Innovativeness – an examination of innovative sales as a measure of innovation output

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Abstract

A central issue in innovation analysis is gaining an understanding of how firms transform knowledge inputs into marketable products and improvements in productivity. Empirically, an important issue in this respect is how to measure knowledge output. Initial studies used patents as a measure of "economically valuable knowledge". However, with the advent of innovation surveys such as the Community Innovation Survey (CIS), researchers have sought alternative measures of innovative output. By far the most commonly used measure is the share of innovative sales, defined as the share of sales that can be attributed to product innovations. However, to our knowledge, little work has been done to investigate the characteristics of this measure and how well it functions as a measure of 'economically valuable knowledge'. This paper examines the share of innovative sales using a variety of approaches, with the aim of gaining a better understanding of what we are actually measuring with this indicator. By characterizing the relation between the share of innovative sales and a variety of other indicators, we hope to shed light on the relation between innovation activity and output that may be useful in econometric modeling.

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1. Introduction

A central issue in innovation analysis is gaining an understanding of how firms transform knowledge inputs into marketable products and improvements in productivity. On the one hand, R&D and other investments in the creation of new knowledge are widely accepted to be a central factor in generating economic growth. However, the process by which R&D leads to growth may be very complicated. Kline and Rosenberg (1986) argue that innovation is often treated as a "black box" where economic analysis has "largely neglected the highly complex processes through which certain inputs are transformed into certain outputs" (Kline and Rosenberg, 1986, p. 278).

Empirically, the first attempt at modeling the production of knowledge and subsequent effects on performance was undertaken by Pakes and Griliches (1984). They modeled this process through a "knowledge production function", in which R&D and other inputs are used to create "economically valuable knowledge". Pakes and Griliches (1984) and a number of subsequent analyses, such as Jaffe (1986), have estimated knowledge production functions using patent grants as a proxy for economically valuable knowledge[1]. While patent data is useful in many respects, it also has a number of shortcomings as a measure of innovative output. First, patents differ greatly in their economic impact, with many patents not being used at all. Second, the majority of innovations are not based on patents. Third, while patents can be considered an output of research, they are generally still inputs in the sense that much development work needs to be undertaken before the new technology can be implemented in new products or processes.

For these reasons, and with the advent of innovation surveys such as the Community Innovation Survey (CIS), researchers have sought alternative measures of innovative output. By far the most commonly used measure is the share of innovative sales, defined as the share of sales that can be attributed to product innovations. This measure has been used in a large number of recent analyses, both in examining the determinants of innovativity (Mohnen et al, 2006) and in modeling the relation between innovation and productivity, drawing on the pioneering work of Crepon et al (1998) (CDM).

However, to our knowledge, little work has been done to investigate the characteristics of this measure and how well it functions as a measure of 'economically valuable knowledge'. As with patents, the share of innovative sales may also have shortcomings, particularly as a measure of innovativeness. For example, one firm might have a truly novel invention that only comprises a small share of its sales while another firm may introduce a fairly minor change that impacts all its sales. However, these 'shortcomings', or variations in the actual activity that has gone into the innovations, may potentially be useful in analyzing the

[1] The transfer of R&D into economically useable knowledge is also a prominent feature in new growth models, such as Romer (1990) and Aghion and Howitt (1992).

relation between innovation and productivity. For example, does novel innovative activity have a greater impact on performance than the adoption of products and technologies already on the market? By characterizing the relation between the share of innovative sales and a variety of other indicators, we hope to shed light on the relation between innovation activity and output that may be useful in econometric modeling.

This paper examines the share of innovative sales using a variety of approaches, with the aim of gaining a better understanding of what we are actually measuring with this indicator. For example, is the share of innovative sales correlated with other measures of innovativeness, such as 'innovation modes' based on novelty and creative in-house activities, or R&D intensity? How does the share of innovative sales (and also the share of sales due to new to market product innovations) vary across industries and size classes? Are we able to characterize or identify different types of innovative firms by looking at their share of innovative sales in combination with other variables? An additional question of great importance is what we are missing in focusing on the share of sales affected by product innovations, i.e. how 'innovative' are firms without product innovations, but have implemented other types of innovations, and how can we best measure impacts on productivity?

