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Paweł Antoszak[1]

THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE WORKFORCE IN POLAND

Abstract

The aim of the article is to analyze the impact of artificial intelligence on the workforce in Poland. The introduction of artificial intelligence may raise concerns about job losses or the need to transform employee competencies. To carry out the analysis, statistical data on employment and dismissal of employees in sections of the national economy, the recruitment and dismissal rate, and vacant, newly created and liquidated jobs will be used. Based on this data, the dynamics of changes and structure will be calculated. The dynamics of changes will show what changes have taken place in the workforce in Poland. The analysis will be carried out on the basis of statistical data published in the Statistical Yearbooks of the Central Statistical Office in Warsaw. As analyzes and assessments show, there have been many changes in terms of employment and dismissals in economic sectors in Poland. It should be stated that the impact of artificial intelligence on the development of the labor market was significant. Conducted research has practical implications. Because the analyzes carried out show that there have been changes in the domestic labor market due to the influence of artificial intelligence on the workforce in Poland, but this has not caused fear of job losses or the need to transform employee competences. The article contributes to the issue of the impact of artificial intelligence on the workforce in Poland and provides a new perspective on the problem of artificial intelligence.

[1] PhD, Kazimierz Wielki University, Department of Economics, pawelantoszak@ukw.edu.pl.

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Introductions

Hiring and firing employees is one of the basic and important issues of modern economics. They concern the human factor and the work service it provides, as well as employees' expectations related to this work in the form of remuneration. The attitudes and behaviors of people engaging in their activities, skills and knowledge "translate" into specific expenditures and measurable effects both in the economy as a whole and in its individual regions and economic organizations. The impact of artificial intelligence on the workforce in Poland is of great importance. According to Janusz Meller, pay is mainly the price of labor, and labor force, work and pay are also economic categories entangled in market relations. (Meller, 1993). Let us also add here that, according to the same author, there are important and objective reasons to treat labor power (work ability) as a special and unique, but still a commodity. First of all, because a person has the full right to freely dispose of his or her ability to work and no one has the right to use other people's labor without its proper remuneration (Meller, 1993). The labor market - unlike other factors of production - cannot be analyzed solely in economic terms. Man is, of course, one of the economic resources, and his work creates new economic values. He is the owner of his competences and qualifications, which he offers on the labor market and for which there is a certain demand on this market. However, man is also an important element of non-economic reality: social, cultural, political, moral and mental. The subject of exchange on the labor market is not a person, but his work. It is not abstract in nature and cannot be separated from the entity that always performs a specific job (Paszke, Piotr, 2003). The extraordinary position of human work in the modern economy, the specific features and properties of the labor market, but also the close connections and interdependencies connecting this market with other markets in the world of final products and services as well as capital and land resources, are the reason for constantly asking new questions about the place of this market in economy, about the way it functions and the conditions of balance and disequilibrium prevailing there, about various competition relations and the types and segments of the market itself, and finally about the most important functional and institutional factors determining its operation (Jarmołowicz, Knapińska, 2005). The labor market is one of the markets for production factors, next to the land and capital markets. Although there are many similarities between the above-mentioned markets, the specificity

of the workforce clearly distinguishes the labor market and influences its functioning. The market economy is based on private ownership of the factors of production. One of the most characteristic features that make it difficult to treat work as other factors of production are the consequences resulting from the imbalance occurring in this market (Kryńska, Kwiatkowski, 2013).

1. Accepted to work in Poland

The results of the analyzes carried out reveal that in the years 2012-2021 in Poland there was a significant diversification of employment in economic sectors. In 2012, 1587,7 thousand people were employed. people. This year, the highest number of new jobs was in industry 439,4 thousand people and in trade; repairs of motor vehicles 269,5 thousand people. There were also many employment opportunities in administration and support activities 225,5 thousand. people. The fewest people employed were in other service activities 6,2 thousand. and in agriculture, forestry, hunting and fishing 11,0 thousand people. In 2014, 1709,4 thousand people were employed. people. This year, the highest number of people employed in industry was 509,9 thousand. people and in trade; repairs of motor vehicles 296,3 thousand people. There were also many employment opportunities in administration and support activities 238,3 thousand. people. The least number of people were employed in other service activities 6,0 thousand. and in agriculture, forestry, hunting and fishing 11,4 thousand people. In 2016, 2042,1 thousand people were employed. people. This year, the largest number of people employed in industry was 571,9 thousand. people and in administration and support activities 353,0 thousand people. There was also a lot of employment in trade; repairs of motor vehicles 337,6 thousand people. The least number of people were employed in other service activities 7,6 thousand. and in agriculture, forestry, hunting and fishing 12,4 thousand people. In 2018, there were 2295,7 thousand people employed. people. This year, the largest number of people employed in industry was 631,7 thousand. people and in trade; repairs of motor vehicles 383,6 thousand people. There were also a lot of jobs in administration and support activities 336,8 thousand. people. The least number of people were employed in other service activities 8,5 thousand. and in agriculture, forestry, hunting and fishing 12,5 thousand people. At the end of 2021, there were 1985,1 thousand people employed. people. This year, the highest number of people employed in industry was 517,5 thousand. people and in trade; repairs of motor vehicles 324,5 thousand people. There were also many employment opportunities in administration and support activities, 290,3 thousand. people. The least number of people were employed in other service activities 6,9 thousand. and in agriculture, forestry, hunting and fishing 9,5 thousand people. The impact of artificial intelligence contributed to an increase in the number of job applicants. The introduction of artificial

intelligence has an impact on reducing labor and business costs. Faster access to information and its use has appeared (Wodecki, 2021).

