72
	Capital intensity	375	0.22	0.22	0.00	1.81
	Highly educated, share	375	0.22	0.15	0.02	0.85
	Foreign ownership	375	0.38	0.49	0.00	1.00
Service sectors	R&D	71	49.88	149.86	0.21	1129.59
	Foreign sales	71	116.50	370.15	0.04	2812.04
	Domestic sales	71	682.98	2609.21	0.68	18903.91
	Capital intensity	71	0.24	0.84	0.00	6.93
	Highly educated, share	71	0.54	0.23	0.04	0.92
	Foreign ownership	71	0.25	0.44	0.00	1.00

R&D and the sales variables are in millions of SEK (1985-year prices).

Time trends in the distribution of innovative activities and exports

Figures 2-5 summarize trends in R&D expenditures and exports in Sweden according to our data 1987-2009. Figure 2 shows that large firms have a decreasing share of total R&D expenditures. Nonetheless, we can note that R&D expenditures are still extremely concentrated in large firms, since almost 97 percent were in firms with at least 200 employees in 1987, a figure that only dropped to 90 percent in 2009. Figure 3 shows that mean R&D expenditure per firm has decreased somewhat over the period, even though it increased from 1993 to 2001.

Figure 2. Share of R&D in firms with at least 200 employees

Figure 3. Mean R&D expenditure per firm (in 1985-year prices)

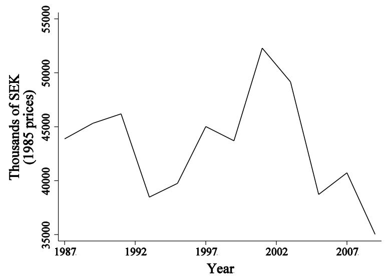


Figure 4 shows that R&D still takes place predominantly in the manufacturing sector. Manufacturing firms conduct a slowly decreasing share of about 80 percent of total R&D in Sweden, with a correspondingly slowly increasing share for service firms. Figure 5 shows the development of the export intensity (exports/total sales) for firms with positive R&D expenditures. This intensity increased from 0.41 in 1987 to 0.49 in 2009, showing the increased trade dependency of Swedish R&D performers.

Figure 4. Share of R&D in manufacturing and service sectors

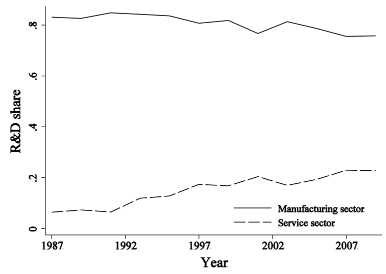
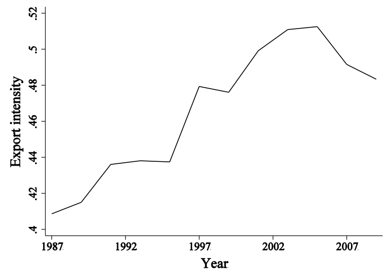


Figure 5. Export intensity for R&D performing firms



Estimation strategy

Estimating the effect of sales on R&D should ideally address several econometric issues. First, as highlighted in our literature review it is likely that there is an endogenous relationship between R&D and trade, where effects go in both directions. Second, arguably particularly productive firms self-select into exporting. Third, managerial talent, firm efficiency, and so on, are unobservables that call for the possibility to control for unobserved heterogeneity in panel regressions. Unfortunately, no panel estimator exists to deal with both selection effects and endogeneity with an instrumental approach. In our estimations we will therefore first examine the extent to which endogeneity and selection is an issue in cross-sections, and thereafter report panel estimation results. The cross-sectional results further serve to illustrate the extent to which our data show a proportional relationship between size and R&D found in the literature (Hypothesis 1). We will also compare the Heckman estimator with ordinary least squares and IV regression results.