2. Empirical results

We first examine variation across sectors and size classes. In order to enhance comparison across sectors, we have looked at unweighted results and results weighted both by number of firms and by firm sales. Industries are grouped into 12 classes across manufacturing and services.

Table 1 shows average shares of innovative sales for industry groups. There is generally not that much variation in manufacturing, contrary to expectations that shares should follow average R&D intensities across industries. For example, average shares for Chemicals and Pharmaceuticals are basically the same as for traditional industry. This is the case for both total shares of innovative sales and new to market shares. Note also that this pattern is not altered when weighting by employees as opposed to firms. Electronics and Instruments have the highest average share for manufacturing.

There is much more variation in average shares for service sectors. Transport and Financial Services have very low shares, while Wholesale (surprisingly) is on level with Manufacturing. Knowledge intensive service sectors, particularly ICTs have extremely high shares, much higher than for high tech manufacturing. This result is interesting and deserves greater attention. For example, are knowledge intensive firms' innovative performance really that much greater (than firms in high tech manufacturing) based on similar resource investments (at least in terms of R&D). Knowledge intensive sectors are

Table 1: Average shares of innovative sales for industry groups

Industry group	Share turnover from new and improved products and services	Firm weighted average	Sales weighted	Unweighted
Food and Beverages (15-16)	Total share innovative sales	23.3	**32.0**	23.3
	New for the firm only	7.5	14.6	8.4
	New for the market	15.8	17.4	14.9
Textiles, Leather, Paper and Wood	Total share innovative sales	16.7	**35.8**	21.4
	New for the firm only	7.7	5.9	7.3
	New for the market	9.0	29.9	14.1
Chemicals and Pharmaceuticals (24)	Total share innovative sales	26.0	17.6	**32.0**
	New for the firm only	11.6	11.8	19.9
	New for the market	14.4	5.8	12.1
Metals	Total share innovative sales	18.2	21.1	19.0
	New for the firm only	8.3	8.5	7.8
	New for the market	9.9	12.7	11.2
Machinery and equipment (29)	Total share innovative sales	24.5	**28.6**	25.6
	New for the firm only	12.2	19.2	13.5
	New for the market	12.3	9.4	12.1
Electronics and Instruments (30-33)	Total share innovative sales	**31.7**	25.5	**32.1**
	New for the firm only	16.8	12.0	16.6
	New for the market	14.9	13.5	15.6
Manufactures (34-38,40-41,45)	Total share innovative sales	21.5	25.5	22.6
	New for the firm only	11.8	13.1	10.7
	New for the market	9.7	12.4	11.9
Manufacturing total	Total share innovative sales	23.1	27.4	25.3
	New for the firm only	11.6	13.5	12.3
	New for the market	11.5	13.9	13.0
Wholesale Trade (51)	Total share innovative sales	22.0	16.9	19.4
	New for the firm only	10.9	7.7	9.7
	New for the market	11.1	9.2	9.7
Transport (60-63)	Total share innovative sales	6.2	8.1	7.8
	New for the firm only	2.0	3.6	2.7
	New for the market	4.2	4.4	5.0
Financial intermediates (65-68)	Total share innovative sales	13.9	7.5	18.8
	New for the firm only	6.4	2.6	7.4
	New for the market	7.5	4.9	11.4
ICT services & telecom (64,72)	Total share innovative sales	**51.6**	23.2	**40.6**
	New for the firm only	27.9	11.9	23.2
	New for the market	23.7	11.3	17.5
Business Services (74)	Total share innovative sales	**40.0**	17.2	26.2
	New for the firm only	28.3	10.2	14.9
	New for the market	11.7	7.0	11.3
Services Total	Total share innovative sales	36.5	15.4	26.8
	New for the firm only	20.0	7.2	14.1
	New for the market	16.5	8.2	12.6
Total	Total share innovative sales	31.8	21.6	26.0
	New for the firm only	17.0	10.4	13.2
	New for the market	14.7	11.1	12.8

Source: Own calculations based on CIS4 data for Denmark. Note: Industry group based on technology. No. 1, 2 and 3 on total marked with **bold**.

likely subject to intense competition, along with high innovation activity. According to the spillovers and appropriation literature[2] high industry levels of innovative activity should boost the innovative output of individual firms (as they can draw on work by other firms) but at the same time negatively affect the profitability of innovations (greater competition in commercializing innovations drives down mark ups).

