European Insurance Markets in Face of Financial Crisis: Application of Learning Curve Concept as a Tool of Insurance Products Innovation – Discussion

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Abstract: The paper aims to present the results of an assessment of development of insurance sector in chosen European countries like Poland, UK, Germany and France over the financial crisis especially from product's innovation point of view. The comparison between the level of taxonomic measures in two points in time let the Authors to write main conclusion that insurance markets have been not so innovative in chosen countries. The level of innovations have been especially law in terms of insurance offer (Products). The first part of the paper ends with a short description of so called new risks that impose a level of innovations within an insurance sector. The second part contains a discussion about possibility of using learning curve concept for the process of insurance product innovation especially products "*without claims history*".

Keywords: Multidimensional data analysis, insurance innovation, new risks, insurance markets.

1. INTRODUCTION

Innovation is key issue in the global economy when problems became more difficult than ever. Talking about innovations we primary think about new technology, new methods of production. However innovation also refers to broadly understood insurance sector. Within the activity of an insurer innovation could concern a number of spheres such as distribution channels, methods of selling insurance, claim management, risk analysis, investment et. Nevertheless in face of globalization and presents of new threats (we discuss it later in the text) we think that one of the most important activity of an insurer which should be innovative is insurance offer. We defined insurance offer as set of products could be used to handle risk face by individual or companies. Thinking about insurance offer we all familiar with for example motor insurance, third party insurance, fire insurance etc. In our opinion taking into account overall progress of human being in terms of new threats impose by science or new technology development insurance companies have to propose new, advanced products to cover such a new risk. The innovative activity we think about should focus on helping an entrepreneurs, individuals or corporation to handle risk and to support further gradual advancement. This paper presents the results of a study on innovation of insurance markets in chosen European countries and application of management accounting in the context of innovation within insurers' products portfolio. The innovation consists in offering insurance to entrepreneurs who wish to expand their businesses following principles of sustainable development and innovative product creation.

Product innovations give the insurer an opportunity to play an important role in contribution to sustainable development on a macroeconomic scale, or even more – on the global scale. We are convinced that at the age of innovation, the insurance sphere, cannot remain insensitive to the need for innovation not only in the area of insurance operation of companies, but also in the area of products. Innovations within an insurance sector become even more important in terms of incising competition on the markets. An innovative offer can maximize an insurer's revenue and profits.

This is due to a special insurance offer within areas of innovation supporting sustainable development. At the same time, in the global world the significance of so called "new" risks such as the risk of nanotechnology or digital risk is more important and causes the need for modifications of the existing insurance cover.

The discussion provided by the authors is illustrated by the examples related to production based on nanotechnology, which is said to be "*the future that begins today*." [1]

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[1]http://www.nano-technologie.pl/, accessible as of: 2014-01-12.

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The problem is considered important for every insurance company which is innovative in such a way. The weight of the problem lies mainly in the fact that insurance products or innovative actions are characterized by elevated risks which are very difficult to handle. It results from the fact that the insurance cover of unique risks has to be concluded in situations where the insurance companies do not have any historical data to accurately quantify risk.

The significance of the problem grows if it is taken into account that the innovative product of an insurance company's client should serve the purpose of sustainable development. This requirement imposes on an insurance company the necessity for a perfect diagnosis of a wide range of important conditions for sustainable development on a scale far greater than just the client area. In addition, these conditions are closely related to the future, when the consequences of the introduction of innovative products are not easy to predict. The problem of sustainable development, even where products already known on the market (with the market history) is concerned, is very complex. In the case of innovative products the problem becomes even more complex, and – in view of this – we search for tools to help to diagnose various risk factors which appear particularly clearly when innovation and products are to be insured, with a potential threat to sustainable development. The innovation and sustainability pose a complex intersection and interaction for insurers, mainly because there are a number of axes and dimensions of risk and event uncertainty.

2. EVALUATION OF INSURANCE MARKET DEVELOPMENT IN FACE OF FINANCIAL CRISIS

Since 2007 the European financial market, which includes the insurance sector, has been in a serious crisis whose consequences are discernible in the whole economy. The entities interested in activities connected with overcoming the crisis are more and more active suggesting different solutions. An example to be quoted is the Communication from the European Commission "EUROPE *2020.* A Strategy for Smart, Intellectual and Sustainable Inclusive Growth." The construction of this document as a strategy is based on three priorities: intelligent development, sustainable development and social inclusion development (Communication from the European Commission 2010:12).

With regard to the insurance risk, it is worth considering the suggested scenarios of overcoming crisis from the perspective of the role which the insurance sector may play in their implementation. Bearing in mind such documents and strategies, it may be worth perceiving the insurance sector not as a lifebelt which, through the product offer, implements the main goal of insurance (the elimination of worries and fears related to the financial effects of random incidents – risk realisation) but as one of many business entities affected by the crisis, a sector component of the financial system. In the next section of the article we present the results of research into the development and innovativeness of the insurance sector. The results empirically confirm a weak innovativeness, especially within an offer through which insurance companies could stimulate economic growth and value creation (Kazuki and Marshall 2016:9). The relation of innovations within financial sector and economic growth has been research by Levine. He concluded that technological innovation and economic growth stop unless financiers innovate (Laeven, Levine and Michalopoulos 2014:29). There are more studies when authors model the relationship between finance and growth. For example papers written by Greenwood and Jovanovic (1990), Levin (1991), King and Levin (1993), Wang (2014) look at how finance influences long-run growth. According to some researchers financial innovation in connection with investors who neglect small risks can induce instability (Gennaioli, Shleifer and Vishny 2012). Henderson and Pearson (20110) find that financial institutions engineered financial products that exploited investors' misunderstanding of the payoffs to these products (Laeven et. Al 2014;4). Although there are a number of studies that show the relation between financial innovations and economic growth it is very difficult to find a study concerning insurance sector. Insurance market is a part of financial markets so the finds should confirm previous study on overall financial sector. Following previous findings we can assume that insurance innovations (especially in scope of products) should have an impact on economic growth and softening an impact of financial crisis. At the same time, as indicated in section 3, there is a growing significance of so-called new risks such as digital risk and nanotechnology or cascading catastrophes related risk. The risk connected with the application of nanotechnology is interesting and challenging for the sector of insurance. The danger and threat created by nanotechnology is relatively new[2].

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[2]The beginning of nanotechnology dates back to the 1950s, when Richard Phillips Feynman delivered a lecture entitled *There's Plenty Room at the Bottom* for the American Physical Society in Pasadena. See example: http://www.pa.msu.edu/~yang/RFeynman_plentySpace.pdf, accessible as of: 2014-01-12.