Regressions on the size-R&D relationship

We conduct regression analyses to sort out the relative importance of the two sales variables – foreign and domestic – in R&D expenditures, while also taking into account effects related to the sample at hand. Equation (4) shows the main estimated equation.

$$\ln RD_{it} = \beta_1 lnS_{it}^F + \beta_2 lnS_{it}^D + \gamma' X_{it} + u_{it}, \quad (4)$$

where *i* is a firm and *t* denotes year. The dependent variable is the log of R&D expenditures, the explanatory variables of main interest are the log of foreign sales (S^F) and the log of domestic sales (S^D). *X* is a vector of control variables including capital intensity, the share of highly educated, a dummy for foreign ownership, industry dummies for our ten sectors and a constant, and *u* is an idiosyncratic error term.

Following the literature, we expect $\beta_1 + \beta_2 = 1$, resulting in a proportional relationship between R&D expenditures and size, in line with Hypothesis 1. If $\beta_1 = \beta_2$ there is no difference in the effect on R&D expenditures of changes in the two types of sales variables, but if $\beta_1 > \beta_2$ changes in foreign sales have a larger impact than changes in domestic sales. This would confirm Hypothesis 2. There would then be evidence of a learning-by-exporting effect or of scale economies in R&D. Furthermore, if the foreign sales effect is more pronounced for manufacturing than for service sectors we take this as evidence in support of Hypothesis 3 and if the coefficient for domestic sales is larger for services it supports Hypothesis 4.

Several issues with the estimation of this equation need attention. First, due to the log specification, we exclude non-R&D performers, which might lead to biased results when using OLS estimation. To correct for sample selection bias concerning the R&D variable, we use the Heckman (1979) two-step estimator where, in the first stage, we specify an equation for the probability of engaging in R&D. From this stage, an inverted Mills ratio is estimated and used to correct for selection. Because the R&D data only includes R&D performers, we construct the selection variable with the help of the Structural Business Statistics data set. We believe that zero values can be expected to be accurate from the SBS, and thus complement the data from the R&D statistics. Therefore, the selection variable is created as follows:

$$s(R\&D) = \begin{cases} 1 & if \quad R\&D_{stat} > 0 \\ 0 & if \quad R\&D_{stat} = 0 \\ 0 & if \quad R\&D_{stat} = missing \ and \ R\&D_{SBS} = 0 \\ missing & if \quad R\&D_{stat} = missing \ and \ R\&D_{SBS} = missing \end{cases} \quad (5)$$

where $R\&D_{stat}$ is R&D data from the R&D statistics and $R\&D_{SBS}$ is from the Structural Business Statistics. Data on R&D from SBS was only collected until 2002, effectively limiting cross-sectional estimations to the period 1987-2001.

For reasons of space we only present regressions for the years 1993, 1997 and 2001, even though we have also run the regressions for the other available years.[7] As we also log the export variable, we exclude the non-exporters who constitute about ten percent of the R&D performers in the data. There is no easy way to control for this exclusion. We just have to acknowledge that our results are valid only for firms with positive domestic and foreign sales.

[7] The latter results are available from the authors on request.

Second, another major issue is the possibly endogenous relationship between R&D and the sales variables, and specifically the variable for foreign sales. It is rather well documented in the literature that the decisions to perform R&D and to export are made simultaneously (Fors and Svensson 2002; Lileeva and Trefler 2007; Aw et al. 2008). However, Lileeva and Trefler (2007) point out that it is exporting that makes it more profitable to improve productivity (investing in R&D) because it increases the output over which the productivity gains will be spread. We deal with this possible endogeneity problem by using an instrumental variable estimator and instrument foreign sales with its lagged values.

Cross-sectional regressions

First we examine the results from OLS and IV, for one specific year, 1997, gauging if there are problems of endogeneity. Estimates are fairly similar over time and hence we present only one year's estimates for illustration, see Table 3.