When weighting by employees instead of firms, average shares fall significantly for knowledge intensive services, suggesting that it is particularly the high innovative activity of small and medium sized firms that are driving the above-mentioned results. This impression holds for business services, where the average share of innovative sales for firms with over 250 employees is 15%, but not for ICT services, where the share is 36% for large firms.

If we examine average shares solely in terms of size classes, average shares are fairly constant across size classes for firms with 10 or more employees, at 22-24 percent. Average shares are in contrast much higher for firms with less than 10 employees, at 44 percent.

Table 2: Average shares of innovative sales for firm size classes

Size class	Turnover from new and improved products and services that are	Firm weighted average
Less than 10 employees	Total	43.7
	New for the firm	24.5
	New for the market	19.2
10-49 employees	Total	24.6
	New for the firm	13.2
	New for the market	11.4
50-249 employees	Total	22.8
	New for the firm	9.7
	New for the market	13.0
More than 249 employees	Total	22.1
	New for the firm	10.8
	New for the market	11.3

Source: Own calculations based on CIS4 data for Denmark.

Firms can innovate in a large number of ways. For example, some firms may be at the cutting edge for their market, developing products and technologies that are truly novel. Other firms may invest little in in-house development activities and instead adopt new technologies from others. For some firms, organizational practices or marketing methods may form the core of their innovation activities.

[2] Eg. Griliches (1979), Jaffe (1986), Spence (1984), Cohen and Levinthal (1989), De Bondt (1996).

The ability to classify and distinguish different types of innovative firms may be of great value for innovation policy design and for further analysis. Bloch et al (2007) classify innovative firms according to degree of novelty and whether innovations are developed in-house or adopted:

- **New to market international innovator** have introduced a product innovation that is new to international markets and have developed new products or processes in-house.
- **New to market domestic innovators** have introduced product innovations that are novel for domestic markets, but not necessarily new for international markets.
- **In-house modifiers** have some in-house development activities, but product and process innovations already exist on domestic markets.
- **Adopters** have not developed product or process innovations in-house, but have had them developed by others.

The structure of the 'output based modes' should by definition imply higher new to market sales shares for the most creative firms, but the classification does not necessarily influence total sales share. The results here show that, for the three in-house modes, the share of innovative sales is increasing in creativity: 'new to market international innovators' have the highest shares, while 'in-house modifiers' have on average the lowest share.

Table 3: Average shares of innovative sales for output based innovation modes

Innovation type	Turnover from new and improved products and services that are	Firm weighted average	With organizational innovation	No organizational innovation
New to market international innovators	Total	35.8	35.1	38.5
	New for the firm	13.0	11.7	18.3
	New for the market	22.8	23.5	20.1
New to market domestic innovators	Total	26.5	29.4	16.9
	New for the firm	14.4	14.8	13.1
	New for the market	12.1	14.6	3.8
In-house modifiers	Total	24.7	28.5	15.9
	New for the firm	22.3	25.4	15.0
	New for the market	2.4	3.0	0.9
Adopters	Total	36.0	42.2	16.7
	New for the firm	27.7	35.9	2.3
	New for the market	8.3	6.3	14.4

Source: Own calculations based on CIS4 data for Denmark.

Adopters, or firms whose innovations are mainly developed by others, however have high shares of innovative sales, equal to that for new to market international innovators. Some of these firms also have new to market product innovations. Two implications of this are: 1)

innovative sales is not necessarily a good measure of 'innovativeness' in terms of in-house creative activity; and 2) it would be very interesting to compare performance of innovation outputs in these two groups: in-house innovators vs. adopters. For example, how does the productivity impact of innovation output by adopters (who generally have invested much less resources in their development) compare to that of in-house innovators?

Organizational innovations are often argued to be important factors in contributing to the success of technological innovations[3]. Table 3 also examines average innovative sales for the four output based modes for firms that have also implemented an organizational innovation and for those that have not. For the most novel innovators, shares are fairly similar and in fact are slightly higher for firms without organizational innovations. However, for all the other categories, shares of innovative sales are substantially higher – around double – for firms with organizational innovations than those without.

