

LAGS BETWEEN ACADEMIC SCIENCE AND INVENTIVENESS IN POLAND

Malgorzata Wachowska

e-mail: malgorzata.wachowska@uwr.edu.pl

University of Wroclaw, Poland

Abstract. The purpose of the paper is to show how fast university knowledge is transferred to enterprises located in Poland. An analysis of patent applications of enterprises made it possible to conclude that (1) academic knowledge diffuses to enterprises faster (11.93 years) than industrial knowledge (13.63 years); (2) university knowledge from patents diffuses faster (11.62 years) than from scientific papers (12.45 years) and (3) academic knowledge of foreign origin diffuses to enterprises faster (9.96 years) than knowledge of domestic origin (12.87 years).

Key words: inventions, knowledge diffusion, patent citations, Poland, universities.

Introduction

Inventions, frequently referred to as breakthrough innovations, are the driving force for enterprise, industry and entire country development. This is why it is so important for policymakers to stimulate inventiveness of domestic entities, which can result in their improved competitiveness but also that of the entire domestic economy.

University research is commonly regarded as one of the key factors that determine creativity and inventiveness and, consequently, competitiveness of enterprises (Rosenberg, Nelson 1994; Monjon, Waelbroeck 2003; MacGarvie, Furman 2005; Branstetter, Ogura 2005; Kim et al. 2005; Motohashi 2005; Nilsson et al. 2010; D'Este, Perkmann 2011; Roessner et al. 2013). Therefore, policies of the most countries use instruments that encourage academic researchers to conduct studies meeting the needs of industry as well as to cooperate and share their knowledge with business representatives (Link, Siegel 2005; Lach, Schankerman 2008). It is also shown that the inventive output of industry is the larger and the economy is the closer to the perfect frontier of innovation capacity the stronger are linkages between science and business and the faster ideas developed at universities reach enterprises (Adams et al. 2006; Adams, Clemmons 2013).

It is therefore an important question how fast academic science leaks to economy. According to common expectations, knowledge of university origin should diffuse more quickly than knowledge coming from company laboratories. It stems mainly from the fact that scientific researchers are interested in rapid dissemination of the results of their studies (Stephan 2004) while enter-

prises tend to protect access to their own know-how (Furman, Stern 2004). So far as academic knowledge itself is concerned, the results of studies included in scientific publications should be more quickly transferred to enterprises than ones included in patent publications because scientific publications become public knowledge faster than patent ones do. In most countries, complete information about an invention is disclosed only after patent protection has been granted (Baughn et al. 1997; Cohen et al. 2002; Wachowska 2015), which results in time of knowledge diffusion from patents being extended by the time of exclusive rights granting procedure. Considering that in many countries patent procedure takes about 3 to 8 years (Niklewicz-Pijaczyńska 2015) and sometimes it extends to as long as about 10 years, the diffusion of academic knowledge from patents may take 3 years longer than in the case of knowledge diffusion from publications.

Although the diffusion of basic research stimulates innovativeness and economic growth, there are relatively few studies addressing the problems of the rate of knowledge diffusion, including that of university knowledge. Moreover, in most of them, authors focus on indicating the factors that are stimulants for or obstacles to the rate of *know-how* diffusion rather than on estimating this rate. Meanwhile, those which make attempts at measuring the rate of diffusion of new ideas yield fairly different results.

The study by Griliches (1957), in which the author undertook the measurement of the rate of knowledge diffusion by estimating time needed by American farmers to adopt hybrid corn, may be regarded as pioneering. Mansfield was also occupied with the problem of the rate of knowledge leakage and he analyzed the causes of lags in the adoption of diesel locomotive by American companies. Mansfield also made an attempt at estimating the rate of diffusion of various types of technological knowledge of enterprises to their competitors (1985) and he found that information on development decisions leaks to the rivals within 12 to 18 months while information on a new product does so within one year. Studies aimed at estimating the rate of industrial knowledge diffusion were also conducted by Adams, Clemmons and Stephan (2006), according to whom industrial knowledge diffuses between enterprises within 3.3 years and by Adams and Clemmons (2013) who showed that lags between basic research and inventions of enterprises are about 11 to 16 years. Sorenson and Singh (2007), meanwhile, argue that the number of years necessary for industry-generated inventions to diffuse depends on what type of knowledge they are based on. According to them, inventions based on university science diffuse faster than any other ones.