For the IV estimation we use the two-stage least squares estimator where we instrument foreign sales with its first and second lag. Including more than one instrument allows us to test the validity of the instruments using the Hansen test of overidentifying restrictions, a test which our instruments pass. The Hansen test rejects the overidentifying restrictions only for the year 1999 on the five-percent level. Even so, whether the first lag of foreign sales is actually an appropriate instrument, despite (mostly) passing the validity test, is debatable. Therefore, we have also tried with only the second and third lag as instruments but we get no differences in the results or in the validity tests. In addition, we have also instrumented domestic sales and the human capital variable and tested these variables for endogeneity. We conclude that they can be treated as exogenous and do not need to be instrumented.

The samples for the OLS are limited to those observations for which the first and second lags of log foreign sales are available, in order to use the same observations as for the IV.

TABLE 3 OLS and IV cross-sectional estimates, 1997

Dependent variable: Log R&D expenditures		
	(1)	(2)
	OLS	IV
Log foreign sales	0.43***	0.48***
	(0.042)	(0.048)
Log domestic sales	0.36***	0.34***
	(0.041)	(0.041)
Capital intensity	0.79**	0.79**
	(0.313)	(0.308)
Highly educated, share	4.32***	4.22***
	(0.454)	(0.456)
Foreign ownership	-0.05	-0.06
	(0.111)	(0.110)
Constant	0.03	-0.16
	(0.620)	(0.628)
Observations	395	395
Censored observations		
R-squared	0.684	0.682
Hansen		0.828

Standard errors in parentheses. ***, **, * Coefficients are significant on the 1, 5 and 10 % levels respectively. Sector dummies not reported. P-value is reported for the Hansen test of overidentifying restrictions. In the IV estimation, the variable for log foreign sales is instrumented with its first and second lag.

The estimates are quite similar across the OLS and the IV estimations, but the latter give rise to higher estimates for the foreign sales variable. Our tests consistently reject exogeneity of foreign sales. What about selection? If selection effects are important, this could severely bias our estimates. Table 4 presents first-stage (selection) estimates for i) all firms, ii) manufacturing firms only and iii) service firms only, and Tables 5 and 6 present the corresponding second stage. We ran Heckman models for available biennial data 1987-2001, but present only the years 1993, 1997 and 2001.

For the selection equation in the two-step Heckman estimator, all the previously discussed variables are included in addition to variables for competition, total number of patents in the region and share of employees in a metropolitan area. Following the Industrial Organization literature we include a measure of competition to control for effects of market structure (see e.g. Aghion et al. 2005; Gustavsson Tingvall and Karpaty 2011; Vossen 1999). We use the Hirschmann Herfindahl Index (HHI), defined as

$$HHI_k = \sum_{i \subset k} s_i^2, \qquad (6)$$

where s_i^2 is the squared market share of firm *i* belonging to sector *k*.[8] The variable patents in the region is intended to capture the potential for knowledge spillovers measured by the total number of patent (minus patents of the own firm) of the local labor market region where the firm has its main workplace. Other firms' patents may stimulate own R&D investments in order to 'absorb' their results (Cohen and Levinthal 1989), and may make it more profitable to invest in own R&D (Audretsch and Feldman 1996). The metropolitan variable shows the share of employees that reside in one of the local labour market regions Stockholm, Gothenburg or Malmoe. The variable uses the location of the individuals rather than that of the firm, as the judicial seating does not always best reflect the firm's main region of activity. Both the regional patenting and the metropolitan variable are intended to capture the advantages for the firms of being located in an agglomeration where much R&D activity takes place, and hence may have a positive spillover effect on the probability of engaging in R&D.

The Heckman models show that both foreign and domestic sales are important determinants for the decision to perform R&D – but in quite different ways. The coefficient for foreign sales is positive and significantly higher than that of domestic sales for all the investigated years 1993-2001, but not 1987-1991.[9] This tendency is clear from 1993 onwards. This difference for all firms together arises both because the foreign market becomes more important, and because of a decline in the coefficient for domestic sales. Interestingly, for service sector firms the domestic sales selection coefficient is *negative* and significant for all years (except 1987 when it is insignificant) in these sets of regressions. This result clearly suggests that putting manufacturing and service firms together blurs the domestic sales effect. Thus, service firms that predominantly are active on the domestic market are less likely to engage in R&D at all. This is logical, for these firms may have more sheltered market shares and need not necessarily be competitive by using the edge that R&D entails.