Insurance companies do not have at their disposal a sufficient number of historical observations allowing for the quantification of such risk. Thus, in the last section of the article we consider a possibility of application of a selected management accounting concept known as *learning curve*. In our opinion this concept may be used in an innovative way in order to support the process of creation of new insurance services allowing for the protection against the realisation of risk whose evaluation in a traditional way is difficult. The presentation of this concept as a tool supporting the evaluation of insurance risk, connected with the insurance protection of innovative companies applying high tech production technologies, is preceded by the results of research conducted in the SGH-Warsaw School of Economics-Department Risk and Insurance showing a low level of product innovativeness of insurance sector in Poland and in Europe.

2.1. The Description of Research and Methodology Applied

This study uses two groups of measures: the distance measure and similarity measure. Measure μ describing the degree of similarity between dimension structures of the two objects is defined by the following equation:

$$\mu_{i,p} = \frac{z_i \, {}^o z_p}{|z_i||z_p|}$$

Where: $z_i \, {}^o z_p$ denotes the scalar multiple of vectors z_i and z_p containing all dimensions of the particular objects and $|z|$ the length of the vectors. This means that the value of the μ is between -1 and 1 as the scalar multiple is the cosine of the angle between the vectors.

The measure of similarity of objects dimensions d*(i,p) is defined by the following equation:

$$d^*(i,p) = 1 - \frac{1}{2\sqrt{kn}} * d(i,p),$$

$$0 \le d^*(i,p) \le 1$$

where: k denotes the number of objects and n denotes the number of dimensions, is a normalized version of the differentiation of objects' dimensions d(i,p).

$$d(i,p) = \sqrt{\sum_{i=1}^{k} (z_{i,i} - z_{i,p})^2}$$

where: d_{ip} denotes the distance between objects i and p and $z_{ij} z_{pj}$ the values of dimension j of object i and p respectively.

We have conducted the research by means of the multidimensional statistical analysis. The comparative approach made use of taxonomic procedures. The analysis of the development of the insurance sector was conducted in relation to four groups of features: *market structure, technical sphere, finance and investment, effectiveness, products* (see Figure **1**). In each group there was a set of diagnostic features. We created the database including the implementation of selected diagnostic features in the years 1997 and 2010. Eventually, we have decided about the number of features after the analysis of correlations between them; whereas the point of observation was determined on the basis of the implementation of features from all the groups.

This part of the paper is aimed at the demonstration of the lack of insurance product innovation. That is why we do not present a detailed description of all groups. The market structure group includes diagnostic features like the number of insurance entities, speed of changes within this number, the market share of the biggest insurers, market concentration, the number of people employed by insurers or the presence of foreign

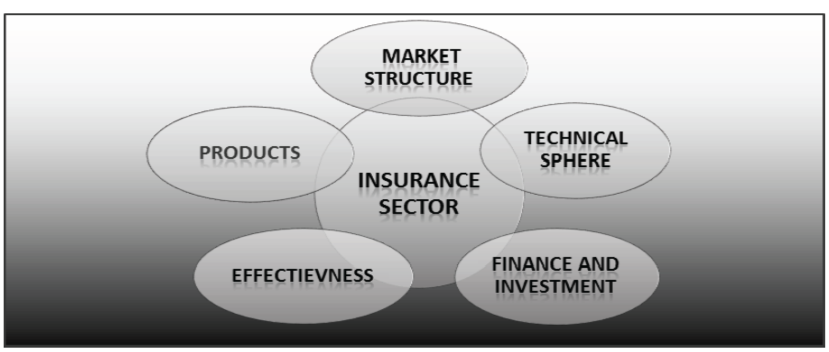


Figure 1: Groups of features used in the study.
Source: Authors' own material.

insurers in the market. The technical sphere refers to the insurance operations. This group includes features like the value of and changes in gross written premium, retention ratio, share of European countries in total gross written premium, divided into non-life and life insurance as well as the reinsurance ratio. The finance and investment group is represented by features like the value of total insurance investments in the European countries, relation between investment and gross written premium or changes in investment level between 1997 and 2010 (separate for non-life and life insurers). The effectiveness represents features that could be used to assess the development of the insurance sector from the macro perspective. In that group we have included features like the share of gross written premium in GDP, relation between insurers investment to GDP, gross written premium per capita separately for nonlife and life insurance. The most important from the perspective of the main aim of the paper is group called PRODUCTS (Group E, at the chart below). There are fifteen features included in it. The features are listed in the table below:

2.2. Results – Lack of Product Innovation within the Insurance Sector

We have made the assessment of sector development directions in the selected years of the analysed period. The reference object (benchmark) was set for comparison. In our case the benchmark based on algorithms was set within the group of experts and presented by well-known statisticians (Z. Hellwig), separately for individual kinds of diagnostic features. In the case of stimulants the benchmark was calculated as a diagnostic feature of the maximum value in the analysed period increased by a standard deviation for the whole time series. In the case of destimulants the benchmark value is 0 or minimum value decreased by a standard deviation, depending on which of the two values is higher. The benchmark for nominants is set as an average value increased by a standard deviation or median depending on the character of the feature and the number of available observations. We have used the radar charts in order to maintain the clarity of the presentation. The chart axes are the analysed groups (in the case of sector analysis). Thus, A stands for market structure; B for technical sphere; C for finance and investment, D effectiveness and E - products. The results of calculation for the measure of differentiation of levels d* and structure similarity μ* are presented in charts below respectively. The results for Poland and chosen EU countries are presented in graphs below.

For the clarity of the presentation we have also decided to present the value of used measures in tables below. The values of measures refer to 1997 and 2010 respectively.

Table 1: The Diagnostic Features Included into PRODUCTS Group

Symbol	Name of the feature
E1	Motor insurance gross written premium per capita
E2	Growth of motor insurance premium
E3	Share of motor insurance premium in total non-life insurance premium
E4	Health insurance premium per capita
E5	Growth in health insurance premium
E6	Share of health insurance premium in total nonlife insurance premium
E7	Property insurance per capita
E8	Growth of property insurance
E9	Share of property insurance premium in total nonlife insurance premium
E10	Liability insurance premium per capita
E11	Growth in liability insurance premium
E12	Share of liability insurance premium in total nonlife insurance premium
E13	Marine, air and cargo insurance premium per capita
E14	Growth in marine, air and cargo insurance premium
E15	Share of marine, air and cargo insurance premium in total nonlife insurance premium

Source: Authors' own material.