Table 4: Average R&D and innovation intensities for shares of sales by new innovation groups

Turnover share from new and improved products and services	Intensities	Firm weighted average	Sales weighted average	Firm weighted average Only R&D firms
Less than 10 percent	R&D intensity	0.019	0.016	0.042
	Innovation intensity	0.048	0.033	0.071
10-25 percent	R&D intensity	0.057	0.021	0.114
	Innovation intensity	0.097	0.036	0.148
25-50 percent	R&D intensity	0.051	0.034	0.108
	Innovation intensity	0.091	0.060	0.154
Above 50 percent	R&D intensity	0.182	0.042	0.256
	Innovation intensity	0.261	0.060	0.354

Source: Own calculations based on CIS4 data for Denmark.

We next examine the relation of shares of innovative sales to R&D intensity. Firms are classified in 4 groups according to share innovative sales (0-10, 10-25, 25-50, 50-100). The goal with this is to gain a general idea of how patterns of innovation activity vary according to their share of innovative sales. Many, and in some countries the majority, of innovative firms do not engage in R&D. Nonetheless, one would generally expect that shares of innovative sales are increasing in R&D intensity. The data here also reflect this slightly, though the correlation is not very strong. For example the average R&D intensity for firms with innovative shares between 10 and 25 % is almost identical to that for firms

[3] See eg. Brynholfsson and Hitt (2000).

with 25 to 50 %, while average R&D for firms with greater than 50 percent innovative sales is substantially higher. To examine this further, we also divided firms by both innovative sales and size class, though this did not result in any qualitatively different results.

All in all, the data does not give an indication that share of innovative sales is a strong measure of creative innovative activity. However, that does not necessarily mean that an innovative sale is a poor measure of innovative output. These 'results' present the interesting question of whether the impact of innovative output differs for firms with strong creative activity compared to firms that have adopted or outsourced much of the creative work (and potentially do not possess the absorptive capacity to do the creative work in-house).

Table 5 shows a correlation matrix for a number of the variables examined in this paper. In general, the correlation matrix does not yield much new, though it supports many of the comments above. One result that is worth mentioning is the correlation between process innovations and innovative sales or product innovations. While the correlation is not high, it

Table 5: Correlation coefficients among selected variables

Variables	1	2	3	4	5	6	7	8	9
1: Turnover from new and improved products and services that are new to the firm									
2: Turnover from new and improved products and services that are new for the market	0.75								
3: Turnover from new and improved products and services; Total	0.68	*0.02*							
4: Own R&D	0.24	0.20	0.14						
5: R&D intensity	0.34	0.36	0.11	0.31					
6: Other innovation expenses	0.20	0.21	0.07	0.08	0.49				
7: Product innovative	0.46	0.31	0.34	0.34	0.10	*0.04*			
8: Process innovative	-0.08	-0.08	*-0.04*	0.06	*-0.05*	0.07	0.30		
9: Organization innovative	*0.03*	*0.02*	*0.03*	*0.04*	*-0.00*	*0.01*	*0.04*	0.10	
10: Sales innovative	0.10	0.07	0.07	*0.02*	*0.01*	*0.02*	0.17	*0.05*	0.14

Source: Own calculations based on CIS4 data for Denmark.
Note: Pearson correlation coefficients based on unweighted data. Insignificants are marked in italic.

is negative (though insignificant for new to firm innovative sales), implying that firms with high new to market innovative sales are less likely to have process innovations. This is

interesting given that many econometric analyses of innovation and productivity find a negative impact of process innovations on productivity.

Finally, we conduct a factor analysis using shares of new to market and new to firm innovative sales along with a variety of other innovation indicators. While many of the factor loading are not particularly high, the analysis identifies some interesting combinations.