Turning to the determinants of the amount of R&D conducted at the firm – Table 5 displays the second stage Heckman estimates for the three chosen years, 1993, 1997 and 2001.

In line with our expectations, the elasticity with respect to foreign sales is again generally higher than for domestic sales. We find a statistically significant difference for five (four) years on the 10 (5) percent level. The estimate for foreign sales

[8] The results are mainly unchanged when using the market share of the top four firms (C4) in the sector instead. The HHI index carries information on the dispersion of all firms in a sector whereas the C4 only considers the top four.
[9] For services, the difference is also significant for 1989.

ranges from 0.41 (in 1989) to 0.60 (in 1999), whereas for domestic sales it ranges from 0.28 (in 2001) to 0.58 (in 1987). There is a continuous decline in the domestic sales elasticity over time and a close to continuous increase in the estimated foreign sales elasticity over time. The difference between the estimates of the sales variables is significant (on the 10 percent level) for 1989 and then from 1995 onwards, in line with Hypothesis 2. Thus, when studying all firms together, it seems we can claim that Swedish firms increasingly link their R&D behaviour to foreign sales rather than domestic sales.

The combined elasticity ranges from 0.78 (in 2001) to 1.10 (in 1987), which is very close to one, and we can only reject that it is one for 2001. Thus, on average, R&D expenditures increase at the same pace as sales, which confirms the stylized finding of a proportional relationship found in the literature (Hypothesis 1).

With regard to the control variables, capital intensity is significant in five (three) out of eight studied years on the 10 (5) percent level. The share of highly educated is significant and positive for all years, indicating that, in line with our expectations, having a well educated work force is an important determinant for the amount of R&D undertaken at the firm. The variable for foreign ownership is negative for most years, but is only significant for 1987 (on the 10 percent level) and 1999 (on the 5 percent level). With regard to the significance for lambda (the Mill's ratio), we find that selection seems to be an issue for half of the years.

To investigate if the results differ between manufacturing and service sectors, Table 6 shows the second stage Heckman estimates for these sectors separately. The lambda coefficient is significant on the 10 percent level or lower in half of the years for manufacturing, but never for services. The elasticity for foreign sales ranges from 0.40 (in 1989) to 0.65 (in 2001) for the manufacturing sector. It ranges from -0.27 (in 1991; this negative value seems to be an exception) to 0.35 (in 1989), and is not always significant, for the service sector. The domestic sales elasticity ranges from 0.25 (in 2001) to 0.61 (in 1987) for the manufacturing sector and from 0.63 (in 1987) to 1.03 (in 1991) for services. The *difference* between the estimates for foreign and domestic sales becomes increasingly bigger over the years for the manufacturing sector, especially after 1991.

