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Philosophical foundations of statistical research

Józef Pociecha[a]

Abstract. Every researcher desires to uncover the truth about the object of the undertaken study. When conducting statistical research, however, scientists frequently give no deeper thought as to their motivation underlying the choice of the particular purpose and scope of the study, or the choice of analytical tools. The aim of this paper is to provide a reflection on the philosophical foundations of statistical research. The three basic understandings of the term 'statistics' are outlined, followed by a synthetic overview of the understanding of the concept of truth in the key branches of philosophy, with particular attention devoted to the understanding of truth in probabilistic terms. Subsequently, a short discussion is presented on the philosophical bases of statistics, touching upon such topics as determinism and indeterminism, chance and chaos, deductive and inductive reasoning, randomness and uncertainty, and the impact of the information revolution on the development of statistical methods, especially in the context of socio-economic research. The article concludes with the formulation of key questions regarding the future development of statistics.

Keywords: philosophy of science, philosophy of truth, theory of probability, statistical learning, socio-economic investigations
JEL: C00, C10, C60

1. Introduction

The term 'statistics' relates to a variety of concepts, with at least three separate dimensions. Firstly, statistics can be understood as a part of mathematics, commonly referred to as 'mathematical statistics'. This is a branch of mathematics based primarily on the theory of probability, but also involving other areas of mathematics, such as algebra or calculus. The substantial use of inductive reasoning is a specific feature of mathematical statistics, which stands in contrast to deductive reasoning, widely applied in other branches of mathematics.

Statistics as 'the science about the condition of a state' is another interpretation of the concept in question, and in fact the one closest to the original understanding of the term (Pociecha, 2016). 'Statistics' traditionally referred to a set of data presented in a table form, describing the condition of a given state. Nowadays, when we mean such a 'quantitative description of the state of things in a state' we use the term 'public statistics'. Contemporary public statistics is a system of gathering statistical data, involving the collection, storage, processing and publishing of such data, as well as making accessible or distributing the results of statistical research. Public statistics is an essential element of the information system of a democratic society, providing state authorities, national and local administration bodies, the economic sector, and society at large with official statistical data on the economic, demographic, social and environmental situation in a given country (Oleński, 2006).

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Statistics may also be perceived as the science of quantitative methods of studying mass processes. This most general and common conception of statistics includes the application of mathematical statistics and other quantitative methods as the methodological basis for research. Moreover, it views public statistics as the basic source of statistical data in social and economic research. At its core, this understanding of statistics considers it the science of uncovering the truth of the surrounding reality based on data which describe this reality. It is an empirical science – the one which makes use of inductive methods. In consequence, the determination of the degree to which an analysis or forecast corresponds to the studied reality (i.e. the degree of veracity of the results of statistical research) is of key importance here. It is crucial then in statistical analysis to be always aware that by using statistical methods we attempt to uncover the truth about the reality under study. In light of the above, the perception of truth in scientific research must be considered.

2. Philosophical notion of truth

Truth is a philosophical notion. It is the main object of the study of epistemology (the study of the nature of knowledge) and one of the branches of philosophy which examines the relationship between knowledge and reality. Scientific knowledge is a specific type of knowledge which requires the fulfilment of a selection of defined rules. The nature of this knowledge is the subject of the philosophy of science (Woleński, 2014). The aim of science, as Strawiński (2011) stresses, is the explanation of the world formulated in scientific theories. Other, concurrent functions of science, such as education, innovation, or 'emancipation', are the derivatives of the cognitive function.

One of the primary concerns of epistemology is the search for an adequate definition of truth and the criteria for suppositions to be true. This problem is addressed by the theory of truth, a subset of epistemology. The key issues that this science investigates is whether truth exists, whether it can be determined, or in what way we can come to know the truth. A variety of answers have been formulated to the abovementioned questions by a number of schools of philosophy, jointly with a wide range of definitions of truth. Below is a concise overview of the most commonly accepted definitions of truth.

2.1. The classical (correspondence) definition of truth

Truth is a supposition which is in accordance with the state of things this supposition concerns (Tatarkiewicz, 1978a). This definition was formulated by Aristotle (4th century BCE) as: 'To say of what is that it is not, or of what is not that it is, is false, while to say of what is that it is, and of what is not that it is not, is true'. This statement was written in 'Metaphysics', Aristotle's most important work on philosophy, handed down through the ages via the publication by Andronicus of Rhodes (1st century BCE). This classical definition of truth is known mainly in the form worded by Thomas Aquinas (13th century AD) 'Veritas est adaequatio intellectus et rei' ('The truth consists of an adequation between the intellect and a thing'). Truth exists, therefore, if what is in our minds corresponds to reality. This classical definition of truth has been subject to critique of many types (Woleński, 2014), including the absence of a set of universal criteria for the 'adequation' and the problem of 'the replication of reality via language' (Pruś, 2018). These shortcomings in the classical definition of truth were rectified by a Polish logician, Alfred Tarski, who formulated a semantic definition of truth (Tarski, 1995).

Despite many attempts to devalue the Aristotelean conception of truth, his definition, formed within the classical Greek philosophy, still presents a challenge to empirical scientific study, as everyone wishes to discover the surrounding reality. The consequence of following the Aristotelean definition of truth is accepting that the world (reality) exists in an objective sense (outside our minds) and that it is knowable. Of course, knowing reality is difficult, but possible, making scientific inquiry relevant. It also means that it is possible and appropriate to conduct scientific research using statistical methods.

2.2. Neopositivist notions of truth

Among many well-known trends of the 19th century philosophy, a significant influence was exerted by the views of the neopositivist school, also known as the Vienna Circle, representing logical positivism. The third wave of the positivistic ideas, called also the 'Third Positivism' (Tatarkiewicz, 1978b), expressed theses of a minimalistic philosophy combining three complementary theories: empiricism, positivism and physicalism. Empiricism presupposes the establishment of all knowledge on the basis of empirical data and the rejection of anything that does not find support in empirical facts, while accepting that experience is the source of all knowledge in the real world. Positivism, on the other hand, assumes that the objects of study may only be facts. It rejects metaphysics and states that only scientific knowledge is certain. Still, neopositivists differentiated between knowledge of the real world which is of an empirical nature, and formal knowledge which is of an axiomatic nature, such as logic and mathematics. This trend was called logical positivism (logical empiricism). Science establishes facts in the form of theorems or formulates tautologies concerning a coherent system of logic and mathematics. Neopositivists thought that the logical-mathematical language is the only language of science. They believed in physicalism, meaning the reduction of all sciences to the expression of physics, or at least the application of research techniques and mathematical descriptions drawn from physics in all branches of science, including social sciences, such as psychology or economics.

Two members of the Vienna Circle, Rudolf Carnap and Otto Neurath, were supporters of the coherence-based definition of truth, according to which 'that which is true is internally coherent', and is 'true on the basis of certain statements of experience', in other words based on acquired experience. This means that truth is determined by the absence of a logical contradiction between these statements (Tatarkiewicz, 1978b). This view is the basis for the logical positivism which was propagated by neopositivists.

The legacy of neopositivism in social and economic sciences includes the appreciation of statistical data as a source of knowledge about the real world, and of quantitative studies based on mathematical modelling of social and economic processes. The recognition of the primacy of physics over other branches of science has become the basis for the methodology of contemporary 'econophysics', a tool used to describe these processes.

2.3. Popper's critical rationalism

Karl Raimund Popper was an active member of the Vienna Circle of neopositivists, but neverthless he expressed theses which were not always in line with the group's views. Popper's discussions held during seminars of the Vienna Circle led him to writing a book entitled 'The Logic of Scientific Discovery', which encapsulated his main philosophical views (Popper, 1977), shaped both under the influence of, and in contrast to, logical positivism.

Popper called his philosophy 'critical rationalism'. It assumed that everything which was proved at a certain moment might at some other point become doubtful. The key points in Popper's views were as follows:

- the perception of thought as the act of solving problems using a deductive method, in which the mind constructs notions, hypotheses and theories which subsequently become subject to falsification;
- the rejection of all *a priori* notions and primary elements of cognition, assuming that the work of the mind is of a temporary nature and does not uncover any unchangeable laws;
- the aim of science is the creation of new, increasingly bold theories which describe an increasingly broad class of phenomena.

Popper introduced the notion of falsificationism, which involves a set of methodological procedures a researcher must apply if his/her goal is to advance scientific knowledge. The approach does not advocate searching for the confirmation of scientific theories (verification), but rather investigating contrary cases that could prove the falsehood of the studied theory. A scientist's aim, then, sholud be the attempt to falsify a theory (to demonstrate that it does not correspond with experience), and if this attempt is unsuccessful, the theory should be temporarily accepted until one of the subsequent attempts at falsification results in the refutation of the theory.

For Popper, the truth needs to correspond to facts, and only such an understanding makes rational critique possible. He proposes treating the notion of 'truth' as a synonym of the notion 'corresponds with the facts'. The truth is a mountain peak enveloped in clouds. An experienced alpinist may not have difficulty reaching it, but may not know when the peak is reached as it may be indistinguishable among other nearby peaks, obscured by clouds. This fact, however, does not in any objective way affect the existence of the peak; an authentic idea of error or doubt entails the idea of an absolute objective truth which can never be attained (Popper, 1977). Popper's critical rationalism constitutes the basis for the testing of statistical hypotheses which aim to refute the null hypothesis. According to Popper's philosophy, we are never able to verify the null hypothesis, but only to refute it. The absence of a basis for the rejection of the null hypothesis is synonymous with its temporary acceptance, until it is falsified.

2.4. Thomas Kuhn's philosophy of science

An American physicist, historian, and philosopher of science Thomas Samuel Kuhn was the creator of the idea of the scientific paradigm. His most important work in the area of the philosophy of science is 'The Structure of Scientific Revolutions' (Kuhn, 1962). In it, Kuhn provides a critique of Popper's falsification, casting doubt on its assumptions. First and foremost, he draws attention to the fact that research hypotheses are verified in the context of a set of generally accepted scientific knowledge, and that this set of knowledge itself is not subject to verification. Kuhn strongly rejects Popper's thesis that in science we learn from our own mistakes and replace erroneous theories with better ones. The aim of science according to Popper is to constantly substantiate its theses, which is a sign of scientific progress. According to Kuhn, however, the problem with the validity of scientific theories being the sign of scientific progress is the conformity of thought within the scientific community, which leads to the rapid development of research in a given field.

Kuhn's primary achievement as a philosopher of science was the introduction of a paradigm as a set of notions and theories constituting the basis of a given science. These notions and theories are seldom questioned as long as the paradigm is cognitively creative, meaning that by making use of it, detailed theories may be formed in accordance with experimental (historical) data assigned to the given branch of science. The most general paradigm is the paradigm of the scientific method, the criterion for recognition of a given scientific operation.

Kuhn argued that science is not a monolithic, cumulative process of acquiring knowledge. Instead, he believed that science is a series of periods of calm interspersed with sudden intellectual revolutions, leading to the replacement of one conceptual worldview with another.

He also analyses the relationship between the philosophy of science and its history. He considers two approaches towards the philosophy of science: one represented by the formal methodology of science, and the other by a historically-oriented theory of science. Kuhn is a representative of cognitive scepticism, holding the belief that although scientific inquiry leads to the discovery of fundamental truths, the shifting of paradigms does not necessarily bring scientists closer to the attainment of truth.

In science, particularly in social science, various paradigms may exist simultaneously, for example the paradigms of classical economics and Keynesian economics. In statistics, the paradigms of mathematical statistics, Bayesian statistics and statistical learning are currently the prevailing ones.