So far as the measurement of the rate of academic knowledge is concerned – depending on the research period and the entities covered by the analysis – the conclusions from the research are fairly different. According to Adams (1990),

the absorption of the effects of university research by industry takes 20 years, Branstetter and Ogura (2005) estimate it to take 16.67 years while Adams et al. (2006) find that 3 years are enough for the knowledge from universities to leak to industry.

Problems of the rate of knowledge diffusion were also addressed by other researchers (Scotchmer 1991; Henderson, Cockburn 1996; Mansfield et al. 1981) but they focused mainly on factors stimulating and delaying adoption of new knowledge rather than on estimating the rate of transfer of know-how.

It must be also emphasized that the majority of studies on the rate of knowledge diffusion are limited to the United States. In the Polish literature on the subject there is a lack of works to address the problems of the rate with which knowledge originating from universities is transferred to enterprises. This paper contributes to the debate on the efficiency in the area of relationships between science and industry by proposing research focused on the rate of diffusion of academic knowledge among enterprises in the conditions of Polish economy.

The purpose of this paper is to indicate how fast knowledge developed in academic laboratories is transferred to enterprises located in Poland. The paper considers three questions: (1) how fast does academic knowledge leak to industry? and (2) how fast does academic knowledge diffusion occur in comparison with industrial one?, (3) what are differences between the rates of knowledge diffusion from academic papers and patents? and (4) what are differences between the rates of diffusion of foreign and domestic academic knowledge?

In order to address these questions, firstly the rate of diffusion of academic knowledge has been estimated with the use of “lags” in patent citations, defined as the difference between the year of the first filing of the citing industrial invention for protection and the year of the first filing of a cited invention or the date of a cited academic publication. More specifically, patent documents of enterprises have been analyzed with the focus on how many years passed from the moment in which a given academic invention had been filed for patent protection or a given scientific paper had been published up to the moment in which they were cited in a patent application by an enterprise located in Poland. Further – based on lags between citing and cited industrial patents – the rate of science diffusion has been compared with the rate of industrial knowledge diffusion. Subsequently, based on lags between citing industrial patents and cited academic patents, the rate of academic knowledge diffusion from papers has been compared with the rate of academic know-how diffusion from patents. And ultimately – with the use of lags between citing patents of enterprises and cited domestic academic papers and patents as well as foreign academic papers and patents – a comparison has been made between the rates of domestic and foreign academic knowledge.

The paper uses a unique database developed by the author that combines the characteristics of cited academic papers and patents with the characteristics of citing industrial patents. Patent documents have been analyzed 22 enterprises filing their inventions for patent protection in Poland which showed the largest inventive activity in years 2005-2011. A total of 413 patent applications have been analyzed which related to protection rights to inventions granted by the Polish Patent Office (UPRP) in years 2005 to 2011.

Because of the fact that Poland is at a different stage of development than the United States, Japan or many EU countries and occupies a distant place in international competitiveness rankings, which results in Polish enterprises being absent from the rankings of world leaders of innovation, the study has covered a relatively small number of enterprises (22). This is due to the fact that in Polish conditions enterprises obtain relatively few patents. For instance, the most active enterprises in terms of innovation received on average from 1.6 to 10 patents a year in 2005-2011 while the enterprise occupying the 22nd place received as few as 0.3 patents a year. Hence including taking further enterprises in the analysis would probably not change the final results which have been based on 22 enterprises only.

1. Measurement of the rate of knowledge diffusion with the use of „lags” in patent citations

Patent documents, by providing various characteristics pertaining to inventors and their inventions, are a valuable source of information on knowledge diffusion. Patent applications disclose, among other things, details of the entity that has received exclusive rights to an invention, the creators of the invention, the number of years of protection paid by the entity eligible to the patent, and finally the detailed information on inventors and their publications (patent and scientific) whose knowledge has been an inspiration to generate the invention. In particular, the latter information is helpful in estimating the size and strength of know-how diffusion and Jaffe et al. (1993) were the first to use it to do this.