Table 1. People admitted to work in Poland in 2012-2021 (thousands of people)

Specification	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOTAL	**1587,7**	**1606,0**	**1709,4**	**1804,0**	**2042,1**	**2291,4**	**2295,7**	**2188,8**	**1809,0**	**1985,1**
Agriculture, forestry and fishing	11,0	11,8	11,4	12,4	12,4	12,8	12,5	11,5	9,8	9,5
Industry	439,4	457,8	509,9	511,5	571,9	615,9	631,7	567,6	473,2	517,5
Construction	145,4	124,7	119,9	116,3	114,9	135,5	144,0	137,1	114,7	118,7
Trade; repair of motor vehicles	269,5	269,8	296,3	305,3	337,6	367,1	383,6	362,0	292,0	324,5
Transportation and storage	84,4	90,1	102,9	112,2	135,1	154,3	169,8	172,6	141,9	164,9
Accommodation and catering	31,5	29,3	30,0	34,0	40,9	46,9	49,9	55,2	37,4	46,4
Information and communication	35,2	37,8	45,9	51,4	60,2	60,3	62,2	62,8	50,0	78,8
Financial and insurance activities	56,3	53,2	49,6	46,5	54,3	55,5	60,7	54,6	35,5	41,2
Real estate activities	12,0	14,8	13,4	15,8	15,9	17,6	18,9	18,9	15,0	16,8
Professional, scientific and technical activities	53,8	59,8	63,1	64,7	74,3	81,5	90,9	84,8	72,8	94,9
Administrative and support service activities	225,5	230,6	238,3	275,4	353,0	372,6	336,8	331,5	300,3	290,3
Public administration and defence; compulsory social securit	74,8	76,9	72,6	80,7	82,1	96,1	90,2	84,4	65,8	72,9
Education	68,4	69,4	75,0	85,0	86,1	155,6	120,1	119,5	94,7	93,8
Human health and social work activities	60,0	61,5	61,0	70,4	79,9	90,1	96,5	98,4	86,6	91,7
Arts, entertainment and recreation	14,3	12,4	14,1	14,7	15,9	18,3	19,5	20,1	14,0	16,4
Other service activities	6,2	6,1	6,0	7,7	7,6	11,1	8,5	7,8	5,9	6,9

Source: Own study based on: *Przyjęci do pracy,* Rocznik Statystyczny Rzeczypospolitej Polskiej 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 Wydawnictwo GUS w Warszawie 2013 s. 247, 2014 s. 248, 2015 s. 250, 2016 s. 250, 2017 s. 247, 2018 s. 250, 2019 s. 250, 2020 s. 251, 2021 s. 250, 2022 s. 252.

2. Dynamics of changes in the number of people hired for work in Poland

In the course of further analysis, the dynamics of changes in those hired for work in Poland in the years 2012-2021 was also presented here, assuming

the previous year = 100 (table 2). The data in this table show that there was quite a significant differentiation in the rate of growth of those hired for work in Poland. In 2012, the number of those hired fell by 12,67%, while in some sections the number of those hired increased by 6,43% (financial and insurance activities), in others it fell by 42,03% (real estate market services), and in the agriculture, forestry, hunting and fishing section the number of employees fell by only 2,65%. In 2014, however, there were slightly larger differences; with the total number of those hired for work increasing by 6,44% in financial and insurance activities, the number of those hired fell by 6,77%, and in the information and communication section it increased by as much as 21,43%. In 2016, there were even larger differences; with the total number of people hired for work increasing by 13,20%, in the administration and support activities section the number of people hired increased by 28,18%, and in other service activities it decreased by 1,30%. Even greater differences were recorded in the years 2017-2021. Although the number of people hired for work in Poland in 2017 increased by 12,21%, in education it increased by as much as 80,72%, and in other sections the number of people hired for work increased only by 0,17% (information and communication). In 2019 the total number of people hired for work decreased by 4,66%, in accommodation and catering it increased by 10,62%, and in industry it decreased by 10,15%. In 2021, the total number of people hired increased by 9,73%, while in information and communication the number of people hired increased by 57,60%, and in administration and support activities decreased by 3,33%. Comparing the dynamics of the growth of the number of people hired in Poland in the years 2012-2021, it is easy to notice that in all sections the growth rate achieved in the years 2012-2016 was higher than in the years 2017-2021. The scale of the slowdown in the growth rate of the number of people hired in this period was evidenced by the fact that in 2016 high growth dynamics were achieved in all sections in Poland. The variability of the growth dynamics of the number of people hired meant that in the long term the growth dynamics of the number of people hired between the sections of the national economy in Poland in many cases equalized. Employment in sections of the national economy will depend on the capabilities of artificial intelligence, which will place emphasis on hiring workers with IT and technical skills (Ćwiertniak, 2024).