Having provided this brief overview of philosophical notions, the author wishes to emphasise that it is important to be aware of how we wish to discover an understanding of the truth of the studied reality in the course of conducting all statistical research.

3. Determinism and indeterminism

Statistical research is by nature empirical, relating to the surrounding reality. Thus, it is crucial to take a philosophical stand regarding the nature of the relationships between things, properties, quantities and events which constitute this reality. In philosophy, two main opposing views have been formed regarding the functioning of the world: determinism and indeterminism.

Determinism is a philosophical conception which assumes that all events are related through the notion of cause and effect: every event and every state is determined by previously existing causes, consisting of other events and states. Everything which occurs in the world, including human actions, is conditioned in advance, outlined, defined and must take place within a cause and effect series of events.

Determinism in the history and prehistory of human thought is the primaeval philosophical standpoint. For ages, the prevailing belief was that all events in nature were predetermined. In ancient times, the most well-known proponent of deterministic causation was Democritus (Tatarkiewicz, 1978a). In the history of philosophy, the most extreme deterministic view is represented by Laplace's 'mathematical daemon', a spirit with an unlimited capacity for mathematical deduction, who would be able to predict all future events if only it knew all the quantities which characterised the present state (van Strien, 2014).

Determinism proclaims unconditional faith in the power and omnipotence of formal logic, which is a tool enabling the discovery and description of the world. It rejects the idea of chance as an objective phenomenon, claiming that the impression of randomness is strictly a subjective state resulting from insufficient information.

Indeterminism, on the other hand, is a philosophical conception assuming that the relationship between cause and effect in nature is not absolute, it presupposes the existence of chance, and rejects the possibility of predicting subsequent events based on previous ones, as the same causes need not necessarily lead to the same effects. In its extreme form, indeterminism totally rejects the existence of (or the possibility of knowing) any conditions. Indeterminism also exists in moderate forms which accept the presence of objective regularities (laws), but only in certain fields and conditions of reality. Indeterminism has become the contemporary scientific viewpoint to the extent to which determinism was the original philosophical standpoint. Indeterminism started as a result of 200 years of discoveries in physics, when it became apparent that in the world of atoms and quants there is no place for determinism, and that regularities occur only in mass events.

Indeterminism negates determinism. The conflict between indeterminism and determinism, ongoing in philosophical debate since ancient times, relates in particular to the issue of the free will, man's responsibility, the aim of nature, causation in nature, necessity and chance.

Statistical research is based on an indeterministic understanding of the world. Statistical regularities are of a stochastic nature; they appear in mass phenomena, and individual cases may differ from general regularities.

4. Chance and chaos

As pointed out in the previous section, determinism was the original philosophical standpoint on nature, which assumed the existence of an eternal order, and the aim of science was its discovery. Yet, philosophers ever since Aristotle's times have recognised the role of chance, considering it as something which violated that eternal order, was beyond human understanding, and thus was impenetrable by science. In the mid-19th century, philosophers realised that the search for the deterministic laws of nature is hampered by logical and practical difficulties, and subsequently they initiated research into models of the laws of nature based on the mechanisms of chance. The key inspiration in the search for such models were Adolph Quetelet's achievements in the field of statistics, involving the application of the notion of probability for the description of social and biological phenomena, including posing 'Quetelet's question' (Ostasiewicz, 2012). Additionally, the formulation of the laws of inheritance by Gregor Mendel, which laid foundation for the science of genetics, stimulated progress in seeking these new models. In terms of physical sciences, inspiration was provided by the statistical interpretation of the fundamental theorem of theoretical physics, namely the second law of thermodynamics, as formulated by Ludwig Boltzmann. These achievements, as well as many others, brought forth a revolution in the understanding of nature. Over time, the roles of order and chance in science were reversed: chance became the primary notion.

A conventional way of thinking would suggest that chance causes chaos, which further leads to the question about the relationship between the two notions. The word 'chance' is used to describe random phenomena, such as drawing a number in a lottery in which the numbers are in a random sequence. A sufficiently long series of random occurrences reveals a certain order which can be discovered using calculations of probability. On the other hand, numbers generated in a deterministic process may express random behaviours which we call chaos. It was from this ground that the theory of deterministic chaos arose, dealing with the irregular, unordered behaviour of deterministic systems which are practically unpredictable over lengthy periods of time (Schuster, 1995). Deterministic chaos, as per the chaos theory, is the property of an equation solution being highly sensitive to any minor disturbances of its parameters. This usually concerns nonlinear finite and non-finite differential equations describing dynamical systems.

Radhakrishna Rao (1994) defines the notions of chance and chaos as follows: 'Chance deals with order in disorder while chaos deals with disorder in order'. Both chance and chaos may be observed and modelled. Chance is modelled using the tools of probability and mathematical statistics. Chaos, which is of a mathematical nature, is described using deterministic models.

Without evaluating the usefulness of the analytical tools for social and economic research provided by the theory of deterministic chaos, it should be noted that contemporary statistical research is based on an indeterministic understanding of the nature of the relationships between the components of the world which surrounds us, modelled by methods of probability and mathematical statistics, and that chance is an inevitable element of this reality.

5. Deductive and inductive reasoning

The assumption of a deterministic or indeterministic approach to understanding the world is linked with the way in which we reason about it. Reasoning is the method by which we come to accept a previously unaccepted position on the basis of previously accepted positions (Ajdukiewicz, 2006). In philosophy and logic, two basic and opposing types of reasoning are recognised: deductive and inductive.

Deduction is a type of logical thinking which aims to arrive at a defined conclusion based on a previously established set of premises. Deductive reasoning is entirely self-contained within its assumptions, meaning that it does not require the creation of new theorems or notions, but is simply a process of drawing conclusions. If it is carried out correctly, meaning that the set of premises does not include false statements, then the conclusions drawn as a result of deductive reasoning are irrefutably true and cannot be validly questioned.

Using deductive reasoning, no new knowledge going beyond the premises is created, as all theses generated are contained within axioms. It is not claimed that either the axioms or the theses generated from them are linked to reality. Logic and mathematics make use of deductive reasoning, including such branches of mathematics as probability or mathematical statistics, e.g. 'Let (Ω, σ, P) be a probabilistic space...', Kolmogorov's axiomatic probability definition, or the definition of a stochastic process.

Deductive reasoning was introduced in the earliest stages of the development of the Greek philosophy, with the greatest role in its development played by Parmenides (Tatarkiewicz, 1978a).

Inductive reasoning involves starting from detail and arriving at the general idea, i.e. the correctness of the statement (conclusion) stems from the correctness of its consequences (premises). In inductive reasoning, we decide on the premises when we have certain data on their consequences. Using this type of reasoning, decisions in the real world are made based on incomplete or faulty information. Inductive reasoning is a logical process by which a hypothesis is selected to fit the data and generalisation is made from an individual case. In consequence, new knowledge is created, however it is uncertain due to the lack of bilateral, unambiguous conformity between the data and the hypothesis. For the human mind, accustomed to deductive logic, this lack of precision in reasoning based on existing data, in contrast to reasoning based on axioms, has resulted in a reluctance towards the application of the rules of inductive reasoning. Knowledge gained by generalisation from details, although initially uncertain, becomes certain if its associated uncertainty is expressed quantitatively.

Induction in mathematics can be complete or incomplete. Complete induction is reasoning about a general regularity based on statements covering all possible cases of the occurrence of this regularity. Complete induction is a method of proving statements about natural numbers. Incomplete induction involves reasoning about a general regularity based on a finite number of statements which cover some occurrences of this regularity. It is the basic tool for discovering the truth in experimental science. A problems arises, however, when selecting a criterion for the purpose of distinguishing between valuable and worthless results of research obtained through incomplete induction. In many cases, one has to simply use common sense to do that.

Statistics is based on the principle of inductive reasoning in its incomplete form. This branch of science discovers the surrounding reality on the basis of a finite number of statistical data to which the theory of probability is applied.

6. Randomness and uncertainty

Randomness, denoting the absence of purpose, cause, or predictable behaviour, is inextricably linked with indeterminism. Randomness is understood as a random process whose results cannot be exactly predicted, but can be presented as a distribution instead. A tool for describing random processes is provided by probability, formally defining a random event as follows: 'Let (Ω, σ, P) be a probabilistic space...'. Intuitively, a random event is the one whose outcome cannot be predicted with certainty. Another notion is the random variable, defined as a function which reflects a probabilistic space in the world of numbers. Subsequently, the distribution of the random variable and its endless analytical forms become defined. This way, the idea of randomness of a philosophical nature was formalised in the basic mathematical notion of probability and mathematical statistics, as shown by several authors, including Richard von Mises (1957).

Randomness occurs in nature, thus it is necessary for the laws of nature to be expressed in probabilistic categories. This constitutes the basis not only for contemporary physics and biology, but also for psychology and social sciences. Random behaviours are also considered as an inherent aspect of the functioning of many classes of objects and their manner of existence. Radhakrishna Rao (1994) poses the following question: 'Does randomness play any role in the development of new ideas and can creative capacity be explained using random processes?' Creative capacity is understood as the source of a new idea or theory which does not align with or cannot be drawn from the existing paradigm, and which explains a broader set of phenomena than any other existing theory. A good example of creative capacity could be Albert Einstein's creation of his theory of relativity. Writer Arthur Koestler, describing the act of creation, said: 'At the decisive stage of discovery, the codes of disciplined reasoning are suspended, as they are in the dream, the reverie, the manic flight of thought, when the stream of ideation is free to drift by its own emotional gravity, as it were in an apparently 'lawless' fashion'. Writer Douglas Hofstadter notes: 'It is a commonly held view that randomness is an indispensable element of the creative arts'. R. Rao claims that random thinking is an important component of creative ability. Thus, the role of randomness is in fact considerably broader than it can appear at first. Carl Gauss once said: 'I've had my results for a long time, but I do not yet know how I am to arrive at them'.

A further philosophical notion which has its own mathematical expression is uncertainty. Within the theory of decision making (Szapiro, 1993), it refers to a situation where defined decisions may cause various effects depending on which of the sets of possible states occurs, with the caveat that the probability of the occurrence of individual states is not known. Formalised principles for decision making are outlined in the theory of mathematical programming (Trzaskalik, 1990).

Uncertainty is an integral part of nature and society. It manifests itself in the behaviour of elementary particles in physics, of genes and chromosomes in biology and of individuals in society, when acting in situations of stress and tension. This makes it necessary to develop theories based on stochastic laws within the natural and social sciences which utilise the notion of random events. The feeling of uncertainty is heightened by such factors as the lack of information, an unknown degree of inaccuracy in the available information, the absence of technical possibilities to obtain the necessary information, and the inability to conduct relevant measurements.

When aiming to reduce uncertainty, it is crucial to express it in quantitative terms. The first attempts at the quantitative expression of uncertainty were made by Thomas Bayes (in the 18th century), who introduced the notion of an *a priori* distribution of a set of possible hypotheses indicating the degree of confidence in them before observing the data. If this distribution is given, then together with the knowledge of the distribution of probability resulting from the data, in the conditions of a given hypothesis, total probability is obtained. The conditional distribution of probability in a specific hypothesis is calculated this way. The Bayes Theorem is an example of the application of the probability theory as a tool in inductive reasoning. It constitutes one of the foundations of Bayesian statistics (Osiewalski, 1991) as a means to taming uncertainty, in the situation where classical statistical methods fail to do so. This theory makes use of the notion of subjective probability. In classical mathematical statistics, probability is an objective quantity understood as a family of measurements serving to describe the certainty of a random event. Subjective probability is defined by subjective opinions of individuals based on the available data. Bayesian statistics combines a deductive mathematical approach with an inductive empirical approach to statistical research, including decision-making under uncertainty.