TABLE 4 First stage Heckman estimates

	Dependent variable: s(R&D)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1993 – All	1993 – M	1993 – S	1997 – All	1997 – M	1997 – S	2001 – All	2001 – M	2001 – S
Log foreign sales	0.27***	0.37***	0.05	0.28***	0.39***	0.09***	0.28***	0.44***	0.05*
	(0.025)	(0.032)	(0.042)	(0.023)	(0.033)	(0.032)	(0.021)	(0.031)	(0.026)
Log domestic sales	0.11***	0.19***	-0.18***	0.07**	0.13***	-0.21***	0.03	0.05	-0.22***
	(0.035)	(0.043)	(0.035)	(0.032)	(0.042)	(0.028)	(0.025)	(0.033)	(0.023)
Capital intensity	-0.04	-0.07	-0.10	0.10	0.11	0.09	0.01	0.40*	0.02
	(0.104)	(0.158)	(0.107)	(0.083)	(0.146)	(0.111)	(0.046)	(0.223)	(0.053)
Highly educated, share	1.82***	1.93***	1.55***	2.49***	3.03***	1.51***	2.69***	2.09***	2.13***
	(0.340)	(0.557)	(0.429)	(0.272)	(0.464)	(0.297)	(0.234)	(0.374)	(0.262)
Log regional patenting	-0.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00	0.00	-0.00
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Metro	0.18	0.08	-0.20	-0.04	-0.09	-0.46	0.22	0.22	-0.36
	(0.155)	(0.188)	(0.322)	(0.153)	(0.195)	(0.284)	(0.144)	(0.184)	(0.268)
HHI sector 10	1.15***	0.89**	2.01***	1.64***	1.58***	2.37***	1.02***	0.75*	1.72***
	(0.367)	(0.431)	(0.740)	(0.398)	(0.491)	(0.683)	(0.334)	(0.422)	(0.532)
Observations	1,271	867	404	1,664	1,027	637	2,409	1,406	1,003
T-test foreign = domestic (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

TABLE 5 Second stage Heckman estimates

Dependent variable: Log R&D expenditures	(1) 1993	(2) 1997	(3) 2001
Log foreign sales	0.51***	0.57***	0.50***
	(0.067)	(0.060)	(0.074)
Log domestic sales	0.41***	0.37***	0.28***
	(0.045)	(0.040)	(0.033)
Capital intensity	0.66*	0.72***	0.23
	(0.347)	(0.142)	(0.195)
Highly educated, share	6.12***	5.55***	5.20***
	(0.588)	(0.555)	(0.639)
Foreign ownership	0.09	-0.04	-0.15
	(0.127)	(0.110)	(0.108)
Constant	-2.34**	-2.61**	-1.08
	(1.100)	(1.120)	(1.237)
Uncensored observations	401	446	500
Censored observations	870	1218	1909
Lambda	0.46	0.92***	1.22***
	(0.359)	(0.297)	(0.356)
T-test foreign = domestic (p-value)	0.179	0.005	0.007
T-test foreign + domestic = 1 (p-value)	0.345	0.399	0.006

Standard errors in parentheses. ***, **, * Coefficients are significant on the 1, 5 and 10 % levels respectively. Sector dummies not reported.

We can reject equality for 1993, 1997, 1999 and 2001 for manufacturing on the 5% level. The change in differences is driven both by a drop in importance of the domestic sales coefficient and an increase in the size of the foreign sales coefficient. During the post 1994 period Swedish exports have increased dramatically, following a depreciated currency and membership of the European Union. Our results suggest that R&D has been affected as well by these trends, consistent with Hypothesis 5.

TABLE 6 Second stage Heckman for manufacturing and service sectors respectively

Dependent variable: Log R&D expenditures	(1) 1993 - M	(2) 1993 - S	(3) 1997 - M	(4) 1997 - S	(5) 2001- M	(6) 2001 - S
Log foreign sales	0.60***	0.20*	0.57***	0.25***	0.65***	0.20***
	(0.077)	(0.113)	(0.062)	(0.087)	(0.081)	(0.065)
Log domestic sales	0.43***	0.36**	0.36***	0.28***	0.25***	0.42***
	(0.050)	(0.174)	(0.041)	(0.104)	(0.037)	(0.134)
Capital intensity	0.58	2.17*	0.55*	0.63***	0.91***	-0.48
	(0.366)	(1.139)	(0.297)	(0.193)	(0.281)	(0.330)
Highly educated, share	6.35***	4.37***	5.67***	2.44**	5.10***	1.83
	(0.599)	(1.335)	(0.510)	(0.998)	(0.499)	(1.348)
Foreign ownership	0.10	0.57	-0.08	0.29	-0.15	-0.18
	(0.129)	(0.527)	(0.111)	(0.359)	(0.108)	(0.324)
Constant	-4.14***	0.59	-3.09***	1.40	-2.74**	2.07
	(1.449)	(1.665)	(1.170)	(1.534)	(1.285)	(1.366)
Uncensored observations	362	39	375	71	407	93
Censored observations	505	365	652	566	999	910
Lambda	0.66*	-0.35	0.51*	-0.09	0.66**	-0.81
	(0.344)	(0.649)	(0.263)	(0.628)	(0.296)	(0.726)
T-test foreign = domestic (p-value)	0.040	0.516	0.006	0.859	0.000	0.199
T-test foreign + domestic = 1 (p-value)	0.798	0.006	0.338	0.000	0.217	0.003

