The Impact of R&D Expenditures and Investments on the Effects of Innovation in the MHT and HT Industry in Poland

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Abstract: This article analyzes the relation between innovation activities and the effects of technological innovations related to products and processes in the medium-high and high technology industry in Poland between 2008-2013. The scope of this survey relates to innovation at the firm level and takes into account the diffusion of that which is "new to the company". Innovation activities include R&D expenditures and investments in fixed assets, including buildings, premises and land, machinery and equipment, and computer software. The effects of innovation concern three areas: (1) competition, demand and market; (2) production & delivery; and (3) regulatory, health and safety matters. The survey covers 1,355 enterprises. It is assumed that innovation activity facilitates the effects. The methodological part of the analysis is based on a probit modeling. The highest level of positive influence relates to investments in buildings and grounds related to an increase in production capacity or service provision, reductions in environmental impacts, improvements in health and safety, and entering new markets.

Keywords: innovation activity, medium-high technology, high technology, innovation, effects of innovation

1. INTRODUCTION

Innovation literature has focused on the role of internal research and development related to firm innovation and productivity (Griliches, 1979; Klette & Kortum, 2004). Research and expenditures play a key role in determining the differences in productivity across firms and the evolution of firm-level productivity over time (Doraszelski & Jaumandreu, 2013). However, R&D investment is not the sole source of productivity gains; technological change embodied in gross investment is of comparable importance on aggregate (Ortega&Argilés, Piva, Potters, & Vivarelli, 2010). Moreover, productivity growth in low-tech firms is still heavily dependent on investment in physical capital (embodied technological change), whereas high-tech sectors not only invest more in R&D, but also achieve more in terms of efficiency gains connected with research activities (Ortega-Argilés, Potters, & Vivarelli, 2011).

Innovation processes differ greatly from sector to sector in terms of development, rate of technological change, linkages and access to knowledge, as well as in terms of organizational structures and institutional factors (Malerba, 2005). In high-technology sectors, R&D plays a central role in innovation activities, while other sectors rely to a greater degree on the adoption of knowledge and technology. Scholars recognize that the ability to exploit external knowledge is critical to firm innovation (Teece, Pisano & Shuen, 1997). Technological innovations related to products and processes are now unavoidable for companies that want to develop and maintain a competitive advantage and/or gain entry into new markets (Stock, Greis & Fischer, 2002).

The Polish economy has attained impressive growth since the late 1990s. One of the most apparent features of this growth is the spillover of technology and knowledge from foreign investment enterprises (FIEs). Drawing on an original survey of Polish manufacturing establishments in medium-high and high technology industry, this paper investigates the relationship between internal R&D expenditures, investments in fixed assets including buildings and grounds, technical equipment and machinery, computer software, and the effects of innovation. The main hypothesis is an assumption that innovation activities facilitate the effects of innovation.

Section 2 briefly surveys the literature linking R&D expenditures and investments to the effects of innovation. Section 3 describes the methodology and research sample. Section 4 presents the results, and Section 5 is the conclusion.

2. INNOVATION - LITERATURE REVIEW

Innovation is a multi-faceted phenomenon which includes factors that enable inventions to become innovations (Chandy, Hopstaken, Narasimhan, & Prabhu, 2006), and determinants of innovation (Love & Roper, 1999) and consumer responses to innovation (Hauser, Tellis, & Griffin, 2006). Innovation can be a process or a result of its implementation. Following the Oslo Manual's lead, innovation is defined as 'the implementation of a new or significantly improved product or process (OECD, 2005, p. 49). Innovation occurs if a firm has the capability to innovate (Laforet, 2011). An innovative firm is one that has implemented an innovation during the period under review (OECD, 2005, p. 49). Both the structure and organization of innovative companies facilitate the process of innovation (Lawson & Samson, 2001). Every innovative enterprise has got the ability to generate permanent innovation, creativity, and is able to maintain a high competitive position based on the following: core competencies, the competence to anticipate the future, the ability to effectively explore the needs of customers, innovation teams to ensure a high level of innovation in the company, and the flexibility to adapt to changing conditions (Sosnowska, Kłopotek, & Łobejko, 2000).

Enterprises engage in various scientific, technological, organizational, financial and commercial steps to implement innovation and allow them to sustain their innovativeness. Innovation activity involves investment in: (a) research and development; (b) technology assets; (c) the purchase of advanced machinery, equipment, computer hardware or software, as well as land and buildings (including upgrades and repairs); (d) training of staff and marketing of new and improved products; and (e) other activities including design work, planning and testing of new products and services (production processes and methods of delivery). Innovativeness depends on the firm structure and its relationship with the various sources of information, knowledge, technology, as well as work practices and both human and financial resources (Okoń-Horodyńska & Zaharowska-Mazurkiewicz, 2007).