Table 2. Dynamics of changes in the number of people hired for work in Poland in 2012-2021 (previous year = 100) in %

Specification	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOTAL	**87,33**	**101,15**	**106,44**	**105,53**	**113,20**	**112,21**	**100,19**	**95,34**	**82,65**	**109,73**
Agriculture, forestry and fishing	97,35	107,27	96,61	108,77	100,00	103,23	97,66	92,00	85,22	96,94
Industry	84,32	104,19	111,38	100,31	111,81	107,69	102,57	89,85	83,37	109,36
Construction	80,46	85,76	96,15	97,00	98,80	117,93	106,27	95,21	83,66	103,49
Trade; repair of motor vehicles	93,03	100,11	109,82	103,04	110,58	108,74	104,49	94,37	80,66	111,13
Transportation and storage	84,15	106,75	114,21	109,04	120,41	114,21	110,05	101,65	82,21	116,21
Accommodation and catering	88,73	93,02	102,39	113,33	120,29	114,67	106,40	110,62	67,75	124,06
Information and communication	92,88	107,39	121,43	111,98	117,12	100,17	103,15	100,96	79,62	157,60
Financial and insurance activities	106,43	94,49	93,23	93,75	116,77	102,21	109,37	89,95	65,02	116,06
Real estate activities	57,97	123,33	90,54	117,91	100,63	110,69	107,39	100,00	79,37	112,00
Professional, scientific and technical activities	95,90	111,15	105,52	102,54	114,84	109,69	111,53	93,29	85,85	130,36
Administrative and support service activities	83,55	102,26	103,34	115,57	128,18	105,55	90,39	98,43	90,59	96,67
Public administration and defence; compulsory social securit	96,77	102,81	94,41	111,16	101,73	117,05	93,86	93,57	77,96	110,79
Education	91,32	101,46	108,07	113,33	101,29	180,72	77,19	99,50	79,25	99,05
Human health and social work activities	88,37	102,50	99,19	115,41	113,49	112,77	107,10	101,97	88,01	105,89
Arts, entertainment and recreation	95,33	86,71	113,71	104,26	108,16	115,09	106,56	103,08	69,65	117,14
Other service activities	82,67	98,39	98,36	128,33	98,70	146,05	76,58	91,76	75,64	116,95

Source: Own study based on data from Table 1

3. Employment admission rate in Poland

Further assessments reveal that in the years 2012-2021 in Poland there was a significant variation in the employment rate in economic sectors. In 2012, the employment rate was 19,7%. This year, the highest employment rate was in administration and support activities 76,7% and in accommodation and catering 29,7%. The employment rate was also high in the construction industry and amounted to 29,6%. The lowest employment rate was in education 7,4% and in health care and social welfare 9,7%. In 2014, the employment rate was 21,5%. This year, the highest employment rate was in administration and support activities 75,9% and in construction 29,7%. The employment rate was also high in accommodation and catering and amounted to 28,8%.

The lowest job recruitment rate was in education 8,3% and in health care and social welfare 10,0%. In 2016, the employment rate was 24,8%. This year, the highest employment rate was in administration and support activities at 98,7% and in accommodation and catering at 37,9%. The employment rate was also high in the other service activities section and amounted to 30,1%. The lowest employment rate was in education 9,3% and in public administration and national defense 12,9%. In 2018, the job recruitment rate was 26,3%. This year, the highest employment rate was in administration and support activities 78,4% and in accommodation and catering 41,8%. The employment rate was also high in the construction industry and amounted to 35,1%. The lowest employment rate was in education 12,6% and in public administration and national defense 14,0%. At the end of 2021, the job recruitment rate was 22,1%. This year, the highest employment rate was in administration and support activities 71,9% and in accommodation and catering 41,8%. The employment rate was also high in the information and communication section and amounted to 30,5%. The lowest employment rate was in education 9,4% and in public administration and national defense 11,1%. One of the elements of gaining a competitive advantage is the use of artificial intelligence in business (Davenport, Mittal, 2023).

Table 3. Employment admission rate in Poland in 2012-2021 (%)