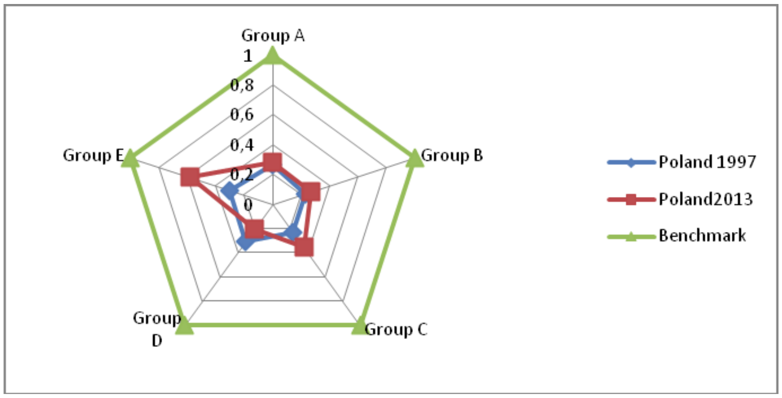


Figure 2: Measure of structure similarity μ* for Poland.

Source. Authors' own calculations.

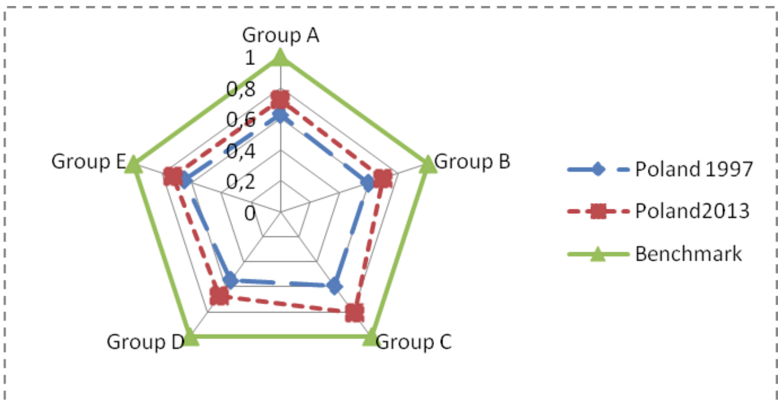


Figure 3: Measure of differentiation of levels d* for Poland.

Source. Authors' own calculations.

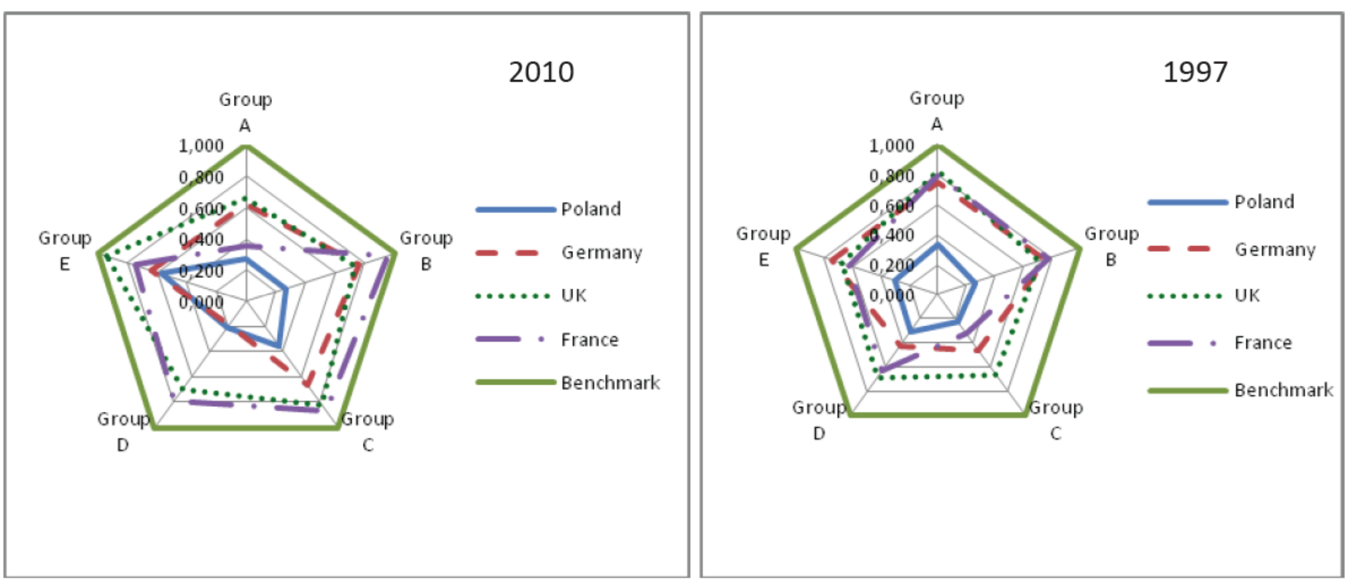


Figure 4: Measure of structure similarity μ* for Poland and chosen EU countries in 1997 and 2010.

Source. Authors' own calculations.

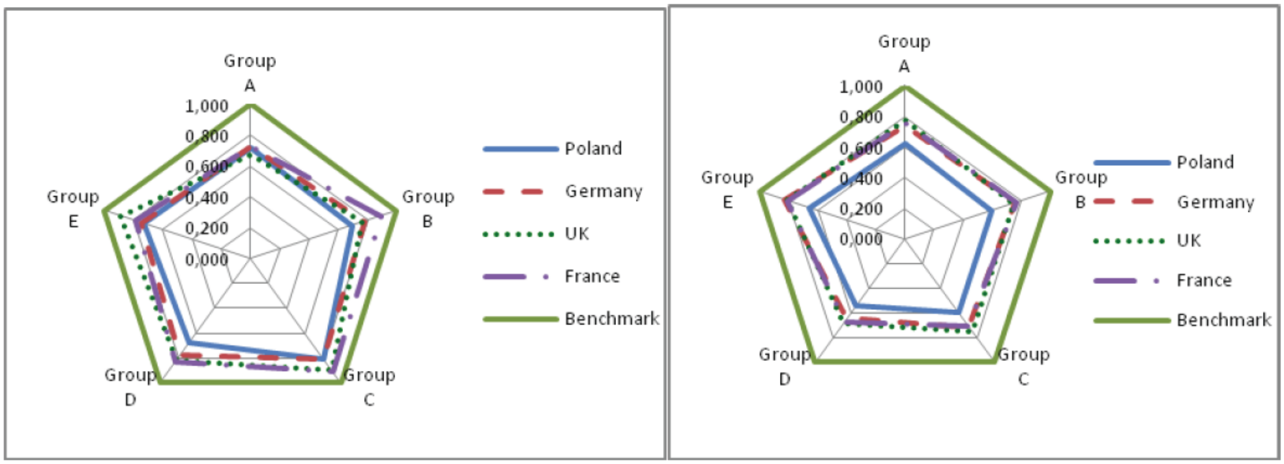


Figure 5: Measure of differentiation of levels d* for Poland and EU chosen countries in 1997 and 2010.
Source. Authors' own calculations.