Standard errors in parentheses. ***, **, * Coefficients are significant on the 1, 5 and 10 % levels respectively. Sector dummies not reported.

For the service sector, on the other hand, domestic sales seem to be a more important determinant of the amount of R&D than foreign sales. As gauged by the estimates, we find that the domestic sales effect has a higher size estimate in six out of eight years, although we can only reject equality between the coefficients for 1991. Part of this lack of significant findings probably comes from a low number of firms for services.

The combined elasticity ranges from 0.84 (in 1999) to 1.03 (in 1993) for the manufacturing sector and from 0.30 (in 1987) to 0.76 (in 1991) for the service sector, though the sales variables are not always significant. For both manufacturing and service sectors we reject that the combined elasticity equals one only for 1999 for manufacturing, but for all years except 1987 and 1991 for services. The sum of the coefficients is clearly lower for services, which might imply that they do not follow the 'stylized' proportional relationship between R&D and sales.

Turning to the control variables, the capital intensity variable is positive and significant for three of the years for manufacturing firms and four of the years for service firms. The share of highly educated is positive and significant for all years in the two sectors except in 1987 and 2001 for the service sector. In general, the size of the estimate is also lower for service sectors, but it is clearly important to have a highly educated work force for the amount of R&D. The variable for foreign ownership is negative for one year for manufacturing, but is positive and significant for two years for services.

Three lessons can be learnt from the Heckman estimations. First, according to the estimates, selection is an issue for about half the years and comes from manufacturing, but not service firms. Selection may therefore not be a major issue. Second, the foreign sales effect is clearly stronger for manufacturing firms in cross-sections than it is for service firms. When combining firms in the same sample, we can confirm that the foreign sales effect is significantly larger, and this is confirmed for manufacturing but not service firms. Thus, in cross-sections we find support for all of our hypotheses. Even though selection effects are found, it is meaningful also to investigate panel regression estimates which we now turn to.

Panel regressions

We run fixed effects panel regressions for the period 1987-2009, shown in Table 7. To conserve space, we have excluded the reporting of "Capital intensity", "Highly educated, share", HHI, year dummies and intercept. The three regressions (1)-(3) follow the setup used above in the Heckman cross-sections, i.e. without instruments and each display the results of all firms, manufacturing and service firms, respectively. Both sales effects are positive and significantly different from zero. They are also similar in size and not statistically different, although the estimated foreign sales effect is somewhat larger in size for manufacturing with the reverse tendency for service firms. Capital intensity has the expected sign and is significant for all firms and manufacturing firms, but not services, confirming the central role of physical capital for manufacturing as a complementary resource for R&D. A higher human capital share gives rise to a higher R&D in all three models, although it is only significant on the 10 percent level for service firms. Models (4)-(6) include a trend-interaction variable for the two sales variables in order to test if the two sales effects have changed over time in significant ways. There is some evidence of a slight positive shift in the foreign sales variable and a negative effect for domestic sales over time. This trend effect is only visible for manufacturing.