Specification	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOTAL	**19,7**	**20,2**	**21,5**	**22,3**	**24,8**	**27,1**	**26,3**	**24,5**	**20,1**	**22,1**
Agriculture, forestry and fishing	16,1	17,1	16,6	18,3	18,1	18,4	18,2	17,1	15,1	14,9
Industry	17,6	18,7	20,7	20,5	22,4	23,5	23,4	20,6	17,1	18,8
Construction	29,6	28,4	29,7	29,9	28,9	34,2	35,1	32,4	26,7	27,3
Trade; repair of motor vehicles	25,0	25,1	27,1	27,8	29,2	30,5	30,8	28,5	22,8	25,3
Transportation and storage	17,5	18,6	21,5	22,9	26,4	28,5	29,5	28,3	22,5	25,7
Accommodation and catering	29,7	27,3	28,8	33,5	37,9	41,3	41,8	44,2	29,5	41,8
Information and communication	20,5	21,7	25,9	26,9	30,0	27,7	27,5	26,0	19,8	30,5
Financial and insurance activities	21,6	21,2	19,5	19,0	22,5	22,3	25,2	22,5	14,8	17,5
Real estate activities	10,6	13,8	12,4	14,8	14,9	16,4	17,8	17,9	14,3	16,7
Professional, scientific and technical activities	23,0	25,1	26,2	26,0	28,7	30,1	31,4	27,7	23,0	29,5
Administrative and support service activities	76,7	80,2	75,9	82,7	98,7	92,7	78,4	80,7	74,9	71,9
Public administration and defence; compulsory social securit	11,8	12,1	11,4	11,9	12,9	15,3	14,0	12,9	9,9	11,1
Education	7,4	7,6	8,3	9,3	9,3	17,3	12,6	12,2	9,5	9,4
Human health and social work activities	9,7	10,0	10,0	11,7	13,2	14,7	15,6	15,8	13,8	14,6
Arts, entertainment and recreation	13,7	11,9	13,6	14,0	15,0	17,1	17,7	17,9	12,3	14,7
Other service activities	28,7	26,2	26,7	32,9	30,1	44,6	28,5	25,3	19,4	24,2

Source: Own study based on: *Przyjęci do pracy,* Rocznik Statystyczny Rzeczypospolitej Polskiej 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 Wydawnictwo GUS w Warszawie 2013 s. 247, 2014 s. 248, 2015 s. 250, 2016 s. 250, 2017 s. 247, 2018 s. 250, 2019 s. 250, 2020 s. 251, 2021 s. 250, 2022 s. 252.

4. Layoffs from in Poland

Further analyzes reveal that in the years 2012-2021 in Poland there was a significant diversification of employment in economic sectors. In 2012, 1623,9 thousand people were dismissed from their jobs. people. This year, the most people dismissed from work in industry were 449,4 thousand people and in trade; repairs of motor vehicles 267,2 thousand people. There were also many people dismissed from work in administration and support activities 217,2 thousand people. The fewest people dismissed from work were in other service activities 5,5 thousand. and in agriculture, forestry, hunting and fishing 11,0 thousand people. However, in 2014, 1,537,0 thousand people were dismissed from their jobs. people. This year, most job losses were in industry 435,0 thousand people and in trade; repairs of motor vehicles 260,7 thousand people. There were also many job losses in administration and support activities, 225,4 thousand. people. The least number of people dismissed from work in other service activities 5,9 thousand. and in agriculture, forestry, hunting and fishing 11.4 thousand people. In 2016, 1790,9 thousand people were dismissed from their jobs. people. This year, the largest number of job losses occurred in industry 497,3 thousand. people and in administration and support activities 310,3 thousand people. There were also many job losses in trade; repairs of motor vehicles 297,9 thousand people. The least number of people were dismissed from work in other service activities 7,0 thousand. and in agriculture, forestry, hunting and fishing 11,6 thousand people. In 2018, 2101,9 thousand people were dismissed from their jobs. people. This year, the most people dismissed from work were in industry, 558,2 thousand. people and in administration and support activities 355,6 thousand people. There were also many job losses in trade; repairs of motor vehicles 383,6 thousand people. The fewest people dismissed from work were in other service activities 8,7 thousand. and in agriculture, forestry, hunting and fishing 13,0 thousand people. At the end of 2021, 1827,0 thousand people were dismissed from their jobs. people. This year, most job losses were in industry 484,6 thousand. people and in trade; repairs of motor vehicles 290,9 thousand people. There were also many people dismissed from work in administration and support activities 288,2 thousand. people. The fewest number of layoffs occurred in other service activities 6,7 thousand. people and in agriculture, forestry, hunting and fishing 10,0 thousand people. Artificial intelligence affects job losses. Many sectors of the national economy use artificial intelligence, and it replaces and displaces workers, contributing to job losses (Springer, 2024).

Table 4. Layoffs from work in Poland in 2012-2021 (thousands of people)