A patent application lets us know, among other things, (1) to whom the invention of scientific paper cited in this application belongs, (2) whether the cited invention or publication has been developed in an enterprise, university laboratory or other R&D entity, (3) in which country the entity that is the creator of the cited invention/publication is located, (4) in which year and what country the cited invention was filed for patent protection for the first time as well as (5) in which year the cited publication was published. If we compile these data with the information on the year of filing of the „citing” invention for patent protection then it will be possible to estimate the „lag” in patent citations, i.e. the rate of knowledge diffusion from the cited researcher to the citing one, including its division into the rates of knowledge diffusion from enterprises and universities.

Although the use of patent citations for the measurement of the magnitude or the rate of knowledge diffusion has some limitations, this method is considered to be one of the best. It is so in the first place because – unlike other methods based on citations – there is little probability that creators of inventions will conceal the work of others on which they based their technical solutions – since this would expose them to legal sanctions – or that they will show irrelevant knowledge – since then they would reduce the extent of patent protection. Moreover, patent citations reflect the most valuable knowledge, the most precious know-how of the researchers. This is because they disclose only this transfer of knowledge which contributes to the development of breakthrough innovations, i.e. inventions, which means that they make it possible to evaluate the actual diffusion of knowledge rather than only the diffusion of imitation processes.

In spite of its advantages, the method of patent citations is not perfect. Firstly, some citations in patent descriptions are included by patent researchers, which means that in fact the inventor did not use the cited knowledge (Azoulay et al. 2011; Alcacer et al. 2009; Alcacer, Gittelman 2006). Secondly, patent citations do not reflect flows of more private knowledge, obtained in an informal way, which has not left its trace „on paper” (Roach, Cohen 2012). Finally, because of the fact that not all innovations are being patented, patent citations are only a partial measure of knowledge flows.

In order to determine the average number of years needed by enterprises from Poland to acquire academic knowledge, the paper uses „lags” in citations included in patent applications of 22 enterprises relating to protection rights to inventions which were granted by UPRP in 2005-2011.

2. Rate of adoption of academic knowledge by enterprises from Poland: analysis of research results

On the basis of an analysis of 413 patent applications of 22 enterprises filing their inventions for patent protection in Poland it may be concluded that knowledge of university origin diffuses among the enterprises covered by the study faster than knowledge created in industrial laboratories (Table 1). This finding is consistent with the expectations and results of analogical studies for other national economies.

Table 1. Adoption times of academic and industrial knowledge by enterprises from Poland

Enterprise	Total number of patents	Average number of years of academic knowledge acquisition	Average number of years of industrial knowledge acquisition	Average number of years of knowledge acquisition in total
ABB Sp. z o.o.	70	11,69	14,84	14,28
Polin Sp. z o.o.	35	14,22	11,60	11,84
Pioma S.A.	34	33,00	14,92	17,18

Zakłady Azotowe Puławy S.A.	31	12,31	21,38	19,52
Sigma S.A.	36	17,75	9,33	9,92
KGHM Cuprum Centrum B+R	27	3,00	7,33	6,25
Zelmer S.A.	12	-	9,77	9,77
Rybnicka Fabryka Maszyn Ryfama S.A.	8	-	13,6	13,60
Apator S.A.	12	15,75	12,05	12,69
Dozut-Tagor Sp. z o.o.	18	16,00	8,3	9,00
Seco/Warwick S.A.	8	6,4	8,27	7,87
Zakłady Mechaniczne Pamet Sp. z o.o.	4	-	12,40	12,40
Południowy Koncern Ener- getyczny S.A.	18	9,0	13,00	12,60
KGHM Polska Miedź S.A.	8	-	12,25	12,25
Przedsiębiorstwo Farmaceu- tyczne Jelfa S.A.	6	-	-	-
Bombardier Transportation (ZWUS) Polska Sp. z o.o.	23	1,00	11,55	11,00
Zabrzeńskie Zakłady Mechaniczne S.A.	14	-	7,11	7,11
Fabryka Okuć Meblowych Stalmot Sp. z o.o.	3	-	11,33	11,33
ICSO Chemical Production Sp. z o.o.	14	10,4	18,30	17,26
Zakłady Organiczne Organi- ka-Sarżyna S.A.	8	9,7	21,61	14,87
Fabryka Zmechanizowanych Obudów Ścianowych FAZOS S.A.	13	15,00	15,00	15,00
Becker-Warkop Sp. z o.o.	11	7,00	8,00	7,84
Enterprises totally	413	11,93	13,63	13,39