7. The probabilistic notion of truth

A crucial question thus arises: Can we discover truth using statistical methods? Can we, on this basis, define truth? Statisticians believe we can. In statistical terms, truth is a belief with an acceptable level of probability (error) which corresponds to reality. Reaching the truth in statistical terms means making a point or interval estimation. Radhakrishna Rao (1994) ends his book by citing an ancient piece of Eastern wisdom:

The road to wisdom?
Well it is plain and simple to express,
Err,
And err
And err again,
But LESS,
And LESS,
And LESS.

A probabilistic understanding of truth on a philosophical basis is represented by probabilism. This is a contemporary variant of scepticism which assumes that our knowledge is only probable knowledge. It is not possible to demonstrate what truth is and what falsehood is, but only to recognise those theorems or suppositions with a high degree of probability. The roots of probabilism date back to the views of the ancient sceptics, who claimed that in practical life it is not necessary to have certainty – a reasonable level of probability is sufficient. The main representative of such ancient probabilism was Carneades of Cyrene (Tatarkiewicz, 1978a).

The ideas of probabilism were reborn on the foundation of neopositivism. Despite the fact that scientific theories, in neopositivists' view, are unprovable, they can be assigned various degrees of probability, estimated using statistical methods, based on the available empirical material. Major advances in this field were made by Rudolf Carnap and Imre Lakatos. Probabilism proposes the replacement of the idea of verification through facts with the idea of probability based on induction. Carnap was the co-founder of the Vienna Circle and a proponent of a radical version of neopositivism (Tatarkiewicz, 1978b), while simultaneously conducting research into the foundations of mathematics and issues of probability (Carnap, 1950). The approach of Imre Lakatos to the philosophy of science was an attempt to reach a compromise between the falsificationism of Popper and the theory of scientific revolutions expressed by Kuhn. Popper's theory requires scientists to abandon their theories the moment they encounter an observation which falsifies them, and form 'bold hypotheses' in their place. On the other hand, Kuhn believed science is a series of interwoven eras of 'normal science', during which academics hold to their pet theories in spite of accumulating observations contradicting them, and 'scientific revolutions' which bring about changes in the ways of thinking; in Kuhn's opinion, nevertheless, the causes of these revolutions are often devoid of a rational basis. Lakatos (1995) searched for a methodological approach which would make the reconciliation of these contradictory standpoints, and at the same time would provide a rational view corresponding to historical facts of the progress taking place in science.

The tool of probabilism is statistical inference. By taking as a given a sceptical understanding of truth as preached by probabilism, we may, however, come to an approximation of truth at a satisfactory level (with the level of error that we find acceptable).

8. The information revolution and statistics

The aim of statistics is to draw information from data. The processing of these data in order to obtain useful information and formulating conclusions on their basis is the subject of data analysis. In the field of statistical data analysis, it is often said: 'Let the data speak for themselves'. This is known as 'learning from data' or 'statistical learning'. The latter is a set of statistical tools for the modelling and analysis of complex data sets. Among the foundational research papers, covering in detail the theory and applications of the methods of statistical learning, are books written by Hastie et al. (2009), as well as by James et al. (2013).

Modern data analysis is based on the application of methods which automatically search for procedures allowing an optimum data analysis. They are part of the field of machine learning, involving the creation of systems which perfect their own operations based on experiences from the past. Two basic types of machine learning can be distinguished: supervised learning and unsupervised learning. The former assumes human supervision in the process of creating a function mapping the system input to its output. This supervision involves providing a program with a set of input-output pairs in order to teach it to take decisions in the future. Unsupervised learning, on the other hand, is a kind of machine learning which assumes the absence of an exact or even approximate output in the training data. The task of learning without supervision involves the determination of interdependencies among various features or the discovery of an internal structure within the data set. Examples of unsupervised learning include cluster analysis and correspondence analysis. Taxonomic methods are also unsupervised learning methods. The literature on machine learning is very extensive and consists of papers which synthesise IT, mathematical, engineering and statistical issues, including work by Cichosz (2000), Koronacki and Ćwik (2005), or Krzyśko et al. (2008).

Machine learning is a scientific discipline connected with the issue of artificial intelligence. This subject involves knowledge from the field of mathematics, statistics, engineering, and IT. It has emerged as a result of the attempts to mathematically model the processes which take place within the human body. At the same time, artificial intelligence is an IT subfield which concerns the creation of models of intelligent behaviours and of computer programmes which simulate these behaviours. It can also be defined as an IT subfield which deals with solving problems that cannot be effectively algorithmised (Rutkowski, 2009). The concept of artificial intelligence has two basic meanings: one involving hypothetical modelling of intelligence, and the other of a technology in service of scientific research. The main task of research in the field of artificial intelligence is to construct machines and computer programmes which are capable of carrying out selected functions of the human mind and senses which cannot be easily reproduced with a numerical algorithm. Thus, AI-related issues are connected with the field of IT, but involve a number of other disciplines, including neurology, psychology, cognitive studies, systematics, as well as contemporary philosophy.

The development of telecommunications and information technologies, the Internet and IT, occurring along with the decrease in the unit costs of gathering and storing data, have caused significant quantitative and qualitative changes in the approach to data itself and to the possibilities of analysing them. This dense, constant, and unstructured stream of data is known as Big Data. Enormous amounts of information are generated not only in many fields involving the study of the natural world, but also in social and economic fields. The role of statistics in this context is to find some meaning and purpose within these data.

Since the introduction of high-performance computers, which signalled the beginning of the 'information era', a dramatic increase has occurred in terms of the possibilities of effectively analysing large and complex statistical problems. This growth in both the technological capacity to store, organise, and search data, as well as in the available methods of analysing data, has led to the emergence of a new field of statistical research, called Data Mining. However, very large data sets also pose various challenges regarding the reliability of inferences drawn from the reality studied through the analysis of the said data. In Big Data sets, apart from information characterised by a sufficient degree of clarity (Clear Data), there is also a significant amount of false, outdated, fuzzy, duplicated, incomplete, and erroneous data (Dirty Data), as well as those data whose quality or usefulness is unknown (Dark Data) (Migdał-Najman & Najman, 2017). Can such data, subject to no filtering based on appropriate methodological assumptions, be used to uncover the truth of the studied reality? Here again we have to pose questions regarding the philosophical and methodological nature of scientific research.

9. Questions

In relation to the new possibilities of conducting statistical research supported by contemporary IT tools, as outlined in the previous chapter, the following questions emerge, jointly with their potential answers.

Is data analysis based solely on empirical foundations expressed by the assertions: 'Let the data speak for themselves' or 'In data analysis no assumptions are necessary'? It can be proven that data analysis procedures, including those regarding Big Data, are also based on assumptions which, nevertheless, are in most cases concealed and more flexible than those observed in classical statistical analysis.

Can large sets of data be analysed at a chosen degree of precision, thus bringing us closer to the truth about the reality we study? Or is it simply a matter of the amount of time dedicated to the execution of computer calculations and the related costs of a given study? Can the future be predicted at the assumed level of accuracy based on such studies? The answers to such questions are inconsistent: IT specialists believe that the computing capacity of modern computers has no limits, and yet, e.g. problems relating to projecting the course of the Covid-19 pandemic indicate that data analysis procedures do in fact have limitations, despite the volume of the tools and resources involved.

Can an AI-based computer justify the relevance of conducting a given piece of scientific research? Here, the answer is rather negative. It can indicate the analytical or prognostic efficiency of the applied, specific research procedures, yet it is unable to formulate general research aims.

Is an AI-based computer capable of philosophical thought? Rather not, but certainly human beings can form a philosophy of artificial intelligence; such a branch of philosophy has already been created (Russell & Norvig, 2003).

And finally, is the development of science even possible without any philosophical underpinnings in the era of high-performance computers? The entire development of epistemology and the philosophy of science from ancient times to this day suggests that science cannot be conducted without a philosophical basis (Heller, 2011). In terms of statistics constituting a basic tool of empirical study, this statement also proves true.

Nevertheless, any attempt to provide full answers to the above-mentioned questions require a separate study.

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Trends and characteristics of patenting activity in Poland in 1990–2018

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Abstract. Patenting activity is broadly analysed in the literature at the micro, mezzo, and macroeconomic levels. Yet, not much attention regarding this issue is devoted to European countries in transition. The main aim of the study is a quantitative analysis of all patent applications filed with and grants issued by the Polish Patent Office throughout the period of 1990–2018 at the aggregate and regional level. We investigate trends and factors determining the patenting activity in Poland – the country at an advanced level of the economic and social transition. The empirical analysis leads to several findings. First of all, we identify changes in the field of patenting related to Poland's accession to the EU in 2004, which resulted in the increase of residents' patenting activity and decrease of that of non-residents (in terms of the number of filed applications and granted patents at a national and regional level). This holds for absolute numbers as well as for a *per capita* perspective. Additionally, we demonstrate that the increase in R&D expenditure is not followed by a proportional increase in patenting, as the patent-to-R&D ratio is systematically shrinking. Finally, the study compares trends in patenting activity in Poland with those in different groups of countries, proving that the dynamic of change in Poland is much slower than could be expected.

Keywords: patents, Central and Eastern Europe, Polish Patent Office, innovations
JEL: O31, O34

1. Introduction

The history of patents goes back to 15th-century Italy, but its modern understanding originated in the 18th century in Great Britain and the United States (Hall & Harhoff, 2012). Since then, governments worldwide have been granting inventors the right to exclude other agents from exploiting the innovation for some time. In exchange for that, inventors agree to share their intellectual property with society as the patent expires, thus increasing social welfare. This demonstrates that patents are an important element of the economy in all its three dimensions, i.e. the microeconomic dimension (generating profits for individual companies), the mezzoeconomic dimension (giving a strategic advantage over competitors), and the macroeconomic one (providing valuable knowledge on the economy).

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This study aims to investigate recent trends in the patenting activity in Poland – the country in transition for the past 30 years, which started upon the introduction of the market economy. We analyse the database of intellectual property rights granted over the period of 1990–2018 and compare the findings with the most important trends worldwide. It should be underlined that our study is most of all quantitative-based, which restricts the complexity of the final conclusions.

The article contributes to the literature in several ways. First of all, to the best of the authors' knowledge, it is the first study that analyses trends in patenting in Poland over a long period (21–25 years). Additionally, the study investigates regional variation within the country. Finally, different measures of patenting activity are utilized.

The remaining part of the article consists of four sections. Section 2 provides a review of the literature on trends and characteristics of patent activity in the world, Section 3 presents the history of patenting in Poland and the relevant literature, Section 4 introduces the dataset and empirical results, and Section 5 features the conclusions of the paper.

2. Literature review

Patenting has been widely discussed in the literature since the unexpected boom in this kind of activity in the early 1980s, which occurred in connection to the revolution in intellectual property rights in the U.S. In 1980 the Bayh-Dole Act was adopted, aiming at strengthening the protection of intellectual property, simplifying the process of resolving disputes, and extending the maximum time a patent is protected (Gallini, 2002). Kortum and Lerner (1999) argue that the increase in patenting activity is related not only to changes in regulations, but also results from the way innovations are dealt with in the U.S., which, in general terms, stimulates innovativeness. Bessen and Hunt (2007) suggest that this trend may be partially caused by the improvement in cost efficiency of patenting over time. Similarly, Posner (2005) finds the intensification of the worldwide patenting activity to be the effect of lower costs and the comparative ease in intellectual property copying, which, as observed by Lee and Lim (2019), has so far found a continuous reflection in the relevant data. The U.S. companies continue to dedicate increasing amounts to gaining new patents. On the other hand, though, this activity entails a decline in the average quality of patents (Caillaud & Duchêne, 2011).