While any innovative action is the result of the relationship between the enterprise and the different sources of information, knowledge and technology, firms should individually decide which sources, external or internal, are the most profitable (Chesbrough, Vanhaverbeke, & West, 2006).

Firms may engage in innovation activities for a number of reasons (Wieser, 2005). Their objectives may relate to products, markets, efficiency, quality, or the ability to learn and to implement change. While objectives concern an enterprise's motives for innovation, effects relate to the actual observed outcomes of innovation. The main incentives for product innovation are competition, demand and markets. Other factors include short product life spans that necessitate the development of new products; the need to diversify product portfolios; or efforts to increase or avoid a decline in market share. In addition, a number of factors aim to identify the main motives for change in production and delivery, i.e. whether their main intent is to improve quality, flexibility, or efficiency/cost reduction. In particular, factors relating to cost reduction are made specific to enable better interpretation of results (OECD, 2005, p. 108-109). Other factors include environmental regulations, and improvement in health and safety (Kneller & Manderson, 2012).

3. METHODOLOGY AND RESEARCH SAMPLE

The scope of this study concerns the effects of innovation in medium-high and high technology industry at the level of firm, and the innovation that is new to the firm. The survey is based on a questionnaire sent by email or conducted during a telephone interview with a manager or a company founder. All data were gathered between 2008-2013 in Poland. Information, based on commercial and non-commercial sources of information such as Teleadreson, PKT and others, was collected from every Polish region and stored in one database. The final number of firms surveyed was 7,800. The success rate was about 15%. Afterwards,

all enterprises representing medium-high and high technology (Hatzichronoglou, 1997) were retrieved. The final dataset includes 1,355 firms, which is about 17.4% of the companies gathered in the database, and relates to the real share of medium-high and high technology firms in the MHT and HT Polish industry (GUS, 2015, p. 485-486). Furthermore, the final data set includes 981 (72.4%) firms from the medium-high technology industry, and 374 (27.6%) enterprises representing the high technology industry.

Table 1 shows the structure of entreprises by technology and firm size.

National capital represents 1,105 enterprises (81.55%), whereas foreign capital firms include 142 companies (10.48%), and 108 firms (7.97%) have mixed capital. The highest number of companies is in the manufacture of machinery and equipment group (see Table 2).

Table 1. Enterprises by technology and firm size

Technology	Micro (<10)		Small (10-49)		Medium (50-249)		Large (>249)		Total	
Medium-high	252	25.69%	350	35.68%	275	28.03%	104	10.60%	981	72.4%
High	172	45.99%	103	27.54%	66	17.65%	33	8.82%	374	27.6%
Total	424	31.29%	453	33.43%	341	25.17%	137	10.11%	1,355	100%

Source: Author's own study

Table 2. Enterprises by industry

Industry type	Share (%)
Manufacture of machinery and equipment	35.42
Manufacture of electrical equipment	16.75
Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks	13.80
Manufacture of chemicals and chemical products	11.51
Manufacture of motor vehicles, trailers and semi-trailers	6.05
Manufacture of basic pharmaceutical products and pharmaceutical preparation	5.17
Manufacture of communication equipment	4.43
Manufacture of computers and peripheral equipment	3.84
Manufacture of other transport equipment	1.55
Manufacture of railway locomotives and rolling stock	1.11
Manufacture of air and spacecraft and related machinery	0.37