Table 6: Results of factor analysis

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Share of turnover from new to market product	0.63236	-0.01545	-0.04798	0.28513	0.01604	0.03625
Share of turnover from new to the firm product	0.16367	0.07163	0.54003	0.14283	0.03815	0.02609
R&D active	0.24158	0.04107	0.13470	0.65734	0.13990	-0.07239
R&D intensity	0.14681	-0.21091	-0.07260	0.63529	0.11484	-0.09252
Product innovative	0.65718	0.13156	0.59735	0.15272	0.00631	0.13825
Process innovative	-0.02767	0.71109	0.01220	0.12404	-0.03657	0.21210
Organization innovative	0.03510	0.05704	-0.00409	-0.07131	0.13462	0.73960
Sales innovative	0.09015	0.04081	0.09537	0.01272	-0.01001	0.67195
New to market international innovator	0.85129	0.21276	-0.18182	0.18467	0.07233	0.06985
New to market domestic innovator	-0.18494	-0.07862	0.90461	-0.01808	-0.02822	0.03829
In-house modifiers	-0.75517	0.10270	-0.45655	0.30592	-0.08204	0.00782
Adopters	0.04366	-0.35922	-0.23870	-0.70561	0.05603	-0.15856
cost effect	0.08400	0.70358	0.07097	-0.11856	0.13954	-0.20162
market effect	0.39388	0.30863	0.28100	0.12387	-0.06690	0.14764
regulation effect	0.13357	0.32889	-0.05518	0.05459	-0.02214	0.12285
process effect	-0.00170	0.77823	0.03806	-0.05141	0.03409	-0.03919
cost barrier	0.07377	-0.02890	-0.01836	0.08432	0.66317	0.03287
sales barrier	0.01844	0.06329	0.00346	0.02326	0.63304	0.09428
knowledge barrier	-0.02705	0.01717	0.02876	0.04301	0.66491	-0.02430
Variance Explained by Each Factor	2.4662325	2.0796629	1.8898918	1.6517777	1.3782162	1.1995977

The first factor represents new to market international innovators, loading highly on new to market sales, product innovations and market effects. The second factor would seem to represent process or cost oriented innovators, many of them with product innovations, though with low shares of innovative sales and new to the firm only.

The second represents market driven innovators, with high innovative sales, marketing innovations, and some R&D though not highly R&D intensive. The third factor represents new to market domestic innovators, loading highly on new to firm innovative sales and product innovations. The fourth factor loads highly on R&D activity and R&D intensity and weakly on new to market innovative sales and in-house modifiers. The last three represent groups without high innovative sales or without product innovations at all. The fifth group represents firms that cite high barriers to their innovation activity, while the final group includes non-product innovators, with process and non-technological innovations.

3. Conclusion

The empirical analysis of 'share of innovative sales'[4] as a measure of innovative output has shown several interesting patterns. The evidence illustrates that the output measure has to be used carefully as a proxy for productivity, but also that it is a usable proxy, i.e. as a measure of 'economically valuable knowledge'.

Shares of innovative sales vary much more greatly across service sectors than across manufacturing sectors. Electronics and Instruments have the highest average shares, while Foods and beverages, Chemicals and pharmaceuticals and Machinery and equipments all have shares around manufacturing averages. In contrast, service sectors such as Transports and Financial intermediates have very low averages shares of innovative sales, while the highest shares among all sectors are found within knowledge intensive services. Somewhat surprisingly, shares of innovative sales are the same for SMEs and large firms. However, shares are much larger for very small firms with less than 10 employees.

Firms with the most novel innovations are generally considered the 'most innovative', and thus also expected to have the highest innovative output. This is also generally found to be the case: firms with new to market international innovations have on average the highest shares of innovative sales.

Organisational innovation is also given an important role and has been found in some studies to have an important impact on the overall productivity of innovation activities. In

[4] The share of innovative sales is defined as the share of sales that can be attributed to product innovations.

terms of innovative sales, we found little difference among the most novel innovators when comparing those with and without organisational innovations. One possible explanation for this is that the organizations of the most novel innovators are very geared towards innovation, including those that have not recently implemented organisational changes. In great contrast to this, we found very large differences for less novel innovators: shares of innovative sales were almost twice as high for firms having also implemented organisational innovations.

It might be expected that shares of innovative sales are highly correlated with R&D expenditures. However, we do not find a strong relationship in the Danish data. While we find a relation for extreme values - firms with very low (high) innovative sales also tend to have very low (high) R&D intensity – for firms with between 10 and 50 percent innovative sales, average R&D intensity is the same. Correlation coefficients between R&D intensity and shares of innovative sales are also quite low.

All in all, evidence is not clear supporting that 'share of innovative sales' is a strong measure of creative innovative activity. However 'share of innovative sales' may still be usable as a measure of innovative output. The evidence suggests that the measures of innovative output differ for firms with strong creative activity compared to firms that have adopted or outsourced much of the creative work.

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