Table 2: Measure of Structure Similarity μ* for Poland

	Group A	Group B	Group C	Group D	Group E
Poland 1997	0.2629	0.2293	0.234	0.3054	0.3006
Poland 2010	0.2773	0.2662	0.359	0.2050	0.5790
Benchmark	1	1	1	1	1

Source: Author's own calculations.

Table 3: Measure of Differentiation of Levels d* for Poland

	Group A	Group B	Group C	Group D	Group E
Poland 1997	0.6270	0.5972	0.5962	0.5429	0.6564
Poland 2010	0.7209	0.693	0.8116	0.6732	0.7309
Benchmark	1	1	1	1	1

Source: Author's own calculations.

Table 4: Measure of Structure Similarity μ* for Chosen EU Countries

2010	Group A	Group B	Group C	Group D	Group E
Poland	0.277	0.266	0.359	0.205	0.579
Germany	0.622	0.765	0.663	0.189	0.640
UK	0.658	0.734	0.829	0.701	0.946
France	0.361	0.956	0.870	0.784	0.753
1997	**Group A**	**Group B**	**Group C**	**Group D**	**Group E**
Poland	0.335	0.263	0.229	0.305	0.301
Germany	0.747	0.757	0.465	0.428	0.747
UK	0.830	0.720	0.662	0.692	0.677
France	0.793	0.782	0.323	0.631	0.621
Benchmark	1	1	1	1	1

Source: Author's own calculations.

Table 5: Measure of Differentiation of Levels d* for Chosen EU Countries

2010	Group A	Group B	Group C	Group D	Group E
Poland	0.721	0.693	0.812	0.673	0.731
Germany	0.730	0.781	0.805	0.779	0.751
UK	0.679	0.765	0.893	0.819	0.887
France	0.724	0.893	0.909	0.832	0.785
1997	**Group A**	**Group B**	**Group C**	**Group D**	**Group E**
Poland	0.627	0.597	0.596	0.543	0.656
Germany	0.738	0.758	0.715	0.645	0.828
UK	0.774	0.750	0.753	0.680	0.809
France	0.756	0.764	0.703	0.668	0.808
Benchmark	1	1	1	1	1

Source: Author's own calculations.

The analysis of aforementioned results show the lack of significant changes in similarities of both structure and level differentiation. In Poland in the analysed period, within the structure similarities the most important change occurred in group E i.e. products. However, it is not possible to speak about considerable product innovations which can change the structure in the product group. A simultaneous analysis of the same measure in selected European countries allows for the conclusion that the Polish insurance market has adjusted to such developed markets as the German or French market. Generally, in the selected European countries there were no changes in structure similarity or level differentiation. The British market is an exception; in group E it has most closely approached the reference object concerning the structure similarity and level differentiation. The present economic situation and the turbulence on financial markets required more radical changes from insurance entities, which are composition elements of these markets.

The lack of significant changes in the structure and the sphere of products allows for the conclusion indicating a weak innovativeness of the insurance sector, especially in the sphere of products. This gives rise to considerations and search for the methods or tools which could be used in the process of motivation and support the pursuit of innovative activities. It seems that in the insurance sector the lack of innovativeness results from the fact that the persons responsible for the development of the sector have not noticed yet the significance of the problem. For example to the growing importance of so-called new risks. As indicated before, the available statistical data are not sufficient enough to evaluate and quantify the risk. That is why, in the following section we will discuss the characteristic features of so-called new risks and then we will present a method to support insurance companies' product innovations in contexts of innovation and sustainability.

2.3. New Risks Faced by the Insurance Market

The research results presented above indicate a low level of innovativeness of the insurance sector, especially in terms of products. Slight changes in the analysed features' structure similarity, as well as differentiation of level in the examined period, occurred practically in all insurance markets considered. Weak level of products innovation is not the domain of Polish market, which is perceived as a developing market. It may be stated that in the period of last several dozen years the Polish market has approached developed markets such as German, French or British market. Ongoing globalisation makes so-called new risks increasingly crucial.

The observation of events occurring in the world, analysing the literature and research conducted by prestigious university or business institutions, allows for the distinguishing of three groups of risk with a significant growth in the degree of their realisation. These risks are relatively new; it is difficult to make use of traditional methods of quantification, applying (for example) the probability of realisation as a basic risk measure. And due to the lack of sufficient statistical data concerning the past, it is impossible to assess the intensity of risk realisation in such cases as digital risk, cascading catastrophe risk or nanotechnology risk[3].

Digital risk is not understood as hacking attacks and computer assisted frauds, but the centralisation of data in connection with the change of likes and dislikes of consumers and the common application of devices not possessing their own hard disks (i.e. "the cloud"). The risk of cascading catastrophes consists in enormous accumulation of damage caused by a catastrophic event. An example to quote may be an earthquake in Japan and the Fukushima nuclear power plant catastrophe related to it. The area of our interest includes the risk connected with the application of highly advanced production technologies which are well exemplified by the development of nanotechnology. The following section describes the issue more in detail.

There are many definitions of nanotechnology. One of the most popular and useful from the point of view of insurance is the definition presented by K.E. Drexler (Drexler 1986). He defines nanotechnology as "molecular production." The Drexler definition for the first time points to the possibility of implementing production through the use of nanotechnology. The word "nanotechnology" was coined by Nori Taniguchi, a Japanese scientist (Taniguchi 1974). He defined nanotechnology as a production technology allowing for extraordinary accuracy of 1nm and exceptionally small sizes. This definition was then extended by the American NASA, claiming that nanotechnology is also a research of new phenomena and physical, chemical, biological and mechanical properties on the nanoscale level (1-100nm)[4]. The innovativeness of nanotechnological solutions was emphasized by the United States' National Nanotechnology Initiative which defined the notion as the perception and control of the matter on the scale from 1 to 100 nanometres, where exceptional phenomena such as new characteristics of materials allow for novel applications. Nanotechnology creates unprecedented possibilities. In future, it may affect many areas of our activity, generating correspondingly enormous threats. According to researchers and persons working on the issue, the most important risks connected with the development of nanotechnology should include[5]:

1. Real Risk: Nanopollutants - nanopollutants are nanoparticles small enough to enter the lungs or to be absorbed by the skin. Nanopollutants can be natural or man-made. Nanoparticles are used in some of the products found on shelves today, like anti-aging cosmetics and sunscreen. The highest risk is to the workers in nanotechnology research and manufacturing processes.

2. Potential Risk: Privacy Invasion - virtually undetectable surveillance devices could dramatically increase spying on governments, corporations and private citizens.

3. Potential Risk: Economic Upheaval (in 5 to 10 years) - molecular manufacturing is the assembly of products one molecule at a time. It could make the same products you see today, but far more precisely and at a very low cost. It is unclear whether this would bring boom or bust to the global economy.