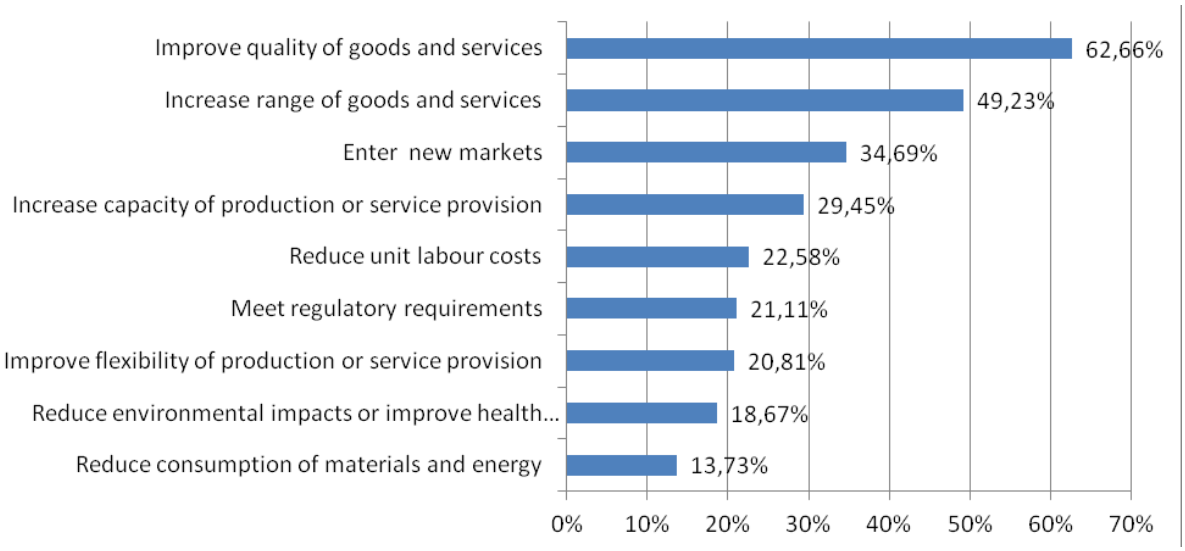
Source: Author's own study.

The most demanding effects include quality improvements of goods and services, increases in the range of goods and services, and entering new markets (see Figure 1).

Investments in new fix assets are the most common innovation activity (see Figure 2).

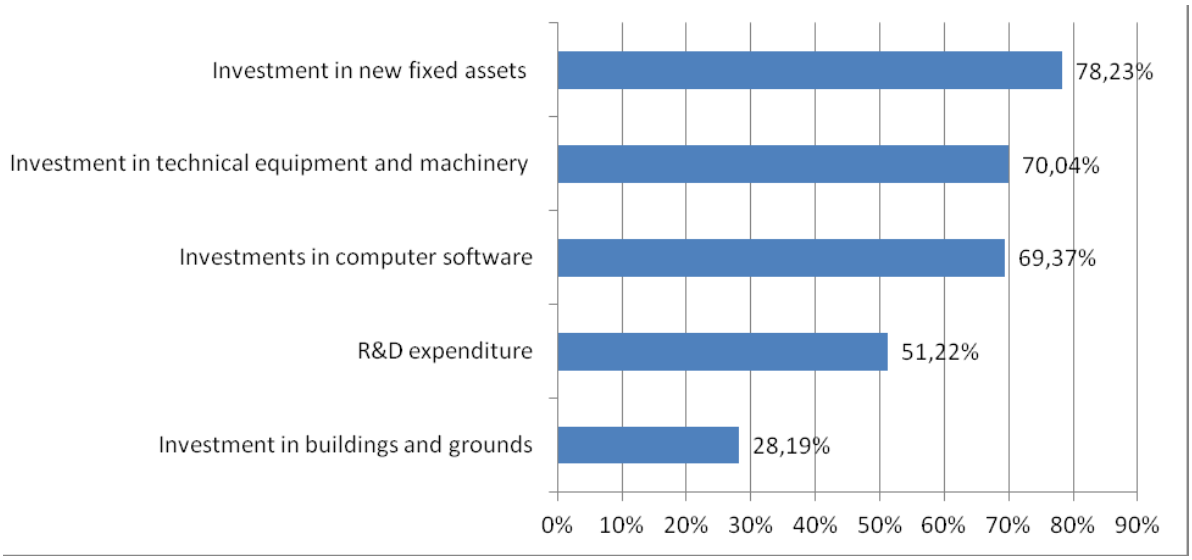
The analysis is based on probit modeling (Aldrich & Nelson, 1984; Liao, 1994). It is assumed that all relations are linear equations, because both effects (dependent variables) and R&D expenditures and investments (independent variables) are binary. Every model is described by two probabilities. P1 determines the probability of occurance of the effect related to a given innovation activity, and P2 determines the probability of occurance of this effect from the perspective of all other innovation activities. If the function parameter is positive (a>0), then P1 takes a higher value for a given investment. Moreover, all statistically significant models are described by standard error (Std), t-Student statistic (T), Chi-square test of independence (Chi2), and confidence level (P).

Figure 1. Structure of innovation effects



Source: Author's own study.

Figure 2. Structure of innovation activities (a firm can feature more than one activity)



Source: Author's own study.

4. EFFECTS OF INNOVATION ACTIVITIES

All calculated models were found to be statistically significant with a confidence level better than $p \leq 0.05$ (5%)). By dividing the probability P1 by the probability P2, the intensity of influence for a given innovation activity is featured. The numbers in parenthesis indicate the probability of performing a given innovative action.