The average lag between the academic science and the inventiveness of enterprises in the period under study was 11.93 years while industrial knowledge took 13.63 years to diffuse into enterprises (Table 1). It should be emphasized here that the time of adoption of know-how of the others – coming both from academic centers and company laboratories – varies, sometimes significantly, between enterprises and also that diffusion of academic knowledge among several enterprises occurred slower than in the case of industrial knowledge, which is an unusual phenomenon.

The analysis of patent documents from Poland made it also possible to formulate the conclusion that – contrary to common expectations – university knowledge from publications diffuses among the entities covered by the study slower than knowledge from patents. On average, the former has taken 12.45 years and the latter 11.62 years to reach enterprises. Moreover, in the case of the strong majority of enterprises it was academic knowledge coming from scientific publications that has taken a longer time to acquire (Table 2).

Table 2. Adoption time of academic knowledge from publications and patents by enterprises from Poland

Enterprise	Total number of patents	Average number of years of academic knowledge acquisition from publications	Average number of years of academic knowledge acquisition from patents	Average number of years of academic knowledge acquisition in total
ABB Sp. z o.o.	70	11,28	11,87	11,69
Polin Sp. z o.o.	35	-	14,22	14,22
Pioma S.A.	34	34,00	32,00	33,00
Zakłady Azotowe Puławy S.A.	31	14,78	9,14	12,31
Sigma S.A.	36	25,5	10,00	17,75
KGHM Cuprum Centrum B+R	27	-	3,00	3,00
Zelmer S.A.	12	-	-	-
Rybnicka Fabryka Maszyn Ryfama S.A.	8	-	-	-
Apator S.A.	12	-	15,75	15,75
Dozut-Tagor Sp. z o.o.	18	-	16,00	16,00
Seco/Warwick S.A.	8	1,00	7,75	6,4
Zakłady Mechaniczne Pamet Sp. z o.o.	4	-	-	-
Południowy Koncern Energetyczny S.A.	18	6,00	12,00	9,0
KGHM Polska Miedź S.A.	8	-	-	-
Przedsiębiorstwo Farmaceutyczne Jelfa S.A.	6	-	-	-
Bombardier Transportation (ZWUS) Polska Sp. z o.o.	23	1,00	-	1,00
Zabrzeńskie Zakłady Mechaniczne S.A.	14	-	-	-
Fabryka Okuć Meblowych Stalmot Sp. z o.o.	3	-	-	-
ICSO Chemical Production Sp. z o.o.	14	-	10,4	10,4
Zakłady Organiczne Organika-Sarzyna S.A.	8	10,08	8,5	9,7
Fabryka Zmechanizowanych Obudów Ścianowych FAZOS S.A.	13	-	15,00	15,00
Becker-Warkop Sp. z o.o.	11	-	7,00	7,00
Enterprises totally	413	12,45	11,62	11,93

The above findings suggest that – although the access to scientific publications is faster than to patent publications – industry representatives base their inventiveness to a greater extent on earlier academic inventions than scientific papers and it is these, and not publications, which are more valuable for them. Considering the fact that the most effects of R&D efforts of academic researchers are disseminated through scientific papers, it may be concluded that a large part of scientific output of academic centers never reaches economic practice.

Finally, on the basis of the conducted analysis of patent documents it may be said that enterprises from Poland take much longer to acquire knowledge of domestic than foreign origin. The average lag between the science of Polish academic centers and the inventiveness of enterprises was 12.87 years while in the case of academic knowledge of foreign origin that indicator was 9.96 years. This means that in Polish conditions geographic proximity is irrelevant to the rate with which academic knowledge is transferred to enterprises as it is emphasized in many theoretical and empirical publications. It may also mean that foreign knowledge coming from foreign research centers is more valuable than domestic one for enterprises from Poland.