We now turn to regressions where we treat the (log) foreign sales as potentially endogenous (models 7-8). We divided up the material again into All firms, Manufacturing firms and Service firms. We also estimate models (9-10) where we include an interaction variable which multiplies the trend by the foreign sales variable and a variable that multiplies domestic sales by the trend. In these cases we treat the foreign sales-trend interaction variable as endogenous as well. In the final model (11) we use all firms. Here, in addition to sales-trend interaction variables, we include dummy variables interacting a service firm dummy with the domestic sales variable and the service firm dummy with the foreign sales variable. We also include a variable that interacts the service firm dummy with the foreign sales variables multiplied by the trend. This last variable captures if the trend for the foreign sales effect differs for service firms relative to manufacturing firms. In this model, we treat all variables interacted with foreign sales as endogenous.

We first test whether foreign sales is endogenous and needs to be instrumented. We find that this is only the case when we use specifications with all firms and manufacturing, i.e. not for services. We think it is interesting by itself that service firms' R&D does not have an interactive 'dynamic' relationship with foreign sales, to some extent already highlighting the point we made about foreign sales. We therefore only report IV-estimations for all firms and manufacturing. For model 7 we instrument foreign sales by its lagged value, one and two periods respectively and add foreign sales x trend by its lagged value for model 9. For model 8, in order to pass the F-test that instruments are sufficiently strong, we add as instruments a dummy variable for foreign ownership and sector dummies.[10] For model 10, we only added foreign ownership. Finally, for model 11 we use as instruments lagged foreign sales one and two periods, lagged interacted foreign-service sales one and two periods, and lagged interacted foreign-service sales multiplied by the trend. Our instruments pass Hansen's J test for overidentifying restrictions for all models and is reported in Table 7. We also tested for weak identification using the Kleipbergen-Paap Wald F-statistic. The "rule of thumb" proposed by Staiger and Stock (1997) is that the F-statistic should be larger than 10. Our models (7) and (9) pass this test, but not models (8), (10) and (11). Nevertheless, the Anderson–Rubin (1949) statistic is robust to the presence of weak instruments and can be used to test the (joint) significance of the endogenous regressor(s). For model (8) this is the case and it rejects that the foreign sales effect is zero. For models (10) and (11) we can only conclude that the endogenous regressors are jointly different from zero.

With this in mind we conclude the following. Foreign sales do have a stronger effect than domestic sales as evidenced by models (7-8). For services, we cannot rule out that they are equally important (model 3). When including trend variables (models 9-11), the evidence is suggestive that the foreign sales (domestic) effect has increased (decreased) over time, but because of the weak instrument problem we cannot be conclusive. Similarly, the domestic sales effect interacted with services is positive and significant in model (11) and the foreign sales x service interaction effect is negative, but again we cannot be conclusive about this. Also the trend effect does not seem to differ between services and manufacturing according to model (11).

A combined evaluation of the cross-sectional and panel results gives us the following. With regard to the relationship between R&D and sales, our cross-sectional estimates strongly confirm proportionality between them for all years except for one estimation year (2001) when looking at all firms together. We thus find support for Hypothesis 1. With respect to Hypothesis 2, we find that the foreign sales effect is generally stronger in the cross-sections. In the panel regressions, we also find support for this when running instrument regressions. This result also holds for manufacturing and gives support for Hypothesis 3. For services, we do not find support that domestic sales effects have a stronger effect, thus not supporting Hypothesis 4. Finally, Hypothesis 5 receives support. First and casually, cross-sectional estimates become larger over time and second and more significantly, in panels we find support in form of a significant foreign sales x trend effect. It can also be noted that the domestic sales effect becomes significantly lower over time.

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[10] The choice of these instruments were inspired by those used by Gustavsson Tingvall and Karpaty (2011).