4. Potential Risk: Nanotech weapons (in 10 to 20 years) - Untraceable weapons made with nanotechnology could be smaller than an insect with the intelligence of a supercomputer. Possible nano and bio technology arms race.

5. Far-Fetched Risk: Gray Goo (in more than 30 years) - Free range, self-replicating robots that consume all living matter. However unlikely, experts say this scenario is theoretically possible, but not for some time.

For the time being, it is most crucial to apply nanotechnology in the process of production, especially from the point of view of risk. The application of nanotechnology in the process of production poses a potential threat on three basic planes, i.e. at the stage of the acquisition of modified raw materials, the production proper as well as the use and utilisation of final products by consumers (see Figure **6**).

Companies applying nanotechnology are becoming innovative entities, but innovation creates additional threat for both the entity and the community. The environmental threat is also important. Therefore,

[3]Research published by Oxford University scientists (see: http://www.risk.jbs.cam.ac.uk/) or Lloyd's of London reports(see: *Managing digital risk,* Lloyd's of London, http://www.lloyds.com/news-and-insight/risk-insight/reports/digital/managing-digital-risk) accessible as of 2014-03-13.

[4]http://www.nasa.gov/offices/oce/appel/ask-academy/issues/ask-oce/AO_1-8_F_small.html, accessible as of 2014-03-13.

[5]http://www.futureforall.org/nanotechnology/risks.htm, accessible as of 2014-03-13.

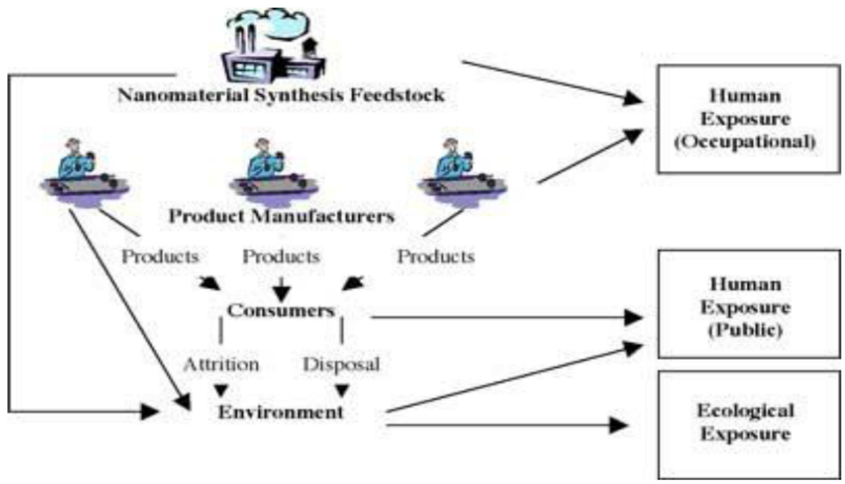


Figure 6: Potential for release of and exposure to nanoscale substances.

Source: Joyce S. Tsuji: "Research Strategies for Safety Evaluation of Nanomaterials, Part IV: Risk Assessment of Nanoparticles", accessible as of 2014-03-13.

insurance companies should offer insurance against the effects of risk realisation connected with nanotechnology. This task is extremely difficult because insurance companies do not possess adequate historical data in relation to the frequency of occurrence of unfavourable phenomena as well as their intensity. Thus, traditional insurance risk modelling, with the application of historical data, is difficult. In the following section of the article we present the application of the management accounting method which makes use of future data.

3. LEARNING CURVES IN THE IDENTIFICATION AND MEASUREMENT OF COSTS CONNECTED WITH THE FUTURE OF PRODUCTS "WITHOUT CLAIMS HISTORY" AND THEIR POTENTIAL INSURANCE PROTECTION

The analysis of insurance risk in relation to an insurance product ”without claims history” (PBH) is a big conceptual challenge and requires the creation, practically from scratch, of model methodology. This methodology will undoubtedly require a systemic approach and focus on:

(a) the condition of the company in which such a PBH is launched and the related technological risks,

(b) PBH life cycle in which cost and benefit forecast is particularly difficult due to:

- the lack of market experience (supply/demand),
- high costs of production resulting possibly from the product novelty and the application of highly specialised technology,
- the need to evaluate the corporate financial condition in relation to the source of financing of this kind of production in order to determine the value of cost of the acquisition of own and third party capitals and to examine the company's ability to cope with them,

(c) the readiness of the target market segment (customers) to purchase the innovative product (PBH) and a possibility of rejecting the product by the market, which means ”sunk costs” and may lead to serious financial problems,

(d) the examination of the whole assortment structure of company's products which could become a safety buffer for the company to continue business activity in the case of the PBH market rejection,

(e) environmental and social aspects and consequences of PBH production and sales, which means the need to get familiar with the expert opinion on the usefulness of PBH in the business development of the company introducing it as well as in the area of effects and role in the civilisation and business development of the region, country and the world.

This sort of research is recommendable due to the threat of costs sunk in PBH, a possibility of serious financial trouble, and (as a consequence) the bankruptcy of the company. It is particularly important in the situation in which an insurance company would undertake the insurance protection of the financial result of the PBH production activity.

However, if the insurance company was to render a third party liability insurance coverage (social, health or environmental) for the damage resulting from PBH use, the problems mentioned in a-c become less important. The priority should be given to the environmental and social plane as well as the need for expert (also engineering) evaluations of PBH technological safety and the determination of the range of possible threats. Presumably, it would be connected to a large extent with the description similar to the information about a medicine: what purpose it serves, how and in which circumstances it should be used, what the threat is for the individual, the closest environment, the region etc.) and in which period, what preventive actions should be taken against the negative aftereffects, whether such activities are technologically possible or whether the environment affected by the negative aftereffects is able to undertake such activities, whether it is in the possession of adequate funds.

It may be concluded from the aforementioned ideas that: (1) sustainable development, (2) PBH innovative technologies, (3) the need to introduce innovative insurance protection into the insurance sphere (which may be conducted in the PBH area) jointly pose big specialist requirements to insurance companies in the area of PBH-related risk determination. These competences include knowledge of not only nanotechnology (PBH) and clairvoyance in relation to its potential effects. An ability to apply tools (concepts) of modelling of its financial results is also important. Eventually, an insurance company pays a monetary compensation or benefit and the point is that the premium as well as the insurance sum connected with such an innovative coverage should be properly calculated, i.e. in such a way that the insurance company could cover losses resulting from the realisation of the ”nanotechnological risk.”

Here we do not present a complex model of evaluation of risk connected with the PBH insurance protection. As a matter of fact, it remains to be created. However, we are witnessing the development of nanotechnology and we should notice both positive and negative aspects of such technology as well as unknown risk factors related to it. Those new factors may become a potential insurance risk. The paper conceptually verifies the application usefulness, in the course of PBH insurance risk evaluation, of one of many management accounting concepts.