Over the last four decades, characteristics of and trends in patenting activity have been investigated in literature at three different levels. First of all, patents are considered as a measure of innovative activity at the macro-level (Acs & Audretsch, 1989; Pakes & Grilihes, 1980; Scherer, 1983), allowing cross-country and cross-industry comparisons, as the propensity to patent varies between sectors as well as between countries. In that latter case, the differences are especially noticeable when comparing developed and developing countries (Chandran Govindaraju & Wong, 2011; Penrose, 1973). Research indicates that the quality of regulations on the protection of intellectual property rights affects the propensity to patent to a large extent. More efficient protection, as well as the introduction of international agreements on co-operation in the sphere of intellectual property (for example the Trade-Related Aspects of Intellectual Property Rights – TRIPS) means more patent applications are filed, whereas less efficient systems promote treating inventions as 'company secrets' (Dass et al., 2015).

On the other hand, more recent literature suggests that due to the fragmentation of research and development (R&D) activity within multinational enterprises, cross-country comparisons may be blurred, for example in terms of patent valuation (Grupp & Schmoch, 1999). Hall and Harhoff (2012) indicate that only in a few industries (e.g. pharmaceuticals) patents stimulate innovative activity, but in general, they are the result of competition between firms ('if your competitors have them, you need them too') and do not enhance social well-being to a large extent. This conclusion leads to the second level of analysis, which is the industry level.

Hall and Ziedonis (2001) argue that companies in the semiconductor industry tend to perform 'patent portfolio races' to gain a strategic advantage over their competitors. Similarly, Cohen et al. (2000) investigate the reasons for which com-panies engage in patenting. Their findings show that except for the standard prevention of invention copying, companies' main motivation is to prevent their competitors from patenting similar solutions (called 'patent blocking'), thus gaining an advantage in negotiations and avoiding lawsuits.

The last level of the analysis (micro) involves examining financial aspects of patenting at firm level. For example, in his classical paper, Griliches (1981) finds a positive relationship between the intangible value of companies based in the U.S. (measured by the number of held patents and other similar indications) and their market value. Austin (1993) observes that a public announcement of a company about having received a patent may have a positive influence on its market value. Additionally, the author points out the possibility of the occurrence of a positive spill-over effect, meaning that the market's positive reaction to one company gaining a patent results in the increase in the market value of other companies operating within the same industry.

Hsu and Ziedonis (2008) suggest that the number of patents in a company's portfolio can increase the likelihood that a company will receive Venture Capital financing. In contrast, Munari and Toschi (2008) show that generally in the case of Venture Capital financing in nanotechnology start-ups, the number of all patents obtained by a company is not related to the amount of financing received. On the other hand, patents concerning the main activity of a company (nanotechnology) significantly affect financing by the Venture Capital.

Useche (2014) investigates the relationship between the number of patents and the Initial Public Offering (IPO) success in the EU and the US and finds a positive relation – each patent application filed prior to the IPO increases the revenue by 0.5% and 1.1%, respectively.

On the other hand, Lee and Lim (2019) argue that the market values primarily the ratio of patent count to R&D expenditure, while citations play a secondary role. Additionally, the authors suggest that the market appreciates patents of younger companies more than those of well-established firms.

Gambardella et al. (2008) analyse the value of patents granted by the European Patent Office (EPO). The authors estimate the average value of patents at EUR 3 million, their median at about EUR 300,000, and the mode between EUR 6,000 and EUR 7,000, which confirms the right-skewed distribution of the patent value. Interestingly, the value of a patent is correlated with patent citations, references, claims, and country of origin, although these do not fully explain the variability of this value.

Bessen (2008) estimates the value of patents in the US and finds out that the average value of a patent granted by the United States Patent and Trademark Office (USPTO) is substantially higher than that granted by its European counterpart. The author also asserts that the value of a patent is positively correlated to the company's size, and estimates the influence of patent citations on its value. He finds out that additional citation increases the value of a patent by 4–7%. It should be noted, however, that patent citations explain the variability of a patent's value only to a limited extent.

A detailed analysis of the inventor's profile is performed by Akcigit et al. (2017), who examine the combination of US patent and census data for the period of 1880–1940. According to the study, inventors then were highly-educated, made delayed marriage decisions and migrated to regions with a higher propensity to innovate. As a result, inventors had larger incomes than non-inventors. Additionally, the authors discover a relation between patenting activity and long-run economic growth, observable also at a regional level.

It should be underlined that the accuracy of patent count as the measure of innovative activity at firm level is widely discussed in the literature. For example, Trajtenberg (1990) suggests that patent count is a better measure of innovative activity than R&D expenditure, but on the other hand, the idea can be criticised as it fails to take into account the quality of a patent. Including patent citations in the analysis may solve this problem. Narin et al. (1987) have similar observations – they suggest that in the case of the pharmaceutical industry, the counts and citations of patents correctly predict the 'technological strength' of a company. The authors distinguish between patent count, which is considered as a measure of research input correlated with the R&D budget, and citations considered as a measure of research output and quality correlated with the financial performance of a company. Thus, citations may constitute an element of the financial analysis of a company.

3. Brief history of patenting in Poland

Surprisingly, little attention has been paid in the literature to trends and characteristics of patent activities in transition economies, especially in the 'emerging Europe'. Countries of Eastern, Central, and Southern Europe are certainly on a different trajectory of patenting activity than developed countries. There are several reasons behind this situation, including history-based ones, such as, at least for some of them, the operating in an innovation-discouraging, centrally-planned economy for nearly half a century. In result, the majority of these countries are considered as modest or moderate innovators (European Commission, 2020), lacking an 'innovation culture'. They are characterised by a lower propensity to patent, which, in turn, results in firms' low awareness and lack of expertise in protecting intellectual property (Turczak, 2010).

On the other hand, the accession to the EU, growing R&D expenditure and steady economic growth observed in the region over recent years seem to have changed those patterns to some extent. From this perspective, patenting activity in Poland – the largest market within the 'emerging Europe' group – is particularly interesting.

The Polish Patent Office (PPO; Urząd Patentowy Rzeczypospolitej Polskiej) was originally established on the basis of a Temporary Decree of the Head of State in 1918, and in 1919 the law on the protection of patents was introduced. Later Poland joined the Paris Convention on the protection of intellectual property (see Zaremba, 1993). The same year the first trademark was registered, and the first invention five years later, in 1924 (a bakery shovel – see Krzemień & Ogurek, 2017). The activity of the PPO was interrupted by the outbreak of the Second World War, and resumed in 1945. Poland joined the World Intellectual Property Organization (WIPO) in 1975 and signed the Patent Cooperation Treaty in 1990. Currently, intellectual property rights in Poland are primarily regulated by the Industrial Property Act of 2000.

As mentioned above, the literature on patent activity in Poland seen from the macroeconomic perspective is scarce. The majority of articles analyse the issue of patenting at a micro level – as a part of knowledge management (Klincewicz, 2011), as a proxy for innovations (Niedbalska, 2001), or in analyses of groups of countries, without a particular focus on Poland (Okoń-Horodyńska et al., 2015).

As far as the existing body of literature focusing on the macroeconomic aspects of patenting activity is concerned, there are a few publications that should be mentioned here. Weresa (2010) analyses patenting activity in Poland from 1995 to 2008 and concludes that after a period of stagnation in the 1990s, a slight increase in this kind of activity has been observed after the country's accession to the EU in 2004. Polish inventors have become relatively successful in gaining patents in the fields of mechanical engineering, lighting, heating, weapons and blasting.

Turczak (2010) identifies the barriers to patenting in Poland, which include the lack of firms' expertise relating to the subject, high costs of patenting inventions, and complex (as well as time-consuming) administrative procedures. Furthermore, Polish inventors are discouraged by lengthy processes of resolving disputes. Finally, the author points out that the PPO does not grant patents for computer software, which results in a lower propensity to patent in the high-tech industry.

Wachowska and Niklewicz-Pijaczyńska (2015) analyse nearly 2000 patents granted to Poland's top eight universities and 20 companies in terms of the number of patents obtained in the period of 2005–2011. The authors assess the quality of patenting by selecting 'dead patents' – inventions whose protection was not extended after the expiry of the initial protection period, which undermines the success of their commercialisation. Interestingly, almost half of all university patents were considered 'dead', whereas in the case of business-obtained patents, it was only 18%. On the other hand, the amount of 'dead' patents was correlated to the overall number of the gained patents – the larger the patent portfolio owned by the company, the more 'dead' patents there.

4. Dataset and empirical results

In order to achieve the broadest possible perspective in analysing patenting trends in Poland, we utilised a dataset comprising 3 different sources of data.

Firstly, we merged the data on patent applications and patents granted from the annual reports of the PPO from 2003 to 2018 and surveys conducted by Statistics Poland (Główny Urząd Statystyczny) from the *Science and technology* reports published from 2004 to 2019. In addition to the classic industrial property rights measures, such as the number of patent applications (filed by domestic and foreign entities) and patents granted (to domestic and foreign entities), we examined the structure of the patenting activity for both domestic and foreign entities within the total number of patent applications and grants from 1990 to 2018. Moreover, we analysed the trends and the structure of patenting in Poland by type of activity according to the International Patent Classification (IPC), covering the period of 1990–2018. There are the following sections of activity:

- Chemistry & metallurgy;
- Human necessities;
- Performing operations & transporting;
- Mechanical engineering, lighting, heating, weapons & blasting;
- Physics;

- Fixed constructions;
- Electricity;
- Textiles & paper.

Secondly, the data were supplemented with figures provided by the Local Data Bank – the largest database of regional statistics on Poland, run by Statistics Poland. Data obtained in the above-described way enabled us to analyse regional trends in patenting activity in 16 Polish voivodships from 2004 to 2018 and to enumerate patent applications per 1 million inhabitants at the aggregate and regional level. Furthermore, we investigated the effectiveness of R&D expenditure in terms of patenting (number of patents per 1 billion PLN GERD – *Gross Domestic Expenditure on Research and Development*).

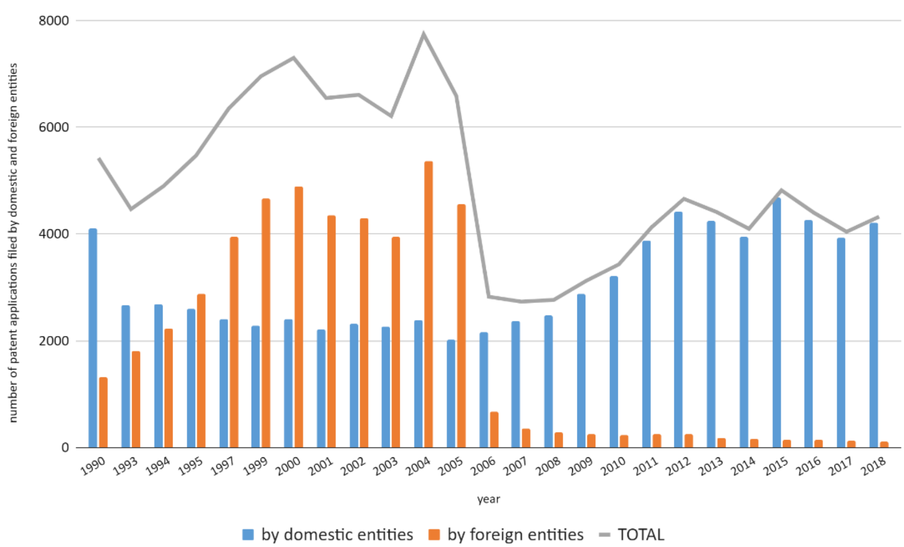
Lastly, we extracted the World Bank data on patent applications and population in groups of countries (World, Europe, and Central Asia; high income, middle income) over the period of 1990–2018 to compute long-term trends in patenting per 1 million inhabitants worldwide, and to compare them to the results for Poland.