Specification	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOTAL	**1623,9**	**1497,7**	**1537,0**	**1666,4**	**1790,9**	**2000,5**	**2101,9**	**2026,5**	**1796,2**	**1827,0**
Agriculture, forestry and fishing	11,0	11,0	11,4	11,5	11,6	12,5	13,0	12,0	10,3	10,0
Industry	449,4	428,4	435,0	450,7	497,3	531,2	558,2	528,8	478,6	484,6
Construction	171,4	137,8	119,8	111,8	114,7	121,8	130,8	127,0	110,9	114,9
Trade; repair of motor vehicles	267,2	243,4	260,7	274,3	297,9	329,9	351,4	330,9	282,4	290,9
Transportation and storage	86,7	90,5	95,1	100,0	110,5	126,8	143,8	149,8	136,7	144,9
Accommodation and catering	31,9	31,4	28,9	32,8	36,3	42,9	46,4	49,8	48,2	38,8
Information and communication	32,6	31,5	34,9	39,9	43,4	49,8	49,7	52,2	42,8	56,4
Financial and insurance activities	59,9	47,1	49,6	50,6	53,5	60,2	57,7	57,1	42,0	47,9
Real estate activities	15,2	14,2	12,9	14,4	15,2	17,3	19,0	18,2	16,3	16,2
Professional, scientific and technical activities	48,1	48,2	53,6	56,5	56,9	64,0	73,2	69,5	64,2	71,9
Administrative and support service activities	217,2	198,8	225,4	247,6	310,3	346,7	355,6	331,7	297,5	288,2
Public administration and defence; compulsory social securit	69,0	69,7	67,1	117,4	77,2	83,8	84,5	79,3	69,3	69,9
Education	81,1	68,4	64,1	73,1	76,3	108,8	104,6	104,9	91,4	85,9
Human health and social work activities	64,2	60,0	60,6	66,0	69,0	82,5	88,3	89,0	84,2	85,3
Arts, entertainment and recreation	13,5	11,5	12,0	13,5	13,8	15,7	17,1	17,6	14,7	14,6
Other service activities	5,5	5,8	5,9	6,3	7,0	6,8	8,7	8,7	6,6	6,7

Source: Own study based on: *Zwolnienia z pracy,* Rocznik Statystyczny Rzeczypospolitej Polskiej 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 Wydawnictwo GUS w Warszawie 2013 s. 248, 2014 s. 249, 2015 s. 251, 2016 s. 251, 2017 s. 248, 2018 s. 251, 2019 s. 251, 2020 s. 252, 2021 s. 251, 2022 s. 253.

5. Rate of dismissals from work in Poland

Further considerations reveal that in the years 2012-2021 in Poland there was a significant variation in the rate of dismissals in sections of the economy. In 2012, the layoff rate was 20,1%. This year, the highest rate of layoffs was in administration and support activities 70,4% and in construction 34,9%. The rate of layoffs was also high in the accommodation and catering industry and amounted to 30,0%. The lowest rate of dismissal from work was in education 8,7% and in health care and social welfare 10,4%. In 2014, the layoff rate was 19,3%. This year, the highest rate of job losses was in administration and support activities 71,7% and in construction 29,6%. The rate of layoffs was also high in the accommodation and catering industry and amounted to 27,7%. The lowest rate of dismissal from work was in education 7,0% and in health care and social welfare 9,9%. In 2016, the layoff rate was 21,6%. This year, the highest rate of job losses was in administration and support activities 86,3% and in accommodation and catering 33,4%. The rate of layoffs was also high in the construction section and amounted to 28,8%. The lowest rate of dismissal from work was in education 8,1%

and in health care and social welfare 11,2%. In 2018, the job recruitment rate was 23,9%. This year, the highest rate of job losses was in administration and support activities 82,4% and in accommodation and catering 38,7%. The rate of layoffs was also high in the construction industry and amounted to 31,8%. The lowest rate of dismissal from work was in education 10,9% and in public administration and national defense 13,0%. At the end of 2021, the layoff rate was 20,3%. This year, the highest rate of job losses was in administration and support activities 71,3% and in accommodation and catering 34,8%. The rate of layoffs was also high in the construction section and amounted to 26,4%. The lowest rate of dismissal from work was in education 8,6% and in public administration and national defense 10,6%.

Table 5. Rate of dismissals in Poland in 2012-2021 (%)

Specification	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOTAL	**20,1**	**18,9**	**19,3**	**20,6**	**21,6**	**23,5**	**23,9**	**22,6**	**19,9**	**20,3**
Agriculture, forestry and fishing	16,1	16,0	16,5	16,9	16,8	17,8	18,9	17,8	15,9	15,8
Industry	18,1	17,5	17,6	18,0	19,3	20,1	20,6	19,1	17,2	17,6
Construction	34,9	31,3	29,6	28,7	28,8	30,7	31,8	30,0	25,8	26,4
Trade; repair of motor vehicles	24,7	22,6	23,8	24,8	25,6	27,1	28,2	25,9	21,9	22,7
Transportation and storage	18,0	18,8	19,9	20,4	21,6	23,3	24,9	24,5	21,6	22,6
Accommodation and catering	30,0	29,3	27,7	32,3	33,4	37,6	38,7	39,8	37,8	34,8
Information and communication	18,9	18,0	19,6	20,8	21,5	22,8	21,8	21,5	16,9	21,7
Financial and insurance activities	23,1	18,9	19,6	20,7	21,9	24,2	23,8	23,5	17,6	20,5
Real estate activities	13,5	13,2	11,8	13,4	14,2	16,1	17,9	17,3	15,6	16,0
Professional, scientific and technical activities	20,5	20,2	22,2	22,6	21,8	23,5	25,2	22,6	20,1	22,2
Administrative and support service activities	70,4	69,1	71,7	74,3	86,3	85,6	82,4	80,6	74,2	71,3
Public administration and defence; compulsory social securit	10,8	11,0	10,5	17,4	11,9	13,2	13,0	12,0	10,4	10,6
Education	8,7	7,5	7,0	7,9	8,1	12,0	10,9	10,6	9,1	8,6
Human health and social work activities	10,4	9,8	9,9	10,8	11,2	13,4	14,1	14,1	13,3	13,5
Arts, entertainment and recreation	12,8	11,1	11,5	12,9	12,8	14,5	15,5	15,5	12,8	13,0
Other service activities	25,4	25,0	25,4	26,7	28,0	27,0	29,1	28,3	21,9	23,3