Conclusions

The rate with what academic knowledge leaks to the economy influences innovativeness and competitiveness of enterprises. Keeping this in mind, the purpose of the paper has been to estimate the number of years that pass from the moment of making knowledge originating in academic centers public to the moment in which this knowledge is used by enterprises in the process of invention.

The main conclusion that comes to mind from this paper is that the patterns of academic knowledge acquisition by Polish enterprises largely differ from the world trends. The only finding consistent with other studies is that science diffuses faster than technology. The diffusion of academic knowledge among enterprises takes 11.93 years and takes on average about 2 years less than in the case of diffusion of industrial knowledge.

It is interesting, however, that university knowledge from patents diffuses faster (within 11.62 years) than from scientific papers (12.45 years). The above findings suggest that inventors from enterprises reach for scientific papers to a lesser extent than for academic patents. Taking into account that the vast majority of the effects of university R&D work is disseminated through publications, it also means that a large part of scientists' work is wasted because it never reaches economic practice. Therefore, state policies should include on the one hand instruments encouraging entrepreneurs to become interested in scientific publications and on the other hand ones motivating academic researchers to make inventions that meet the needs of industry.

It is also atypical that academic knowledge of foreign origin on average diffuses to enterprises covered by the study faster (within 9.96 years) than knowledge of domestic origin (within 12.87 years). This is due to the fact that, because of cultural and geographic proximity, domestic knowledge tends to be the fastest to diffuse. In Polish conditions, however, such tendency may be justified. Probably, Polish enterprises prefer to reach for foreign scientific achievements because it is other countries and not Poland which are world leaders of innovation. When it is taken into account, however, that there are many world-class

Polish technical solutions and at the same time they are better suited for use in the Polish reality, then state policies should put greater emphasis on tightening the relationships between science and business in order to make industry representatives more appreciate the work of Polish academic researchers.

The results of these analyses can be useful for future research which could focus on the estimation of differences in the rate of academic knowledge diffusion between particular sectors and areas of science as well as on the attempt at answering the question of what do these differences result from. Moreover, further research could shed more light on geographical directions from which Polish enterprises acquire knowledge the fastest. And finally, further research could extend this analysis by the rate of academic knowledge diffusion among not only enterprises but also other scientific researchers. To this end, lags should be measured between citing and cited scientific publications as well as between citing academic patents and cited academic publications.

References

- Adams, J.D. (1990), Fundamental stocks of knowledge and productivity growth, *Journal of Political Economy*, 98(4): 673-702.
- Adams, J.D., Clemmons, J.R. (2013), How rapidly does science leak out? A study of the diffusion of fundamental ideas, *Journal of Human Capital*, 7(3):191-229.
- Adams, J.D., Clemmons, J.R., Stephan, P.E. (2006), How rapidly does science leak out?, NBER Working Paper Series, No. 11997.
- Alcacer, J., Gittelman, M. (2006), Patent citations as a measure of knowledge flows: The influence of examiner citations, *The Review of Economics and Statistics*, 88(4): 774-779.
- Alcacer, J., Gittelman, M., Sampat, B.N. (2009), Applicant and examiner citations in U.S. patents: An overview and analysis, *Research Policy*, 38(2): 415-427.
- Azoulay, P., Graff Zivin, J.S., Sampat, B.N. (2011), The diffusion of scientific knowledge across time and space: Evidence from professional transitions for the superstars of medicine, NBER Working Paper Series, no. 16683.
- Baughn, C.C., Bixby, M.L., Woods, S. (1997), Patent laws and the public good: IPR protection in Japan and the United States, *Business Horizons*, 40(4): 59-65.
- Branstetter, L., Ogura, Y. (2005), Is academic science driving a surge in industrial innovation? Evidence from patent citations, NBER Working Paper Series, no. 11561.
- Cohen, W.M., Goto, A., Nagata, A., Nelson, R.R., Walsh, J.P. (2002), R&D Spillovers, patents and the incentives to innovate in Japan and the United States, *Research Policy*, 31(8-9): 1349-1367.
- D'Este, P., Perkmann, M. (2011), Why do academics engage with industry? The entrepreneurial university and individual motivations, *Journal of Technology Transfer*, 36(3): 316-339.