The main features of this collection of data are: its focus on relatively long periods of time and the capacity of the patents to be disaggregated into more specific divisions, e.g. according to the type of activity and place of residence of the main applicant. All of this makes it possible to provide a very detailed and unique description of patent activity in particular transition economies.

In the study, we mainly focused on analysing the patenting activity of domestic (Polish) entities recorded by the PPO, for two reasons. First is the lack of sufficient data on domestic entities which applied for patents in the period of 1990–1999 and the lack of data on patents granted to them by the EPO in the period of 1990–2006. Secondly, relatively low numbers are recorded during the available period at the EPO. According to the statistics provided by Statistics Poland and by the PPO, patent applications filed by domestic entities with the EPO accounted for only 13 percent of the total number of domestic patent applications filed in 2018 (538 patent applications were filed with the EPO that year, compared to 4,207 applications filed with the PPO). Likewise, the amount of patents granted by the EPO to Polish entities in 2017 accounted for only 10 percent of all patents granted to these entities in this period (216 granted by the EPO and 2,795 by the PPO). Basically, it could be said that the patenting activity of Polish entities in the EPO is on an upward trend, but the numbers are still relatively low.

We start with trends in aggregated patent applications and patents granted. As Figure 1 indicates, the aggregated highest number of patent applications received by the PPO equalled 7,740, and it was in 2004. The total number of patent applications filed with the PPO plunged to the lowest level of 2,732 entries in 2007 (marking a decrease of 65% compared to 2004). Moreover, looking closer at the structure of applications distinguishing between domestic and foreign entities, one can observe a drop of 93% for foreign entities and only a 1% decrease for domestic entities over the period of 2004–2007, which is due to Poland's notifying the Convention on the Grant of European Patents and the country's accession to the EPO in 2004. This institution was established to grant European Patents which guarantee the protection of an invention in all states being parties to the European Patent Convention. Consequently, since then the outflow of patent applications filed by foreign entities with the PPO has been substantial, and in the last decade foreign enterprises were more likely to file patent applications with the EPO than the PPO (in 2018, the number of patent applications filed with the PPO by foreign entities equalled 115). However, a reverse trend could have been observed for domestic entities. A gradual increase in the number of their patent applications occurred in the period of 2005–2015. In 2005, domestic entities filed 2,024 patent applications with the PPO (which is the lowest recorded number), whereas in 2015 this number rose to 4,818 – a more than twofold increase, and fluctuating at around 4,000 applications until 2018, when it stabilised at about 4,300 applications.

Figure 1. Trends in patent applications of domestic and foreign entities

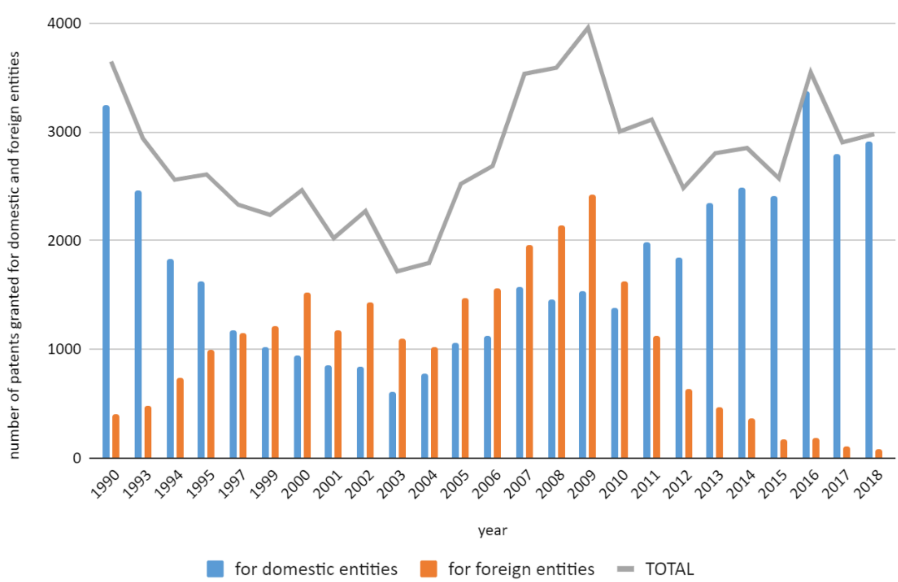


Source: Urząd Patentowy Rzeczypospolitej Polskiej (2003–2018).

Figure 2 shows statistics relating to patents granted to domestic and foreign entities. As previously mentioned, during the transformation of the Polish economy, the number of issued patents reached the level of 3,647. From 1990 to 2003, a decline in patenting activity was observed, and the structure of patents granted changed significantly. At the beginning of the 1990s, 89% of all patents were granted to domestic entities, while in 2003 it was only 36%, and 64% were granted to foreign enterprises. A record low number of patents granted in Poland occured in 2003, when it plummeted to 1,716. In the next 6 years, this figure was on the rise, reaching a record-high of 3,958 patents granted in 2009, which mainly resulted from the intensification of innovative activity undertaken by both foreign and domestic entities. After 2009, the structure of patents granted changed back to that from the 1990s, with a decreasing number of foreign entities involved in the patenting activity, and domestic companies showing an upward trend. The year 2018 only confirms the above-described tendency, as 2,906 patents were granted to domestic entities (98% of the total number), and only 74 to foreign entities (2%). The total amount of patents issued for domestic and foreign entities that year reached 2,980.

Two factors determined the increase in the number of filed patent applications and patents granted. The first is Poland's accession to the EU, and the second – the worldwide trend of intensified patenting, described by Posner (2005) as resulting from decreasing costs of technology transfer. Finally, it can be argued that along with Poland's transition to the market economy and dynamic economic growth, the innovation management within firms significantly improved, as described in Kortum and Lerner (1999).

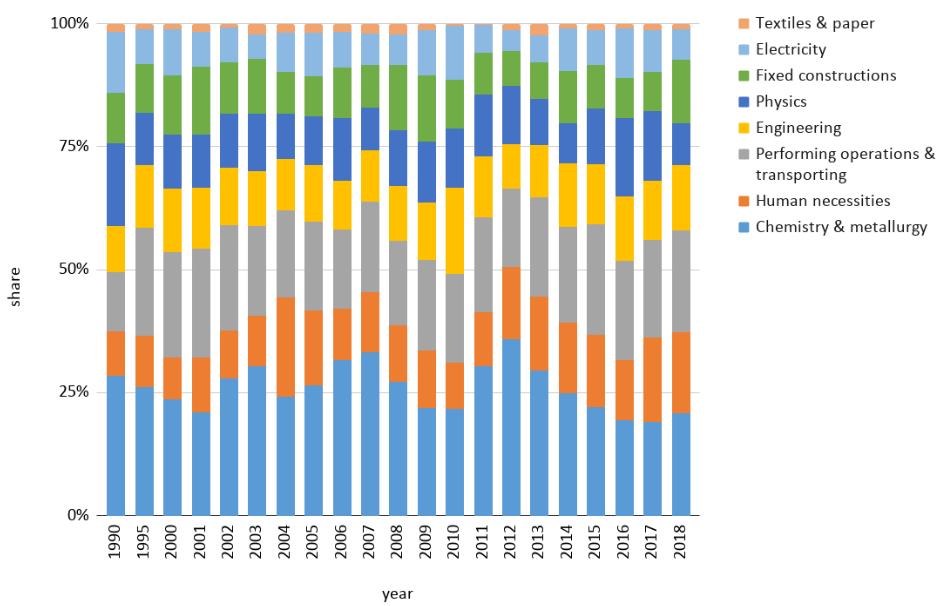
Figure 2. Trends in number of patents granted for domestic and foreign entities



Source: Urząd Patentowy Rzeczypospolitej Polskiej (2003–2018).

When disaggregating data to specific sectors, slight changes in the structure of the domestic patenting activity could be observed. Figure 3 shows the structure of patents granted over the period of 1990–2018. In general, a fluctuation of trends is visible across all the sectors. Most patents were granted to the Chemistry and metallurgy and the Performing operations and transporting sectors, with their share approximating 21% in 2018. After these came the Human necessities industry, following a gradual upward trend, having almost doubled its share, to 16% of all patents granted. Examining the consecutive sectors, it can be noticed that Engineering and Fixed constructions have had quite stable shares that amounted to 13% in 2018. A comparatively small number of domestic entities received patents in the Physics, Electricity, and Textiles and paper sectors, obtaining only one-digit shares in 2018. Interestingly, the graph shows the Physics industry's gradual decrease in the number of patents granted, from a 17% share in the transformation period (the second-largest amount of patents granted in 1990) to only 8% in 2018, thus illustrating a change in the behaviour of domestic entities. This change involved shifting the number of issued patents to the Human necessities sector. The above results are in line with Weresa (2010), taking into account trends at the country and sectoral levels.

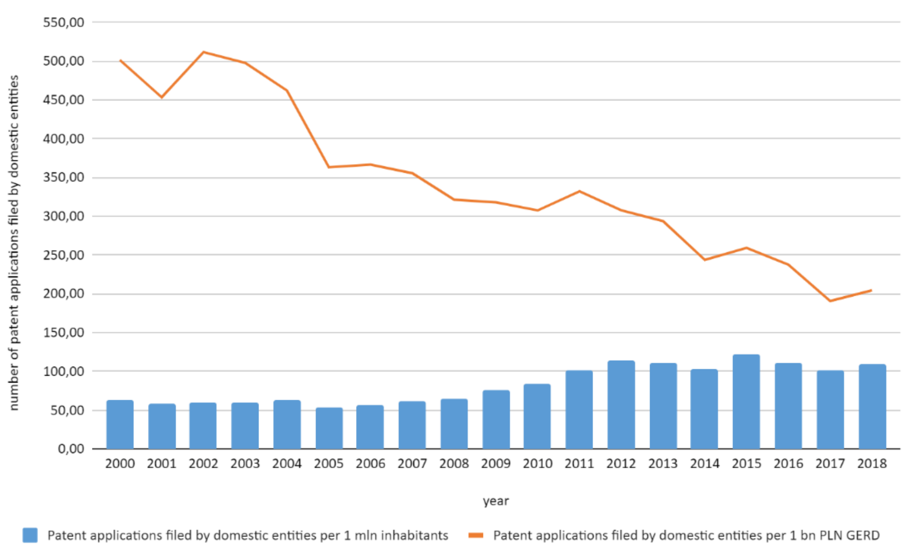
Figure 3. Structure of patents granted to domestic entities according to the type of activity



Source: Urząd Patentowy Rzeczypospolitej Polskiej (2003–2018).

When we analyse the patenting activity of residents, it is crucial to present the indicators per 1 million inhabitants and per 1 billion PLN GERD. This also proves helpful when analysing the outcomes in relation to the whole country, specific regions, and comparing the results of Polish residents with those of other countries. As shown in Figure 4, the patent-to-R&D ratio was systematically decreasing over the period of 2000–2018 and dropped from 501 patents per 1 billion PLN spent on research and development in Poland to 191 patents in 2017, and 204 patents in 2018. This trend can be related to the significant increase in research and development expenditure following the EU accession in 2004 and the support from the European Funds. The above result is in line with a study conducted by Lee and Lim (2019) for the United States. Moreover, the trends in patent applications filed by domestic entities per 1 million inhabitants in Poland over the period 2000–2018 should be taken into account. The data show relatively low dynamics of the indicator until 2005, when it reached its lowest point of 53 patent applications. After Poland joined the EU, notified the Convention on the Grant of European Patents, and became a member of the EPO, the trajectory reversed and numbers started to increase, reaching a peak of 122 patent applications per 1 million inhabitants in 2015, before levelling off in 2018.