In the case of R&D expenditure, all probit models were found to be statistically significant (see Table 3). Thus, R&D expenditure has a significant impact on achieving effects. All models are positive, hence the more companies invest in R&D the more effects they achieve. The highest influence oscillates around a 30% increment and concerns entering new markets (0.66), increase in the range of goods and services (0.61), and reduction in environmental impact or improvement of health and safety (0.66).

The impact of R&D expenditures lower than a 20% increment is related to reduction in unit labour costs (0.58), meeting regulatory requirements (0.59). and improvements in the flexibility of production or service provision.

All models were found to be statistically significant for investment in new fixed assets (see Table 4). Moreover, models take a positive parameter so the relation between investment and effects is positive. The influence is rather moderate and is at about a 17% increment and concerns entering new markets (0.88), increased capacity of production or service provision (0.89), and improvement in the quality of foods and services (0.83). The lowest impact was related to a reduction in the consumption of materials and energy (0.77).

Table 3. The effects of R&D expenditures

Innovation effect	Parameter	S	T	Chi2	P1	P2	P	P1/P2 (%)
Enter new markets	+0.56	0.07	7.67	59.78	0.66	0.44	0.00	33.33
Increase range of goods and services	+0.47	0.07	6.88	47.75	0.61	0.42	0.00	31.15
Reduce environmental impacts or improve health and safety	+0.45	0.09	5.07	26.20	0.66	0.48	0.00	27.27
Increase production capacity or service provision	+0.40	0.08	5.32	28.58	0.63	0.47	0.00	25.40
Reduce consumption of materials and energy	+0.41	0.10	4.05	16.77	0.65	0.49	0.00	24.62
Improve quality of foods and services	+0.31	0.07	4.40	19.40	0.56	0.44	0.00	21.43
Improve flexibility of production or service provision	+0.30	0.09	3.55	12.74	0.61	0.49	0.00	19.67
Meet regulatory requirements	+0.24	0.08	2.86	8.25	0.59	0.49	0.00	16.95
Reduce unit labour costs	+0.22	0.08	2.65	6.97	0.58	0.49	0.01	15.52

Legend:
S – standard error,
T – t- Student statistic
Chi2 - Chi-square test of independence
P1 – the probability of effect
P2 – the probability of effect for all other innovation activities
P – confidence level

Source: Author's own study.

Table 4. The effects of investment on new fixed assets

Innovation effect	Parameter	S	T	Chi2	P1	P2	P	P1/P2 (%)
Enter new markets	+0.54	0.09	6.19	40.33	0.88	0.73	0.00	17.05
Increase production capacity or service provision	+0.62	0.09	6.56	46.64	0.89	0.74	0.00	16.85
Improve quality of foods and services	+0.42	0.08	5.35	28.70	0.83	0.70	0.00	15.66
Increase range of goods and services	+0.46	0.08	5.95	35.99	0.85	0.72	0.00	15.29
Reduce environmental impacts or improve health and safety	+0.48	0.11	4.32	20.03	0.88	0.76	0.00	13.64
Improve flexibility of production or service provision	+0.44	0.10	4.19	18.62	0.87	0.76	0.00	12.64
Meet regulatory requirements	+0.37	0.10	3.65	13.94	0.86	0.76	0.00	11.63
Reduce unit labour costs	+0.30	0.10	3.13	10.13	0.85	0.76	0.00	10.59
Reduce consumption of materials and energy	+0.26	0.12	2.23	5.17	0.84	0.77	0.03	8.33

Source: Author's own study.

Investment in buildings and grounds was found to be statistically significant (see Table 5). All models are positive. The impact is quite strong: more than 40% for an increase in production capacity or service provision (0.41); for reduction of environmental impacts or improvement of health and safety (0.43); and for entering new markets (0.39).

All models occurred to be statistically significant for investment in technical equipment and machinery (see Table 6). Furthermore, models take positive parameters so the relations are positive.

The impact is about 20% and includes an increase in production capacity or service provision (0.82), an increase in the range of goods and services (0.78), and improved quality of foods and services (0.75).