- Furman, J.L., Stern, S. (2004), Climbing atop the shoulders of giants: The impact of institutions on 24 cumulative research, Working Paper, Boston University and Northwestern University.
- Griliches, Z. (1957), Hybrid corn: An exploration in the economics of technical change, *Econometrica*, 25(4): 501-522.
- Henderson, R., Cockburn, I. (1996), Scale, scope, and spillovers: the determinants of research productivity in drug discovery, *RAND Journal of Economics*, 27(1): 32-59.
- Jaffe, A.B., Trajtenberg, M., Henderson, R. (1993), Geographic localization of knowledge spillovers as evidenced by patent citations, *Quarterly Journal of Economics*, 108(3): 577-598.
- Kim, J., Lee, S.J., Marschke, G. (2005), The influence of university research on industrial innovation, NBER Working Paper Series, no. 11447.
- Lach, S., Schankerman, M. (2008), Incentives and invention in universities, *RAND Journal of Economics*, 39(2): 403-433.
- Link, A.N. Siegel, D.S. (2005), Generating science-based growth: An econometric analysis of the impact of organizational incentives on university-industry technology transfer, *European Journal of Finance*, 11(3): 169-181.
- Macgarvie, M., Furman, J.L. (2005), Early academic science and the birth of industrial research laboratories in the U.S. pharmaceutical industry, NBER Working Paper Series, No. 11470.
- Mansfield, E. (1985), How rapidly does new industrial technology leak out?, *The Journal of Industrial Economics*, 34(2): 217-223.
- Mansfield, E. (1963), Intra-firm rates of diffusion of an innovation, *The Review of Economics and Statistics*, Vol. 45, no. 3: 348-359.
- Mansfield, E., Schwartz, M., Wagner, S. (1981), Imitation costs and patents: An empirical study, *The Economic Journal*, 91: 907-918.
- Monjon, S., Waelbroeck, P. (2003), Assessing spillovers from universities to firms: Evidence from French firm-level data, *International Journal of Industrial Organization*, 21(9): 1255-1270.
- Motohashi, K. (2005), University-industry collaborations in Japan: The role of new technology-based firms in transforming the national innovation system, *Research Policy*, 34(5): 583-594.
- Niklewicz-Pijaczyńska, M. (2015), Commercialization of research results: Effectiveness of the patent system, in: (Eds.), Loster T., Pavelka T., *The 9th International Days of Statistics and Economics: Conference Proceedings*, Prague: 1191-1200.
- Nilsson, A.S., Rickne, A., Bengtsson, L. (2010), Transfer of academic research: Uncovering the grey zone, *Journal of Technology Transfer*, 35(6): 617-636.
- Roach M., Cohen, W.M. (2012), Lens or prism? Patent citations as a measure of knowledge flows from public research, NBER Working Paper Series, No. 182292.
- Roessner, D., Bond, J., Okubo, S., Planting, M. (2013), The economic impact of licensed commercialized inventions originating in university research, *Research Policy*, 42(1): 23-34.

- Rosenberg, N., Nelson, R.R. (1994), American universities and technical advance in industry, *Research Policy*, 23(3): 323-348.
- Scotchmer, S., Standing on the shoulders of giants: Cumulative research and the patent law, *Journal of Economic Perspectives*, 5(1): 29-41.
- Sorenson, O., Singh, J. (2007), Science, social networks and spillovers, *Industry and Innovation*, 14(2): 219-238.
- Stephan, P.E. (2004), Robert K. Merton's perspective on priority and the provision of the public good knowledge, *Scientometrics*, 60(1): 81-87.
- Wachowska, M. (2015), The role of the Polish patent system in knowledge diffusion, in: *Strategic guidelines of Ukraine's economy development*, Materials of 2nd international scientific internet-conference of students, postgraduates and young researches, Ivan Franko National University of L'viv, L'viv: 6-7.