This verification is undertaken in view of our conviction that, irrespective of the way insurance companies assess insurance risk connected with nanotechnologies, it seems useful to:

1. analyse the concept of the *learning curve* and verify its parameters in the condition of highly advanced technologies,
2. indicate the possibility of the *learning curve* application as a tool supporting the evaluation of the insurance risk.

3.1. Analysis of the *Learning curve* Concept and Verification of its Parameters in the Conditions of Highly Advanced Technologies (e.g. “Machine Learning”)

Learning curve is a function which, in the primary classical meaning, measures the reduction in outlays (C) per effect unit (for example of a product) (P) together with the growth – in the process in which these effects (P) are created – in the total volume of repetitive activity (QP). In the *learning curve* it is assumed that the decline in outlays (C) is a result of the process of learning and acquisition of experience: knowledge, skills and other competences allowing for the achievement of repetitive effects (P) with lower outlays.

Practically, there are two learning curve models (Horngren, Datar and Foster 2006):

(1) cumulative average learning time model,

(2) incremental unit time learning model.

For example, the cumulative average learning time model assumes that an average cumulative time per product unit (e.g. 56.17 time units (TU) per each of six product units) declines by a constant percentage (e.g. 20%, with 80% inclination of the learning curve) every time when the volume of the product doubles (e.g. with the production dimension at the level of 12 production units (PU), an average cumulative time per each of these twelve TUs amounts to 44.93 TUs, i.e. 80% of 56.17 TUs). It may be said then that as a result of learning, an average cumulative time per product unit declines by 20%.

The model of cumulative average learning time may be presented in the form of the following function:

$y = aX^b$

where:

y – cumulative average time per unit

X– cumulative number of manufactured products

a – unit time of first product manufacturing

b – ln (coefficient of learning time effects)/ ln 2

This concept is broadly applied in management accounting, in which there are important decisions to be made, for example in the area of planned remuneration costs in connection with the growth of production volume. For example (Horngren et.al 2006:350), with 80% of learning curve, parameter b will have the value: b=ln 0,8/ln 2 = - 0,2231/0,6931= - 0,3219. And if the volume of output amounts to 3 units and the unit manufacturing time of the first product amounted to 100 man-hours, the cumulative average time with the volume of output of 3 units accounts for 70.21 man-hours (i.e. $y=100 \times 3^{-0,3219}$), which means that the cumulative production time of these three units amounts to 210.63 man-hours (i.e. 3 x 70.21). Knowing the cost of one man-hour, one can forecast the outlays on work directly related to production.

According to Horngren, Datar, Foster (Horngren et.al 2006:349), the learning curve is more and more frequently mentioned also in the cost analysis of processes taking part in value creation, i.e. in distribution, marketing or rendering services. In these processes there are no products in the classical sense and this is probably why these broader applications of the *learning curve* are described by them as the *experience curve*. Such *experience curves* are usually examined in corporate activities included in the value chain (e.g. marketing or sales) and they present a decline in the unit cost of this product identified in this activity, i.e. (P), (in the terminology of activity cost accounting this activity product may be called an *activity carrier*) in the context of volume growth of these activities to be measured with the number of implemented activity carriers.

From the conceptual perspective, on the basis of the aforementioned observations made by Horngren, Datar and Foster, there are no contraindications to thinking in the *learning curve* categories in relation to the costs of practically every process, even the one in which there are no classically perceived products. It is important to observe that the experiences translate into the decline in costs, as a result of which there is a decline in the unit cost of the object in which the experiences have been consumed.

If we assume that, in the evaluation of insurance risk connected with a PBH nanotechnological product, it will be important (despite the lack of market experience) to analyse the business cycle of such a product, it will be essential:

(a) to estimate probable volume of sales in every phase of the life cycle of such a product, and consequently the value of incomes, which, expectedly, may be subject to changes over time – demand fluctuations, competition or substitutes,

(b) to forecast manufacturing and other costs, also financial appropriate for individual life phases of this product. It seems that one should consider, within the PBH product life cycle, the decline in costs achieved thanks to the implementation of solutions resulting from the experience gained over a longer and longer period of PBH production. It may be a significant value in the whole economic account of this kind of production, which may be of particular importance in the evaluation of insurance risk connected with the financial results of the PBH manufacturing company. The application of learning effects requires a prior diagnosis in view of which it should be found out if a given nanotechnological company is really, in the economic sense, a learning organisation. Because only in this case is the application of effects of the decline in costs determined by the learning curve or experience curve could be justified. It is not connected with the application of more and more advanced technological knowledge. In a learning organisation people are searching all the time for new possibilities of achieving the desired effects, they create new patterns of non-stereotypical thinking, develop their teamwork and learn constantly. A learning organisation is experienced in the implementation of creative tasks, the acquisition and transferring of knowledge, and the modification of their behaviour in reaction to new knowledge and experience. The concept of learning is closely connected with the implementation of the corporate innovative strategy. However, at present according to management experts there are no clear principles of how to manage learning organisations, as well as the descriptions of methods and techniques related with it. There are no measuring tools to assess the organisational level of competence and level of learning, and these tools are indispensable to assess what practical effects are achieved by corporate management within the concept of learning organisation. See more: (Gierszewska and Romanowska, 2003:140-149).

If the diagnosis mentioned above brings a positive reply, it is worth noting that in the analysis of future costs of a nanotechnological product in the course of its whole life cycle *learning curves* and *experience curves* should be considered. They are connected with outlays and effects in a few processes: (1) marketing, (2) production, (3) sales, (4) PBH aftersales service (warranty, guarantee) and – in a given company – they are characteristic of these processes, and may be really unique in in the PBH production process. Each of these processes have its own specificity and requires different classification of outlays (C), as well as a different definition of repetitive effects (P). It should be underlined that the efficiency of people involved in a given process depends on personal competences but also sufficiency and quality of resources provided for them to use.

The discussion presented below includes modifications and limitations and deals with an opportunity to use the *learning curve* in forecasting costs of the manufacturing process conducted in the PBH technology**.** Assuming that an insurance company in the developed model of evaluation of insurance risk connected with PBH considers the concept of the *learning curve* in the credibility assessment of cost forecast of a PBH product manufacturing in the course of its entire life cycle, the explanation of this concept has a universal character. It means that in this form it may be used in the company itself as well as in the insurance company verifying the source documents examined in the process of evaluation of insurance risk and submitted by a potential customer (company).

The priority in the concept of learning curve is given to the understanding of experience outlays and effects.