Figure 4. Patent applications filed by domestic entities per 1 million inhabitants and per 1 billion PLN GERD



Source: Urząd Patentowy Rzeczypospolitej Polskiej (2003–2018).

Table Residents' patent applications by place of residence of the main applicant per 1 million inhabitants

Voivodship	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Dolnośląskie	90	77	65	112	97	100	110	115	157	134	151	152	115	118	128
Kujawsko-Pomorskie	43	36	40	45	40	56	59	74	81	81	55	78	81	81	65
Łódzkie	61	48	46	60	62	70	83	111	131	124	94	97	123	113	94
Lubelskie	34	29	29	48	59	64	57	97	95	90	100	98	86	119	66
Lubuskie	39	33	19	14	28	23	27	49	46	38	28	60	66	59	138
Małopolskie	62	62	62	57	62	78	93	100	125	139	102	157	118	114	130
Mazowieckie	99	84	93	91	96	123	133	146	184	178	171	184	158	133	140
Podkarpackie	31	21	27	26	40	33	39	56	48	53	52	91	109	93	95
Pomorskie	63	47	53	59	63	97	88	97	105	102	90	110	91	80	89
Śląskie	87	75	80	87	82	81	94	117	125	113	122	131	107	107	115
Warmińsko-Mazurskie	19	19	19	32	21	25	41	44	57	51	37	75	68	55	47
Wielkopolskie	66	52	59	56	64	83	91	119	124	104	85	134	134	97	106
Zachodniopomorskie	48	41	49	51	56	64	67	85	80	100	113	123	121	111	117
Świętokrzyskie	24	34	23	42	38	37	38	53	55	38	66	59	52	72	51
Opolskie	49	38	53	43	63	73	69	94	84	52	76	78	76	75	60
Podlaskie	22	21	14	29	40	42	47	61	67	32	59	50	93	89	116

Sources: Urząd Patentowy Rzeczypospolitej Polskiej (2003–2018) and Główny Urząd Statystyczny (2020).

Furthermore, the above-mentioned indicator can be further fragmentised into regional-level data. Table depicts the number of residents' patent applications by place of residence of the main applicant per 1 million inhabitants over the period of 2004–2018. Longer periods are unavailable due to the lack of sufficient data at the regional level. A significant stratification and divergence can be observed between the values of the indicator. Mazowieckie and Małopolskie voivodships led the rating with approximately 130–140 residents' patent applications per 1 million inhabitants. Mazowieckie itself accounted for about 20% of the total applications filed in Poland, thus vastly distancing other voivodships. Dolnośląskie, Śląskie, Zachodniopomorskie, and Podlaskie voivodships followed Mazowieckie in the respective order.

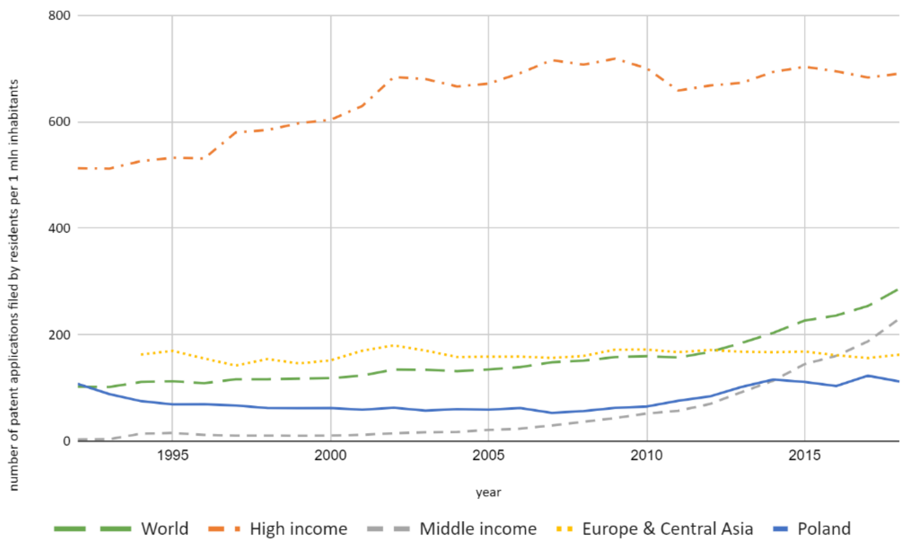
Interestingly, Lubuskie voivodship recorded almost a threefold increase in 2018 compared to 2017, this being the result of an intensified participation of local entrepreneurs in projects involving innovative activities. However, at this point it cannot be stated whether Lubuskie has become more innovative-oriented permanently, or the good results in the above-mentioned years should be treated as exceptions.

On the other hand, the fewest numbers of innovators were located in Warmińsko-Mazurskie and Świętokrzyskie voivodships, with only about 50 domestic entities' patent applications per 1 million inhabitants. However, in most cases, an upward trend was observed since the relatively low initial levels noted in the first few years following Poland's accession to the EU. The analysis shows large gaps between regions, and considerable effort should be made to bridge them in order to enhance the patenting activity at the regional level.

Then the results were compared with other countries, either European or the Central Asian markets, due to the fact that the data on patent applications provided by the World Bank and the Polish Patent Office were consistent. Figure 5 shows the statistics for country groups which illustrate trends in patenting activity worldwide, calculated per 1 million inhabitants. The World Bank classifies Poland as a part of the region of Europe and Central Asia, and at the same time as a country whose income is comparatively high.

As the figure below shows, in the early 1990s the initial outcomes for Poland and the world were comparable. Over time, however, the average figures for the world tripled to the level of 302 patent applications per 1 million inhabitants in 2018, while the patenting activity in Poland fluctuated, finally reaching the number of 111 the same year. What is more, even the countries from the middle-income group have developed steadily in terms of patenting activity, achieving a result twofold higher than Poland (258 patent applications in 2018). A minimal convergence can be observed in terms of the outcomes of the group of Europe and Central Asia (154 patent applications in 2018) and Poland, but still, the figures for the country are low. The most concerning are the conclusions resulting from comparing Poland with other countries from the high-income group. Over the period of 1990–2018 Poland's distance from the other members of that group increased substantially, resulting in the country's outcome six-fold lower (666 patent applications in 2018), thus unveiling Poland's weak position within the said group in terms of patenting activity in 2018.

Figure 5. Patent applications filed by domestic entities per 1 million inhabitants – worldwide trends



Source: World Bank (n.d.).

Therefore, in general terms, we can state that the trend for the world and the above-mentioned specific groups of countries is upward, but the figures for Poland indicate a relative stagnation in patenting activity. In conclusion, in order to equalise Poland's results with those of the rest of the world, this country has to put much effort into activities enhancing innovativeness. It must be noted that the presented results are not fully reflected in the literature of the subject, and the causes and determinants of the above-described situation call for further investigation.

To sum up, several trends can be observed on the basis of the obtained results. First of all, in terms of the number of patent applications and patent grants, the analysed period can be divided into two sub-periods: before Poland's accession to the EU and after that. The first period saw a dynamic increase in both of these figures, mainly due to foreign entities' activity before 2004. In terms of foreign patent grants, the numbers started to decrease slightly later, which can be attributed to the long period between filing an application and obtaining a patent. As regards the numbers of domestic applications and patent grants, both of them were decreasing before Poland's joining the EU and rising afterwards, which seems a common phenomenon when developing countries access international organisations (see Bombardini et al., 2018; Iacovone et al., 2011; Liu et al., 2016). As could be expected, the above result remains the same when applying the 'per 1 million inhabitants' calculation.

It should also be mentioned that the world average, high- and middle-income countries' patenting activity increases slowly, gradually converging with the regional (Europe and Central Asia) average. On the other hand, the patent-to-R&D expenditure ratio was constantly decreasing over the analysed period.

Throughout the analysed period, according to the sectoral disaggregation of the patenting activity in Poland, Chemistry and metallurgy and Performing operations and transporting were the leading sectors in terms of the volume of aggregate patenting activity. The above-mentioned changes do not seem to impact the industrial structure to a great extent.

From the regional (NUTS-2) perspective, Mazowieckie voivodship was the most active in terms of patent applications in the analysed period, while Warmińsko-Mazurskie was the least active. The causes of regional disparities should be, however, further investigated.

5. Conclusions

The paper aims to investigate recent trends in the patenting activity in Poland, and to present the main ones worldwide. Compared to other such studies concerning Poland, we analysed a significantly longer period of time, and researching trends at aggregate and regional levels. In the light of the results obtained during the analysis, it is clear that Poland still has a relatively long way to go before its level of patenting activity comes close to that of developed countries. The country is definitely on a different trajectory in terms of the propensity to patent than other high-income or even middle-income economies. As mentioned before, in Poland, the largest country of the 'Emerging Europe' group, the level of patenting activity is still low mainly due to historical factors (involving a transition to a market-based economy) and the failure to develop the 'innovation culture'.

As time shows, after 16 years of the EU membership, Poland still struggles with patenting activity, both at the country, regional, and sectoral level. Firstly, dissimilarities in the development and involvement in innovative activities of specific regions implicate poor outcomes for the country as a whole. Secondly, the general outflow of foreign patent applications (and consequently patents granted) from the PPO to the EPO after the country's accession to the EU caused changes in the structure of the patenting activity in Poland. Even though the data for domestic entities show an upward trend, the average number of patent applications filed by domestic entities calculated per 1 million inhabitants is lower than that observed in developed economies.

Interestingly, the data indicates a decreasing patent-to-R&D ratio, which in practice means that the increase in innovative activity funding (innovation-input measure) does not yield a proportional output, i.e. patents. On the other hand, it means that at the aggregate level, 'producing' a patent is becoming more expensive. These two conclusions are concerning at both the government and company levels.

It should be stressed that the level of patenting despite its common use as a proxy for innovations, does not fully reflect innovativeness of a country or a region. The relation between the propensity to patent and innovativeness is complex, and thus they cannot be regarded as the same phenomenon (Acs & Audretsch, 1989).

Furthermore, the above analysis makes several policy recommendations possible to be formulated. Firstly, the data for patent citations at the PPO is not available (and to the authors' best knowledge, it is not collected by the PPO). The lack of data makes the analysis of patent quality impossible; moreover, it may also affect companies' valuation by the market.

Secondly, the example of the Bayh-Dole Act indicates that a novel approach toward legislation can boost the innovative activity of a country. Although several changes have been introduced in recent years in the intellectual property law in Poland, no significant effects on the propensity to patent have been observed by the PPO. Thus the effectiveness of the intellectual property law in Poland should be critically reviewed in the future.

Finally, the decreasing patent-to-R&D ratio can be partially caused by a non-optimal allocation of R&D subsidies. Nevertheless, both R&D effectiveness in terms of patenting activity as well as the propensity to patent among Polish firms and citizens should be further investigated.