TABLE 7. Panel fixed effects estimations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Sector	All	Manuf	Service	All	Manuf	Service	All	Manuf	All	Manuf	All
Note							IV	IV	IV	IV	IV
Log foreign sales	0.14***	0.17***	0.11**	0.09***	0.12***	0.22*	0.51***	0.42***	0.35***	0.32***	0.40***
	(0.023)	(0.028)	(0.043)	(0.035)	(0.041)	(0.118)	(0.132)	(0.099)	(0.119)	(0.099)	(0.124)
Log foreign sales x t				0.01*	0.01*	-0.01			0.02***	0.02***	0.02***
				(0.004)	(0.004)	(0.012)			(0.006)	(0.006)	(0.006)
Log domestic sales	0.15***	0.15***	0.17***	0.32***	0.31***	0.29**	0.13***	0.11***	0.38***	0.34***	0.34***
	(0.024)	(0.028)	(0.049)	(0.041)	(0.045)	(0.120)	(0.028)	(0.032)	(0.054)	(0.051)	(0.053)
Log domestic sales x t				-0.02***	-0.02***	-0.01			-0.03***	-0.02***	-0.03***
				(0.004)	(0.004)	(0.011)			(0.005)	(0.005)	(0.005)
Log domestic sales x Services											0.13**
											(0.060)
Log foreign sales x Services											-0.28**
											(0.132)
Log foreign sales x services x t											-0.00
											(0.003)
Observations	5,122	4,272	777	5,122	4,272	777	3,133	2,686	3,133	2,686	3,132
R-squared	0.060	0.066	0.104	0.071	0.076	0.112	-0.059	0.004	-0.056	0.017	-0.052
Number of firms	1,617	1,268	379	1,617	1,268	379	692	579	692	579	692
T-test log for. sales = log dom. sales	0.902	0.569	0.318	0.000	0.005	0.718	0.004	0.003	0.839	0.897	0.680
Hansen J-statistic (p-value)							0.762	0.533	0.722	0.120	0.177

Note: Capital intensity, Highly educated, share and HHI and year dummies not reported. Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Summary and conclusions

Are manufacturing and services different in terms of how their investments in innovative activities relate to trade? Services have grown dramatically in importance to constitute the bulk of economic activity in western economies. There is at the same time much discussion about an ongoing servitization of manufacturing while we can observe rising trade and increased investments in services' expenditures on research and development (R&D). All this suggests that the distinction between services and manufacturing may be arbitrary, or perhaps even unnecessary. Yet, relatively little has been known about the role of trade and how it affects innovation investments (Miles 2005; Breinlich and Criscuolo 2011). Our paper provides new evidence to show that the two sectors work distinctly different in terms of how trade impacts on R&D. We find that, while sales in general have a proportional relationship with R&D, the composition in terms of foreign and domestic sales matter. In particular, foreign sales are more important for stimulating R&D in manufacturing than in services. Consistent with our results, this suggests that arms-length relationships are more important for stimulating innovation in services. Services may therefore have a more central role as sources of localized spillovers. The result also shows that manufacturing has a more important role for developing new knowledge inspired by signals from foreign markets.

Our results are supported by the use of a comprehensive panel dataset over an extended period of time (1987-2009). During this time period the Swedish economy opened up and became more integrated with other European economies. The results suggest that this liberalization has mainly impacted on how manufacturing firms invest in R&D. Thus, despite what might superficially seem like a convergence between manufacturing and services in terms of R&D investments and trade, the two sectors have become more “dual” over time with respect to how the relative role of trade and the domestic economy affect R&D. The results may, however, hide an indirect dependence of services on manufacturing through the provision of knowledge intensive business services (KIBS). Therefore, a fruitful venue for further research might be to investigate the particular role of service firms in R&D emphasizing the dependency on manufacturing firms’ R&D and a possible role of services as a conduit of knowledge from manufacturing to other parts of the economy.

Our results also have bearing on the discussion of ”R&D paradoxes” that have been discussed in Sweden and other European countries. The Swedish version claims that despite a high level of business R&D, the outcome of this R&D has been disappointing (Ohlsson and Vinell 1987; Edquist and McKelvey 1998). Our study focuses on the reverse direction – from sales to R&D – and highlights that it is not necessarily the domestic economy to which R&D is linked the most, but that it is highly influenced by the extent of the internationalization of the firm.

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