In the classical approach, in the *learning curve* outlays (C) are measured by man-hours involved directly in the effect (P). It is assumed that the experience acquired by people in the manufacturing process, similarly to exercised skills, may contribute to people's higher efficiency while performing the next (the same as the previous one) effect unit (P). The skill perceived in this way may be measured by the time of performance of a given (repetitive) effect (P). The learning curve presents – in this primary sense – the relation between: (1) the effectiveness of people involved in a given process, (2) productivity of this process as well as (3) decline in unit costs of effect creation (P) of this process.

In our analysis, the problem of outlays is important because at present, in view of robotisation of manufacturing processes, the cost of purely productive (in a sense manual) human labour time plays a lower and lower role or is an insignificant driver of costs of nanotechnological products (PBH). The most important are the costs of: (a) used material assets, (b) amortization of nanotechnological know-how value and technical appliances used in this production, (c) costs (most probably fixed) connected with monitoring of production quality and maintaining production capacity at the highest technological level.

In view of the above, there is a well-grounded question to be asked: Do the observations disqualify the application of the learning curve in relation to highly advanced manufacturing technologies? In the first impression – yes. However, let us note that:

1. if a nanotechnological company is a learning organisation, there will be a kind of standard consisting in a permanent desire to optimise costs, which requires a permanent cost monitoring and improvement of processes, in particular those with a large share of fixed costs,

2. in a nanotechnological company, for the re-engineering (optimising manufacturing costs) of nanotechnological processes, the work and learning of people employed outside the process of direct PBH production is a key issue.

As a result, for a nanotechnological company it seems well justified to verify the understanding and measuring outlays important for the determination of the *learning curve*. It is here where learning of a man not working manually in the manufacturing of the PBH product translates into the costs of manufacturing process, in particular these costs which in this process may have a character of fixed costs. The reduction in these costs will certainly cause a decline unit complete costs of PBH manufacturing, even with the same (not increased) volumes of production. This impact, i.e. the decline in fixed costs in absolute values will take effect abruptly**,** i.e. after the introduction – as an effect of experiences and observations gained by people – of reengineering changes in the manufacturing process, improving the activity efficiency and effectiveness of manufacturing process and appliances used in it. This is the first issue. Secondly, in highly advanced technologically (really futuristic) nanotechnological manufacturing processes, to determine the *learning curve* in the manufacturing process of nanotechnological PBH, it is necessary to choose an appropriate cost driver thanks to which outlays can be measured.

As stated above, in the case of nanotechnological production which does not involve people in the manufacturing process (not at all in direct manufacturing or to a slight extent), the function of the cost driver should be performed by the measures reflecting in the best possible way the PBH production cycle or – even better – both *production cycle* and a notionally broader *operational cycle.* It may be, for example, the duration of the production or/and operational cycle expressed in days. The duration of these cycles and the observed tendencies to make them shorter may reflect the gained experience, the ability to use it in the organisation of the production cycle as well as in the pre- and post-production management (also in the financial sense).

Whether we are dealing with a company producing PBH nanotechnologically or another company, it should be noted that *the duration of the production cycle* – technologically appropriate – of the unit measure of a nanotechnological product does not depend on the volume of production. It is strongly dependent on the organisation of the production process. There are two components of the production cycle time measured in this way, only one of which is susceptible to changes resulting from experience. The use of organisational experience of people thanks to which the duration of the production process may be shortened is limited to the possibility of affecting the duration of particular activities in the production cycle that are different than those strictly technological, pursued in compliance with the manufacturing technology[6]. In a given technology, the duration of these activities cannot be affected, unless there is a change in the prescription or manufacturing process in a physical or chemical sense. The time that can be affected is connected with performing a logistic activity.

The time absorbed by logistics of the production cycle on the one hand lengthens the production cycle, and on the other consumes the company's assets; in short, it is costly and it makes manufacturing unit costs higher. In this organisational fragment of the production cycle, which is ”soft,” i.e. susceptible to changes, one may find potential opportunities to make use of the acquired experience. The organisation of such production cycle fragments determines to a large extent fixed costs, as it shortens the production cycle duration and at the same time optimises the work of fixed assets involved in this production. It may also lead to the elimination of production defects and low-quality production, which is not indifferent for the production cycle duration, the volume of production implemented, and costs related with it. Thus, as it may seem, to a large extent primarily organising, re-engineering and improvement of the organisation of PBH manufacturing process logistics-causing decreases in the level of fixed costs accompanying production (nanotechnological or different)-may strongly affect the pace of decline in unit manufacturing costs.

In the case of companies applying highly advanced technologies it cannot be excluded that experience may be acquired not only by people [but by organizations (?) technologies (?)], which – in the context of the learning curve – gives rise to the need for the verification of the term “experience.” Highly advanced technologies stimulate imagination and lead to philosophical questions: Is experience a human-specific attribute or can nanotechnology (although artificial), be intelligent enough to gain experience and make correction of the production process in the course of manufacturing of a nanotechnological product? It sounds futuristic but not unrealistic. Importantly, a fast growing area of the so-called machine learning (making use of the achievement in the area of artificial intelligence, robotics, information technology and statistics) in nanotechnology may have a comprehensive application. In such a case machine learning is a process:

- consisting in the creation of an automatic system which could improve itself by means of the collected experience (in the form of acquired data) and the acquisition, through algorithms of data analysis – from the human perspective, new knowledge and skills,
- perceived as a change (improvement) – thanks to artificial intelligence – in selection

[6]The application of knowledge of new technologies is not considered here, as this text is concerned with the situation in which nanotechnology has already been fixed and the decision about its commercial application have been made. From the company perspective, there is a need for risk management of this production through the purchase of an adequate insurance policy, and from the perspective of an insurance company, there is a need for the evaluation of such a new insurance risk which has not been analysed so far.

of important choices of algorithms of machine operation, leading to the improvement and development of its own steering system.

This process may improve and shorten the time of an inaccessible for a human being, technological fragment of the production cycle period, which is a goal of machine learning.