Source: Own study based on: *Zwolnienia z pracy,* Rocznik Statystyczny Rzeczypospolitej Polskiej 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 Wydawnictwo GUS w Warszawie 2013 s. 248, 2014 s. 249, 2015 s. 251, 2016 s. 251, 2017 s. 248, 2018 s. 251, 2019 s. 251, 2020 s. 252, 2021 s. 251, 2022 s. 253.

Conclusions

The analyzes conducted show that there have been changes in the domestic labor market due to the influence of artificial intelligence on the workforce in Poland. In the years 2012-2021, there was significant variation in employment admissions, dismissals, as well as the employment recruitment and dismissal rates in economic sectors in Poland. It should be noted that until 2018, the number of people employed and dismissed from work increased, and since

2019 this number has decreased in all sectors of the economy. The situation was similar in terms of the recruitment and dismissal rates. Until 2018, the employment rate and the dismissal rate were increasing, and since 2019 these rates have been decreasing in all sectors of the economy. In 2012, the number of layoffs exceeded the number of job hirings. Since 2013, the number of job admissions has been increasing and was higher than the number of job losses. However, in 2020, the number of job admissions and dismissals decreased and the number of job admissions did not significantly exceed the number of job dismissals. From 2021, the number of job recruitments and dismissals increased, and the positive gap became larger. The introduction of artificial intelligence may have raised concerns about job losses or the need to transform employee competencies. As analyzes and assessments show, there have been many changes in terms of employment and dismissals in economic sectors in Poland. It should be stated that the impact of artificial intelligence on the development of the labor market was significant.

Discussion

The largest number of people were hired for work in the analyzed period was in industry and trade; motor vehicle repairs. There were also many people hired for work in administration and support activities. The fewest people were hired for work in other service activities and in agriculture, forestry, hunting and fishing. In the analyzed period, the highest employment rate was in administration and support activities and in accommodation and catering. There was also a high employment rate in construction and amounted to. The lowest employment rate was in education and in health care and social assistance. On the other hand, the largest number of people dismissed from work was in industry and trade; motor vehicle repairs. There were also many people dismissed from work in administration and support activities. The fewest people were dismissed from work in other service activities and in agriculture, forestry, hunting and fishing.

Based on the results of research by many authors, it should be noted that the impact of artificial intelligence on the workforce in Poland is large. However, there are professions that artificial intelligence will not replace, but can only support. It is not possible to give systems human characteristics. Studies also show that the number and rate of hiring affects the rate of dismissals. This is related to job rotation, seasonality and the economic cycle. According to the authors, changes in the number of people employed and dismissed in sections of the national economy are the result of easier access to services, products and the development of technological progress and the development of artificial intelligence.

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ARTICLES

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Małgorzata Białas[1], Izabela Emerling[2]

PRESENTATION OF R&D EXPENDITURES OF THE LARGEST BANKS IN POLAND

Abstract

Innovation is the foundation of economic development. The subject of this paper was to identify how banks communicate to their stakeholders about their R&D activities and spending. The financial statements and non-financial reports of the 6 largest banks in Poland in 2017-2022 were verified. It was decided to choose business entities from this sector, as it was considered that banks are characterized by high expenditures on modern technologies and innovation. It is a sector that is developing rapidly, using the latest technological solutions to meet the ever-growing needs of customers for new banking products and the security of their operation. Unfortunately, despite the high expenditure on intangible assets disclosed in the balance sheet, it turned out that the banks do not boast about their research. There is no precise information on what expenditures on development work or the increase in expenditure on software, patents or licenses are about. Such information cannot be found either in the notes or in the non-financial reports.

This paper contributes to the sustainability reporting literature by providing new insights into banks' R&D spending reporting practices. Although the subject of R&D expenditure appears quite often in the literature on the subject, it is quite rare in the context of financial statements and non-financial reports. There is, therefore, a research gap in this area.

[1] PhD, AGH University of Science and Technology in Krakow, Faculty of Management, Department of Finance and Accounting, mbialas@agh.edu.pl, ORCID: 0000-0003-2703-4836.
[2] PhD, Cracow University of Economics, Faculty of Finance and Low, Department of Financial Accounting, izabela.emerling@uek.krakow.pl, ORCID: 0000-0002-9371-9430.

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Introduction

The concepts of innovation and innovation are understood differently in the literature on the subject. There are two distinct trends in defining innovation, the first of which emphasizes the process itself (i.e. the sequence of events) and the second – the result, which is the new solution.