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Zbigniew Pawłowski's 90th birth anniversary

Janusz Leszek Wywiał[a]

Zbigniew Maria Pawłowski was born on November 22, 1930 in Lviv as the son of Leopold Pawłowski and Maria née Krukowska. After a few years, the Pawłowski family moved to Poznan. During the turmoil of the Second World War, he initially found himself with his mother in Romania, and then in Algiers, where he attended junior high school, first in Polish, then in French. In 1946, Pawłowski and his parents moved to Warsaw. In 1949 he passed the matriculation examination. Later, in 1949, he began studying at the Main School of Planning and Statistics SGPiS (currently the SGH Warsaw School of Economics) in Warsaw. In 1950, he started working there as a deputy assistant at the Department of Statistics. In 1952 and 1954, he completed his bachelor's and master's degrees, respectively. His thesis for his doctoral studies (1954–1957) was titled *Selected classes of complex hypotheses verified with the Wold sequence test in statistical quality control*. From 1957 to 1958, having gained a scholarship from the Ford Foundation, he completed a research internship at the Institute of Statistics of the University of Uppsala, under the supervision of a well-known econometrician, prof. Herman Wold. In the academic year of 1960/1961, he worked under the guidance of the later Nobel Prize laureate, John Richard Stone, at the Department of Applied Economics at Cambridge University. There, he had the opportunity to participate in the process of devising the first econometric model of the British economy (called the Rocked Model). In 1962, the Council of the Faculty of Finance at SGPiS awarded him the degree of habilitated doctor in economic sciences after he wrote his monograph *Econometric methods of researching consumption demand* (PWN, Warsaw 1961). Finally, in 1967 and 1972, he received the titles of professor and full professor, respectively.

From 1962, Pawłowski continued his scientific work at the Higher Educational School of Economics in Katowice (WSE – currently the University of Economics in Katowice), where he was appointed head of the Department of Statistics. In 1969, he became the Director of the Institute of Economic Account Methods and in 1974 the Director of the Institute of Econometrics. The structure of the Institute itself reflected the Professor's broad competences, as the Institute's staff were involved in a wide range of subjects, including econometrics, statistics, mathematics, operations research and linear programming.

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Image: Department of Statistics, Econometrics and Mathematics, University of Economics in Katowice

Professor Zbigniew Pawłowski also held positions within the university administration. He was the Vice-Dean of the Faculty of Industry and the Vice-Rector of the WSE in 1963–1965 and 1968–1974, respectively. He was an active member of the Economic Sciences Committee (from 1966), of the Statistics and Econometrics Committee (as deputy chair, starting from 1972), and of the 'Poland 2000' Research and Forecasting Committee. He was also a member of the Editorial Committee of *Przegląd Statystyczny. Statistical Review*, the Scientific Council of the Department of Statistical and Economic Research of Statistics Poland and the Mathematical Committee of Statistics Poland (as its chair from 1978).

This outstanding scientist is regarded by Polish econometricians, mathematicians, and statisticians as one of the pioneers of econometrics in Poland. In his lectures, monographs and textbooks, Professor Pawłowski presented, often as the first scientist in Poland, the basic methods of estimating and verifying hypotheses which were useful in the construction and inference of econometric models. He shared his expertise in a simple and accessible way, encouraging the study of statistics and econometrics. Almost all his publications were in Polish, but some academic textbooks were translated into Russian, Hungarian and German. He was a recognised expert in the field of econometrics. Professor Pawłowski also researched many specific issues in econometrics and statistics, which was reflected in his academic lectures and scientific articles and monographs. His interesting analyses and original ideas are still frequently referred to. He was mainly interested in econometrics, forecasting, mathematical statistics and survey sampling methods. His co-workers and students continued and developed his ideas. I had the honour to be one of them.

The Professor educated many scientists. He was the promoter of 25 doctoral dissertations and the tutor of many habilitations. He published approximately 200 papers, 149 of which were scientific papers, including nine monographs and four textbooks. A full list of his scientific publications is provided by A. S. Barczak (1983). Profesor Pawłowski reviewed most doctoral and postdoctoral dissertations as well as professorship applications for both faculty councils and the Central Qualification Committee. Professor Pawłowski was also an excellent lecturer. Professor Jan Kordos (1981) emphasised his great merits in improving the methodological level of statistical applications in the work of Statistics Poland. The Professor was also a member of the Polish Economic Association and the Econometric Society. His hard work was well appreciated and earned him numerous ministry awards. He was awarded the Cross of the Order of Polonia Restituta, the Gold Cross of Merit and the Medal of the National Education Commission.

Professor Pawłowski was a polyglot: he spoke French, English, Russian and German. He enjoyed playing bridge, chess and hiking. He also took interest in classical music.

Professor Pawłowski's activity went beyond purely scientific pursuits. He co-organised numerous scientific conferences, including the renowned annual conference of the Departments of Statistics, Econometrics and Mathematics of the Higher Educational Schools of Economics in Katowice, Cracow and Wroclaw, held annually since 1965. The outcome of the conferences included strengthening the role of statistics in economic research and propagating the subject of statistics in all Polish universities of an economic profile. During one of these meetings, Professor Pawłowski initiated an important undertaking: the creation of a field of study called informatics and econometrics. It was intended for graduates of this field of study to join highly qualified staff dealing with quantitative analyses in enterprises. For this purpose, students were taught the necessary IT skills and statistical inference, which is useful for forecasting, survey sampling and data analysis. Moreover, Professor Pawłowski initiated the organisation of the Summer Econometric School in Ustronie Wielkopolskie, where young scientists were given an opportunity to broaden their knowledge.

Professor Pawłowski maintained professional contact with foreign scientific centres, especially with the Netherlands Economic Institute in Rotterdam, where many young employees of the University of Economics in Katowice were able to complete research internships. The Professor, commissioned by the United Nations, also delivered a series of lectures at the National Institute of Statistics and Applied Economics in Rabat. His foreign activity also included collaboration with the International Institute for Applied Systems Analysis in Austria, the Humboldt University in Berlin, and the UNESCO office in Paris.

Image: Department of Statistics, Econometrics and Mathematics, University of Economics in Katowice

The original scientific achievements of the Professor have become inherent in the methodology of statistical inference. Professor Z. Hellwig (1981) described Professor Pawłowski as a gifted and the most consistent student of Oskar Lange (a well-known Polish economist), who continued Lange's ideas in the field of quantitative methods in economics, and as a distinguished Polish statistician. There are many examples of his achievements in the field of statistics and economics. Below is a presentation of selected research papers describing the Professor's findings, with the titles translated from Polish to English.

Professor Pawłowski's publications concerning mathematical statistics include the textbooks *Introduction to mathematical statistics* (PWN, Warsaw 1965, 1966 and 1969), which was translated into Russian: *Statistika* (Moscow 1967) and German: *Verlag der Wirdschaft* (Berlin 1971), and *Mathematical statistics* (PWN Warsaw 1976 and 1980). Many scientific papers written by the Professor concern the construction of econometric models, their estimation and practical application. He is the author of numerous scientific articles, textbooks and scientific monographs on this subject, including *Econometrics* (PWN, Warsaw 1969, 1972, 1975, 1978, 1980), which was translated into Hungarian – *Közgzdasagi es Jogi Könyvkiadi* (Budapest 1970), *Elements of econometrics* (PWN, Warsaw 1981), and *Econometric methods of researching consumption demand* (PWN, Warsaw 1961 and 1971). He examined the application of econometric models in supporting production management, mainly in the book entitled *Econometric analysis of the production process* (PWN, Warsaw

1971 and 1976). Professor Pawłowski devoted a major part of that publication to modelling the impact of the so-called organisational effect on production efficiency. He also wrote about this issue in an article entitled *The production function considering the organisational factor* (*Ekonomista* 1970 issue 4, pp. 711–719).

Professor Pawłowski's numerous fields of interest included econometric modelling of macroeconomic phenomena in practice. He led a team of specialists who built one of the first models of the Polish economy. The results of this work were published in a collective work under his editorship – *The econometric model of the economy of the People's Republic of Poland* (PWN, Warsaw 1968). In several of his papers, including *A demoeconometric model of Poland and its application to counterfactual simulation* (IIASA, Laxenburg 1980), Professor Pawłowski drew attention to the need to consider demographic variables in the construction of economic macromodels.

The scientist also recognised the need to develop inferences based on non-simple samples, which resulted in the publication of a textbook on the survey sampling method, entitled *Introduction to the survey sampling method* (PWN, Warsaw 1972). In the light of the latest trends in the development of survey sampling methods, it can be argued that the methodology used in econometrics, especially the one relating to prediction, proves useful in the so-called model approach, which is now commonly applied in the field of small area statistics and in some other fields as well. Moreover, models taking into account (spatial) autocorrelation are used in the course of replicated population studies (conducted, e.g., on the basis of rotation samples). It is a well-known fact that some issues related to statistical quality control are similar to those encountered in the survey sampling method. In this field, Professor Pawłowski analysed the usefulness of statistical inference. A good example of such analysis could be found in his article *Examining a selected class of hypotheses formulated by means of the Wold sequence test in statistical quality control* (*Zeszyty Naukowe SGPiS* 1959, issue 11, pp. 231–272).

Professor Pawłowski's scientific achievements in the area of forecasting are also deemed highly significant. Apart from the well-known classical prediction principles, he also promoted the principle which leads to the determination of a forecast near the dominant of the variable whose value is predicted. He suggested that this principle could be especially useful in forecasting for short periods into the future. He proposed interesting concepts of determining the 'optimistic' and 'pessimistic' forecasts, which depend on favourable or unfavourable systems of values of the model's explanatory variables. Almost all the ideas the Professor implemented in this field can be found in several monographs, including *Econometric prediction* (PWN, Warsaw 1973) and *The theory of econometric forecast in a socialist economy* (PWN, Warsaw 1968 and 1974), and in a collective publication he edited, entitled *Econometric methods of forecasting the execution of economic plans* (PWN, Warsaw 1979) and

Principles of econometric prediction (PWN, Warsaw 1982). The last two were published in the series 'PWN Econometric Library', to which Professor Pawłowski largely contributed.

The Professor considered the method for predicting 'turning points' in the course of time series in the article entitled *Prediction based on control cards* (*Statistical Review* 1969, pp. 3–4). He proposed a definition for the concept of predictor flexibility and methods of its evaluation. This is of particular importance from the point of view of the selection of a predictor for forecasting time series characterised by an unstable trend course. Professor Pawłowski introduced many interesting considerations on the forecasting horizon in the work *On the concept of the prediction horizon* (*Systems Science* 1979, issue 1, pp. 81–90).

Professor Pawłowski developed the concept of alternative forecasts in papers including *The use of alternative predictions in long-term inference into the future (with special reference to water demand)* (IIASA, Laxenburg 1978) and *Contribution to the theory of alternative predictions* (*Oeconomica Polona* 1977, issue 3–4, pp. 381–400). He also greatly appreciated the value of ex post analysis of forecast errors, especially useful in selecting a method for forecasting phenomena in subsequent periods of time. He analysed this problem in several articles, including *Predictive ex post information and its use* (*Statistical Review* 1980, issue 3/4, pp. 239–255) and *On the use of ex post information in econometric prediction*, in Contributed Papers to the 40th Session of the International Statistical Institute in 1975.

Professor Pawłowski also formulated an interesting problem of determining the admissible values of the explanatory variables of the econometric model when the value of the dependent variable exceeds the desired level. He referred to this issue as a discriminatory prediction and wrote about it in, e.g., the work entitled *Discriminatory prediction and its relation to optimum control of economic systems* (*Control and Cybernetics* 1979, issue 1, pp. 55–66). In the article *Methods of analysing forecast sequences* (*Ekonomista* 1974, issue 4, pp. 847–874), Professor Pawłowski examined the possibility of determining a consistent forecast. This issue can be simplified to the problem of producing, for example, a forecast that is a common part of interval forecasts prepared on the basis of different methods. In this context, he also analysed the 'incoming forecasts', i.e. those which are developed successively, as the forecast period approaches.