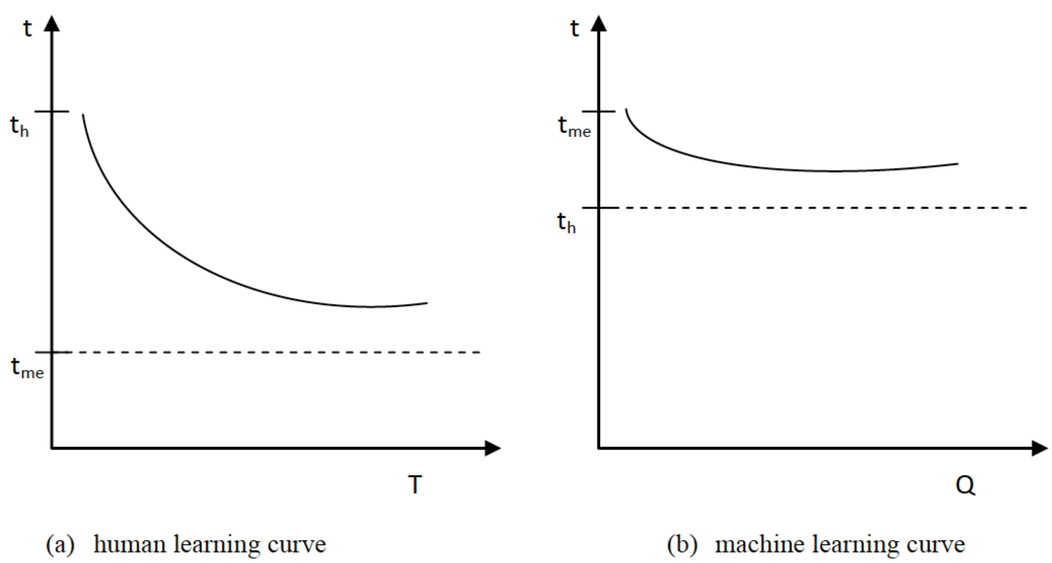
All in all, in a technologically advanced production process the *learning curve* seems exceptionally complex, in a sense double-track, because outlay reduction may be achieved here thanks to experience (learning), which in the manufacturing processes, making use of robotics and artificial intelligence, may be acquired at the same time by humans and machines. Theoretically, a *joint learning curve* could be considered, or two separate curves: a *human learning curve* and a *machine learning curve*. Such an analysis seems intriguing. However, here only scientific interest is being communicated.

The problem is complex, and in practice if the aforementioned observations were to be applied in relation to a nanotechnological company, they should be well matched with the specificity of the organisation and technology used in the company. The key issue here is the awareness of the appearance in the production cycle period of some fragments of this period which are susceptible to changes introduced due to: (a) the experience of people who actually are not involved directly in production as well as (b) learning machines used in this process. The joint learning curve would express the pace of shortening the *production cycle unit period*, which could be interpreted as outlay C, with the growth of the parameter which should be properly set now to correspond to the QP size, according to the classical perception of the learning curve.

The problem which needs to be discussed at the moment is *parameter QP*. Theoretically, it could be: (a) the growth in in the volume of PBH production for the *machine learning curve* and (b) lengthening of the period of this kind of production activity for the *human learning curve*. Symbolically, it could be presented as follows:

3.2. Learning Curve as a Tool Supporting the Evaluation of Insurance Risk

In practice, learning curves, which are important in forecasting costs, are determined on the basis of



T – product business life period (without the design and liquidation phases)
t – production cycle unit period ($t_{he} + t_{me}$)
t_{he} – fragment of PBH production cycle unit period susceptible to human experience
t_{me} – fragment of PBH production cycle unit period susceptible to learning machines experience
Q – PBH production volume.

Figure 7: Human and machine learning curves.
Source: Authors' material.

retrospective data. In the situation which the aforementioned considerations refer to, i.e. in the case of PBH producing companies, which the authors tried to emphasize referring to the example of nanotechnology, the retrospective information is simply unavailable. (For the sake of clarity, it should be underlined that what is meant here is the situation in which the PBH technology has been determined and an insurance company makes a decision about the insurance coverage of the company's expected results from the PBH production or company's liability on account of potential consequences (effects) of the PBH production process or the use of finished PBH). In view of the above, there is another well justified question: Should the lack of retrospective data needed to mark out a learning curve in a PBH producing company mean a definite rejection of this concept, even if it was to be used only as one of many tools supporting the evaluation of insurance risk?

For an insurance company it could be important to know whether or not the retrospectively determined *learning curves* appear in other processes, not only and exclusively those connected with the PBH production. Such information could be a signal to show the insurance company that it has to do with a learning *organisation*, which could allow for the general identification of company susceptibility or openness to innovation in the area of management of activities, including logistics, which appear also in PBH production (although they may be different than in a pre-production phase) and are crucial, as already indicated before, for the learning curve in the process of production using highly advanced technologies.

Lack of unavailability of the gradient of a retrospectively determined learning curve in the process of PBH production does not eliminate a possibility of thinking in the categories connected with a potential learning curve in this process. One can try to model such a curve considering several factors: learning curves known from other processes, remarks made above in relation to the very concept of a learning curve in processes applying highly advanced technologies, the structure of costs of production, ascribed to the detailed production activities, divided into variable and fixed costs, the structure of managerial competences of the management staff as well as the quality of intellectual capital of the staff responsible in particular for the effectiveness of the PBH production process. The modelling will not be simple but the proposal in this area would certainly be a great contribution to science in the area of cost management of such a process and the management of insurance risk connected with such a process.

4. CONCLUSIONS

In conclusion, there are important issues are to be considered when modelling the evaluation of insurance risk connected with the high technology production (e.g. nanotechnology), for example:

1. the necessity for the acquisition of technical and environmental expert reports, safety certificates and other documents confirming the limitation of technological and environmental risk factors connected with a PBH product,
2. the need for a number of quality analyses, in relation to the company which is a potential customer, thanks to which the insurance company may obtain its opinion on the following questions:
   - Is the company really a socially responsible organisation and not the one that only declares this responsibility and whether it behaves ethically with regard to its customers and stakeholders?
   - To what degree does the corporate financial condition guarantee the continuity of operation even in the case of serious technological problems and difficult social consequences requiring large financial outlays to overcome them? Does the company apply other risk management instruments (including financial risk) apart from insurance?
   - Does the company possess any features of a learning organisation? What is the experience curve in this organisation in relation to other processes and activities, not the production process?
   - Is it possible to determine a probable *human learning curve* for the production process based on the extrapolating of experience curves observed retrospectively in this company with reference to a pre-production logistic process?
   - What is the degree of technicisation or robotisation of production? Are there any technological solutions in this production

steered by learning machines? Is it possible to determine a probable learning curve for such machines and what can the probable effects of such corrections be, including cost, quality and, in a broader sense, environmental effects?

3. taking into consideration, if possible, in the prognostic business account, the life cycle of PBH production, incomes and costs, relevant and complete for every phase of this cycle as well as costs exceeding respectively far beyond the phase of liquidation of such a production.

The analysis results show the lack of significant changes within insurance sector through the financial crisis. Generally, such a situation concerns all analysed European countries. The British market is an exception; in group E it has most closely approached the reference object. The present economic situation and the turbulence on financial markets required more radical changes from insurance entities. It looks that the lack of innovativeness effects from the fact that the insurance professionals have not noticed yet the significance of the problem and relation between insurance and economic growth. We hope that the findings presented would have an impact encouraging professionals to introduce more innovative solutions within the sector. In our opinion if the sector is more innovative the economy will go through the financial crisis more smoothly. However confirmation of such an opinion requires further and deeper studies.

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