Within the first trend, there are explanations in which innovation is treated as a process of creative use of knowledge, transformation of knowledge possessed by the organization or acquired from outside – into new products, services or processes (Cavagnoli, 2011, p. 111). The procedural aspect is particularly clearly emphasized in these words: "Innovation is the process by which a perceived opportunity becomes a new idea, which finds widespread practical application" (Tidd, Bessant, 2009, p. 16). As a result, innovation is understood as a sequence of events that should ultimately bring benefits to the organization through the implementation of a new solution.

Looking through the prism of the second approach, in which attention is paid mainly to the result in innovation, it should be noted that nowadays more and more often not only the effect for the company itself but also for its stakeholders is taken into account (O'Sullivan, Dooley, 2009, p. 5). Currently, it is believed that innovation should be understood as the introduction of significant changes that improve the products/services of a given organization, its processes, procedures and business model, thus providing new value to stakeholders (Timmerman, 2009, p. 6). On the other hand, according to D. Smith, innovation is a new idea, practice or object (Smith, 2006, p. 6).

Innovation is the basis of economic development. The pace of this development in the case of industry and services is determined by the speed of the creation of new ideas and the concept of efficient use of resources. New ideas arise in the course of various research work. Investments in them are therefore the engine of the economy and contribute to long-term economic and social development.

The subject of this paper is research and development (R&D) and the way in which banks communicate to their stakeholders about their performance and expenditure. The 6 largest banks operating in Poland were selected as the research group. It would seem that banks are the entities that invest a lot in R&D, especially in the context of the changes being introduced, for example as a result of the Covid-19 epidemic.

The aim of this research paper is to find answers to the following questions:

1. How did the 6 largest banks operating in Poland report their R&D expenditure over the last 6 years?
2. Were banks willing to boast about their research in their financial statements?
3. Has there been an increase in expenditure on this type of research in these banks in the last 6 years?
4. What was the R&D work carried out by the analyzed banks about?

In order to answer the above questions, an analysis of information published by the 6 largest banks operating in Poland in the period 2017-2022 was carried out (reports for 2023 are not yet available at the time of writing this paper).

This paper is divided into 4 parts. In the first part, we will take a closer look at the definitions and scientific research on R&D expenditure in the literature on the subject. Next, you will find places where you can look for information on R&D in financial statements. In the third part, issues related to non-financial reporting will be discussed. In the next part, the results of the analyses and final conclusions will be presented.

1. R&D IN THE LITERATURE

Before considering a research problem, it is necessary to define and know the basic concepts, so to begin with, R&D activities and the various aspects related to it will be described in detail. The terms research and development have been coined by Polish and international organizations that collect and process data from various fields of human economic activity.

Research and development (R&D), according to the Cambridge dictionary, is a business activity that is based on improving existing solutions and creating new ones.

The term research and development refers to activities that can be defined as creative work carried out on a regular basis in order to increase the body of knowledge. This definition also includes knowledge about man, culture and society. R&D activities are also looking for new applications in already known areas. In addition, you should pay attention to whether it is a R&D or related activity. An innovative and new element and the lack of uncertainty in the area of science and technology determine its classification as a R&D activity (Frascati, 2015, p. 38-39).

Research and development is defined as the improvement of a product or process. It is worth mentioning that if the main purpose of an activity is to develop a market for a given product or to improve production, such work is not assigned to R&D (Sawulski, 2018, p. 14).

Polish legislation also defines what R&D is. Such activity has been recognized as an eligible cost under the Corporate Income Tax Act of 15 February 1992. Research and development activities according to Article

4a(26) are innovative activities that include scientific research or development work. According to this Act, R&D activities should be carried out systematically, and their aim is to increase the resources of knowledge that is to contribute to finding new applications. The glossary of this Act, when referring to the term development work and research, refers to the Law on Higher Education and Science. Pursuant to Article 4(2) of this Law, scientific research is an activity that can be divided into basic research and applied research. Basic research is empirical, but also theoretical work that contributes to the acquisition of new knowledge about the basic elements of phenomena and observable facts. At the same time, according to this Act, they are not aimed at direct commercial use. Meanwhile, applied research is an activity carried out with the intention of acquiring new skills or knowledge, the aim of which is to create new services, processes or products. Significant improvements can also be made.

On the other hand, according to Article 4(3) of the Law on Higher Education and Science, development work is an activity which consists of acquiring, combining, forming and using the knowledge and skills available at a given time. Particular attention was paid to the use of knowledge to create IT tools or software, to create production plans. In addition, the legislator points to the use of science to create new projects and changed, improved or completely new products, processes or services. Conventional and periodic amendments to them are excluded from this scope, even if such changes bear the hallmarks of improvements.

R&D activities can be associated with innovative activities. Some statistical studies combine these two concepts. However, they are not synonymous by definition. Work related to the innovation process, i.e. patents, licensing, initiating production and market research, is excluded from R&D. Some activities are fragmented in R&D, such as pilot plants, prototypes, industrial design and process improvement. The key criteria to distinguish R&D activities from non-R&D innovation activities are the presence of easy-to-see novelties in R&D activities and the elimination of the element of uncertainty in the area of science, technology or technology. The Frascati Handbook also points to the creation of new knowledge or the use of knowledge to create new applications.