Table 5. The effects of investment on buildings and grounds (1Ba)

Innovation effect	Parameter	S	T	Chi2	P1	P2	P	P1/P2 (%)
Increase production capacity or service provision	+0.5	0.08	6.70	44.83	0.41	0.23	0.00	43.90
Reduce environmental impacts or improve health and safety	+0.51	0.09	5.68	32.05	0.43	0.25	0.00	41.86
Enter new markets	+0.46	0.08	6.08	36.96	0.39	0.23	0.00	41.03
Improve flexibility of production or service provision	+0.37	0.09	4.31	18.41	0.39	0.25	0.00	35.90
Reduce consumption of materials and energy	+0.29	0.10	2.85	8.07	0.37	0.27	0.00	27.03
Reduce unit labour costs	+0.24	0.09	2.82	7.89	0.35	0.26	0.00	25.71
Increase range of goods and services	+0.22	0.07	3.01	9.10	0.32	0.25	0.00	21.88
Meet regulatory requirements	+0.21	0.09	2.40	5.10	0.34	0.27	0.02	20.59
Improve quality of foods and services	+0.17	0.80	2.21	4.92	0.30	0.25	0.03	16.67

Source: Author's own study.

Table 6. The effects of investment on technical equipment and machinery

Innovation effect	Parameter	S	T	Chi2	P1	P2	P	P1/P2 (%)
Increase production capacity or service provision	+0.53	0.08	6.24	40.70	0.82	0.65	0.00	20.73
Increase range of goods and services	+0.46	0.07	6.26	39.71	0.78	0.62	0.00	20.51
Improve quality of foods and services	+0.38	0.07	5.16	26.61	0.75	0.62	0.00	17.33
Enter new markets	+0.39	0.08	4.99	25.46	0.79	0.66	0.00	16.46
Reduce environmental impacts or improve health and safety	+0.39	0.10	3.98	16.42	0.80	0.68	0.00	15.00
Improve flexibility of production or service provision	+0.35	0.09	3.76	16.61	0.79	0.68	0.00	13.92
Meet regulatory requirements	+0.26	0.09	2.89	8.50	0.77	0.68	0.00	11.64
Reduce consumption of materials and energy	+0.28	0.11	2.57	6.78	0.78	0.69	0.01	11.54
Reduce unit labour costs	+0.22	0.09	2.52	6.48	0.76	0.68	0.01	10.53

Source: Author's own study.

All models were found to be statistically significant for investment in computer software (see Table 7). Models take also positive parameters in computer software support. The influence is rather moderate and variable at about 22% increment related to an increase in the range of goods and services (0.78), entering new markets (0.88), and increased production capacity or service provision (0.80).

Table 7. The effects of investment in computer software

Innovation effect	Parameter	S	T	Chi2	P1	P2	P	P1/P2 (%)
Increase range of goods and services	+0.47	0.07	6.51	42.93	0.78	0.61	0.00	21.79
Enter new markets	+0.43	0.08	5.48	30.70	0.79	0.64	0.00	18.99
Increase production capacity or service provision	+0.44	0.08	5.37	29.79	0.80	0.65	0.00	18.75
Reduce consumption of materials and energy	+0.37	0.11	3.29	11.26	0.80	0.68	0.00	15.00
Reduce environmental impacts or improve health and safety	+0.32	0.10	3.29	11.08	0.78	0.67	0.00	14.10
Improve quality of foods and services	+0.25	0.07	3.40	11.54	0.73	0.64	0.00	12.33
Improve flexibility of production or service provision	+0.24	0.09	2.69	7.35	0.76	0.68	0.01	10.53
Meet regulatory requirements	+0.25	0.10	2.70	7.45	0.76	0.68	0.01	10.53
Reduce unit labour costs	+0.18	0.09	2.09	4.40	0.74	0.68	0.04	8.11

Source: Author's own study.

5. CONCLUSION

The effects of innovation are greatly facilitated by R&D expenditures and investments in new fixed assets, including buildings and grounds, technical equipment, machinery, and computer software. The most significant effects include quality improvements of goods and services (63%), increased range of goods and services (49%), and entering new markets (35%). Firms invest the most in new fixed assets (78%), but at the same time, only 28% of companies invest in buildings and grounds. The analysis sheds the light on the nature of relations between investments and the effects of those investments. The intensity of this influence depends on innovation activity. The highest values of influence concern investments in buildings and grounds (more than 40% increase), which may suggest that firms essentially invest to increase production capacity or service provision, as well as entering new markets. Furthermore, enterprises invest in research and development to increase the range of their goods and services. Important effects include the reduction environmental impacts or improvements in health and safety. The effects with the least influence include reductions in unit labour costs, consumption of materials and energy, and meeting regulatory requirements. Hence, costs and reductions in costs are not primary goals for firms.

The analysis has some limitations. It only includes nine effects of firms' investments. Such an approach considerably limits the interpretation of results and does little to help us gain a better understanding of the phenomenon. So as to reduce this gap, it is recommended that future research not only consider more effects of innovation, but also examine those innovation activities that concern implementations of innovation and innovation cooperation.

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