One of the most interesting proposals put forward by Professor Pawłowski is a statistical test aimed to verify the hypothesis of the occurrence of autocorrelation in time series, whose description can be found in the article *The nonparametric test for autocorrelation* (*Statistical Review* 1973, issue 1, pp. 3–10) and in the article *The nonparametric test for the simultaneous verification of hypotheses for several autocorrelation coefficients* (*Statistical Review* 1974, issue 2, pp. 189–209).

In the article *The power of a certain test of normality in large samples* (*Statistical Review* 1959, issue 2, pp. 141–150), the Professor introduced a test to verify the hypothesis based on Geary's theorem on the independence of the mean and variance from a sample drawn from normal distribution. In this article, he also demonstrated his outstanding skills by analytically evaluating the power of these tests.

Professor Pawłowski's co-workers have emphasised that he had always had a never-ending supply of original scientific ideas and their potential applications. The Professor's work continues to inspire doctoral students and their collaborators to this day.

Sadly, Professor Zbigniew Pawłowski passed away prematurely at the age of fifty, on August 4, 1981 in Katowice, and was buried at the Powązki Cemetery in Warsaw.

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Report from the 29th Scientific Conference 'Classification and Data Analysis – Theory and Applications'

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The 29th Scientific Conference 'Classification and Data Analysis – Theory and Applications' (the 24th Taxonomic Conference) of the Classification and Data Analysis Section of the Polish Statistical Association (SKAD) took place on 7–9 September 2020, in Sopot, Poland. The conference was organised by the Faculty of Management of the University of Gdansk and held online through the Microsoft Teams communication platform. Krzysztof Najman, PhD, DSc, Assoc. Prof. at the University of Gdansk was the chairman of the Organising Committee, and Kamila Migdał-Najman, PhD, DSc, Assoc. Prof. at the University of Gdansk, Teresa Plenikowska-Ślusarz, MSc, and Katarzyna Raca, MSc, were the Committee members.

The basic information about the conference is available at: http://wzr.ug.edu.pl/skad-2020/.

The topics discussed included:

- theoretical aspects (taxonomy, discriminant analysis, linear ordering methods, multivariate statistical analysis, methods of analysing continuous variables, methods of discrete variables analysis, symbolic data analysis, graphical methods);
- practical applications (financial data analysis, marketing data analysis, spatial data analysis, other areas of data analysis application – medicine, psychology, archeology, etc., computer applications of statistical methods).

The main objective of the SKAD conference was to present the ongoing research and to create a platform for the exchange of ideas relating to theoretical and applied aspects of classification and data analysis. This annually-held forum is meant to present and promote state-of-the-art research and to indicate the possible directions for its development.

The conference featured 44 speakers who are faculty members and doctoral students of the following universities and institutions: AGH University of Science and Technology in Krakow, Warsaw University of Life Sciences – SGGW, SGH Warsaw School of Economics, University of Economics in Katowice, Cracow University of Economics, Poznań University of Economics and Business, Wroclaw

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University of Economics and Business, University of Gdansk, Poznań University of Life Sciences, University of Szczecin, West Pomeranian University of Technology in Szczecin, Medical University of Silesia, and Professor Brunon Synak Pomeranian Research Institute. During 10 plenary sessions, 34 presentations were delivered, introducing research results concerning the theory and applications of classification and data analysis. The sessions were held by: Mirosław Szreder (two sessions), Marek Walesiak, Andrzej Dudek, Józef Pociecha, Kamila Migdał-Najman, Krzysztof Najman, Grażyna Trzpiot, Grażyna Dehnel, and Krzysztof Jajuga.

Selected papers presented at the conference will be published in a book entitled *Data Analysis and Classification: Methods and Applications*, edited by K. Jajuga, K. Najman, M. Walesiak, published by Springer. Below is a list of all papers presented during the conference:

- Grażyna Dehnel, Marek Walesiak, *Dynamic approach in relative taxonomy applied to the evaluation of social cohesion of Polish provinces in the years 2010–2018*;
- Jacek Batóg, Barbara Batóg, *Spatial factor in the classification of administrative units with regard to the level of socio-economic development*;
- Andrzej Dudek, *Evaluation of the two-step spectral clustering algorithm for large untypical data sets*;
- Barbara Batóg, Katarzyna Wawrzyniak, *Propositions of transformations of asymmetrical nominants into stimulants on the example of chosen financial ratios*;
- Dorota Rozmus, *Determining the number of groups in cluster analysis using classical indexes and stability measures – comparison of results*;
- Katarzyna Raca, *Dark data – hidden data of unknown value*;
- Beata Bieszk-Stolorz, *Models of competing events in assessing the effects of the transition of unemployed people between the states of registration and de-registration*;
- Wioletta Grzenda, *Direct adjusted survival probabilities in the analysis of finding a job by the unemployed depending on their individual characteristics*;
- Magdalena Kawecka, *Clustering of the selected European Union countries with regard to the situation on the job market for people aged 20–24 in the years 2008 and 2018*;
- Agnieszka Chłoń-Domińczak, Aneta Ptak-Chmielewska, *Spatial characteristics stimulating the development of companies on the local level*;
- Urszula Cieraszewska, Monika Hamerska, Paweł Lula, Marcela Zembura, *The significance of medical science issues in research papers published in the field of economics*;
- Agata Majkowska, Kamila Migdał-Najman, Krzysztof Najman, Katarzyna Raca, *Identification of the words most frequently used by different generations of Twitter users*;

- Grażyna Trzpiot, *Gini regression in the capital investment risk assessment – sensitivity risk measures in portfolio analysis*;
- Anna Gdakowicz, Ewa Putek-Szeląg, *The use of duration analysis methods in examining the exit of a real estate sale advert from the advert database system*;
- Romana Głowicka-Wołoszyn, Andrzej Wołoszyn, *Proposal of the measure of local spatial inequality*;
- Aleksandra Łuczak, Małgorzata Just, *Application of positional OTS-TOPSIS method to the evaluation of the sustainable development of territorial units*;
- Michał Bryś, *Classification algorithm applications for information security on the Internet: a review*;
- Krzysztof Najman, Krystian Zieliński, *Outlier detection with the use of Isolation Forests*;
- Dominik Krężołek, *Estimation of Value-at-Risk using Weibull distribution – portfolio analysis on the precious metals market*;
- Klaudia Przybysz, Agnieszka Stanimir, *Europe 2020 strategy – objective evaluation of the implementation of assumptions regarding seniors*
- Joanna Kos-Łabędowicz, Joanna Trzęsiok, *Do seniors get to the disco by bike or in a taxi? – classification of seniors according to their preferred means of transport*;
- Agnieszka Orwat-Acedańska, *Evaluation of forecasts of mortality obtained by methods of regional forecasting for counties in Poland*;
- Anna Adamus-Matuszyńska, *Validation of psychometric tests in the measurement of propensity of negotiators to heuristic thinking and to cognitive errors*;
- Robert Bęben, Izabela Dempc, *The impact of weather on consumer behavior on the leisure market, on the example of the St. Dominic's Fair in Gdańsk*;
- Mariusz Doszyń, *Ex post errors for rare demand*;
- Jacek Wolak, *The use of the spatial taxonomic measure of development to assess the tourist attractiveness of poviats of the Lesser Poland voivodship*;
- Paweł Baran, Iwona Markowicz, *Using the value and weight of commodities to determine the asymmetry of mirror data in the international trade*;
- Alicja Antonowicz, Paweł Antonowicz, *The capacity to forecast enterprise insolvency on the Polish market using the precursory Altman Z-score model*;
- Krzysztof Dmytrów, *Impact of the method of normalization criteria to time and path of picking*;
- Sylwia Słupik, Joanna Trzęsiok, *Is society ready for long-term ecological investments? Profiles of electricity users in Silesia*;
- Paweł Baran, Izabela Szamrej-Baran, *Convergence of the EU members with regard to energy poverty*;

- Ewelina Nojszewska, Agata Sielska, *The impact of Covid-19 on the economies of European countries in the first half of 2020, using business cycle indicators*;
- Marcin Salamaga, *Modelling the risk of foreign divestment in the Visegrad group countries during the COVID-19 pandemic*;
- Joanna Landmesser, *The use of the dynamic time warping (DTW) method to describe the Covid-19 dynamics in the EU countries.*

The members of the Classification and Data Analysis Section held an annual meeting on the first day of the conference. The meeting was chaired by Krzysztof Jajuga, PhD, DSc, ProfTit, and its agenda included the following items:

- report on the SKAD activity;
- information on the planned domestic and international conferences;
- organisation of SKAD conferences in 2021 and 2022;
- elections to the SKAD Council for the term of 2021–2022;
- other issues.

The report on the activities undertaken by SKAD was presented by the Secretary of the SKAD Council, Barbara Pawełek, PhD, DSc, Assoc. Prof. at the Cracow University of Economics. According to the report, SKAD has currently 236 members, and any by-laws and membership applications are available on the SKAD website.

Subsequently, Prof. Pawełek introduced information relating to a book containing papers presented during the previous SKAD conference (which was held in Szczecin, Poland, on 18–19 September 2019). Prof. Pawełek also mentioned that the report on that SKAD conference could be found in issue 4/2019 of the *Statistical Review*.

Another important piece of information mentioned by Secretary Pawełek was the recent election of the Vice-Chairman of the SKAD Council to the position of the Secretary of the Executive Committee of the International Federation of Classification Societies (https://ifcs.boku.ac.at) for the 2020–2022 term.

The impact of the COVID-19 pandemic on the planned conferences was then discussed. In effect, the following domestic conferences were rescheduled to 2021: the 14th Professor Aleksander Zeliaś International Conference on Modelling and Forecasting of Socio-Economic Phenomena, the 2nd MET2019 'Methodology of Statistical Research' scientific conference, and the 39th Scientific Conference on Multivariate Statistical Analysis MSA 2018. In addition, the following inter-national conferences are planned for 2021: ECDA 2021 (Rotterdam, 5–9 July 2021), IFCS 2021 (Porto, 24–28 August 2021), CLADAG 2021 (Florence, September 2021), and GPSDAA 2021.

It was also decided that the next SKAD Conference will be hosted by the Poznań University of Economics and Business, which will take place on 8–10 September 2021.

The next part of the meeting, chaired by Prof. Paweł Miłobędzki, was devoted to the election of members of the SKAD Council for the 2021–2022 term. Katarzyna Raca assumed the duties of the Returning Committee. Józef Pociecha, Andrzej Sokołowski, Marek Walesiak, Barbara Pawełek, Krzysztof Najman, Grażyna Dehnel, Andrzej Dudek, and Krzysztof Jajuga were proposed as candidates for the membership to the SKAD Council, and they all accepted the call. The Returning Committee then held a secret ballot through the Microsoft Teams system, which selected Grażyna Dehnel, Andrzej Dudek, Krzysztof Jajuga, Krzysztof Najman, Józef Pociecha, Barbara Pawełek, Andrzej Sokołowski, and Marek Walesiak as new SKAD Council members. 23 members took part in the ballot, all of whom casted a valid vote. The candidates received between 20 and 23 votes each.

The meeting was subsequently closed.

The newly elected SKAD Council held its first meeting using the Microsoft Teams platform. The following presidium were elected:

- Krzysztof Jajuga – Chairman of the Council;
- Andrzej Dudek – Vice-Chairman of the Council;
- Barbara Pawełek – Secretary of the Council;
- Józef Pociecha, Marek Walesiak, Andrzej Sokołowski, Grażyna Dehnel, Krzysztof Najman – Members of the Council.

At the end of the conference, Prof. Marek Walesiak presented the new membership of the SKAD Council and informed the participants about the potential publication of the presented papers in a book, by Springer. Prof. Krzysztof Jajuga expressed his gratitude to the conference organisers and invited all the present guests to the next SKAD conference.