Research and development activity has also been defined by the Central Statistical Office in Warsaw as the systematic conduct of creative works undertaken to increase the body of knowledge, including knowledge about man, culture and society, as well as to find new applications for this knowledge. R&D activities are distinguished from other types of activity by a perceptible element of novelty and the elimination of scientific and/or technical uncertainty, i.e. a solution to a problem that does not result from the current state of knowledge.

Research and development work in banks is particularly focused on investment and development of IT tools based on algorithms, which make human activity similar in its operation. In particular, work on artificial intelligence has recently become popular. The definition of artificial intelligence was proposed by, among others, a group operating at the European Commission called the High-Level Expert Group on Artificial Intelligence (AI HLEG). According to them, "Artificial intelligence (AI) refers to systems that operate in the physical or digital world, draw conclusions from the knowledge gained from this data, and select the best actions to take to achieve a set goal." (HLEG AI, 2018) Artificial intelligence is a field of computer science that aims to create systems capable of performing tasks that require human intelligence (Surma, 2017, pp. 66-69). Accompanied by artificial intelligence are Big Data analyses which offer opportunities for increased efficiencies, reduced costs, and greater customer satisfaction through the delivery of higher quality services/products (Belhaj, Hachaichi, 2021). Big Data and artificial intelligence (AI) are related fields that are contemporary pillars of technological innovation and cornerstones of the modern digital era (Gandomi, Haider, 2015, pp. 137-144). In the book "*Big Data and Artificial Intelligence in Digital*" the authors showed how recent advances in these technologies facilitate banks, FinTech, and financial institutions to collect, process, analyze, and fully leverage the very large amounts of data that are nowadays produced and exchanged in the sector (Soldatos, Kyriazis, 2022). Moreover, the development of natural language processing, machine learning, social networks and sentiment analysis allows to some extent to forecast financial markets (Zanc, Cioara, Anghel, 2019, pp. 459-466). Despite the benefits, AI adoption faces barriers such as a lack of organizational competence in data management and individual AI skills (Bérubé, Giannelia, Vial, 2021).

The activity of research and development includes three types of research, namely:

- basic research,
- used (including industrial) and
- development.

Basic research is considered to be such experimental or theoretical activity aimed at acquiring new knowledge related to the basis of phenomena and observable facts, the main purpose of which is not a specific use or application. Such research is supposed to broaden knowledge about the world, discover new laws or principles of science. They are usually characterized by a focus on the development of science and have a cognitive purpose. The researcher's interests determine the choice of the subject of research as well as cognitive methods. Targeted research often has a specific research goal and assumptions about the results that are

a consequence of previously observed regularities. Targeting research creates a knowledge base that can help solve specific or potential problems in the future. The scope of targeted research may be influenced by the entity funding it (Sawulski, 2018, p. 14-15).

Applied research is work that is aimed at a defined and practical goal, and additionally original activities that expand knowledge. This research results in trial models of products, methods or processes. This is how we distinguish between basic research, which is aimed at expanding knowledge, and applied research, which is aimed at creating trial versions of projects. As a consequence, such research can be the basis for development and later implementation work. They are considered to be a bridge between basic research and the introduction of manufacturing techniques (Sawulski, 2018, p. 15).

The third type is development work, which is defined as an activity undertaken in a methodical manner, based on knowledge obtained as a result of R&D activities and practical experience. The Frascati Handbook also points out that development work generates additional knowledge that is aimed at creating new products, processes or improving previously created products or processes.

It is worth mentioning that the specification of the three types of R&D activities does not mean that basic research always has to lead to applied research and then to development work. Development work can result in many ideas for basic research. Basic research, on the other hand, can contribute to the development of new products or processes (Frascati, 2015, p. 47-48).

In the area of R&D, research is dominant that aims to compare R&D expenditure in different perspectives (countries, regions) and as a result of various economic events (e.g. Covid-19 pandemic, war in Ukraine). Examples include the following publications: A. Turczak, 2016, *Causal analysis of differences in the amount of expenditure on research and development in selected countries of the European Union and the world,* J. Heller, M. Bogdański, 2005, *Expenditures on research and development in Poland against the background selected European countries* or E. Walczak, 2012, *Factors of economic growth in European Union countries*. The publications also include an attempt to link entrepreneurship and R&D expenditure. From this point of view, the work of W. Gierańczyk, 2010, *Research and development as an element of entrepreneurship in European countries* and T. Janusz, J. Lis, 2003, *The role of the research and development base in the process of economic growth* was written. You can also find publications that try to indicate the reasons for the increase and limitations in R&D expenditure. Answers to these problems can be found in the collective work edited by S. Pangsy-Kania (ed.), 2007, *Knowledge and innovations in the development of Polish regions, driving forces*

and barriers. The topic of R&D expenditure in international and domestic articles is also discussed by, among others: Czerniak J., 2006; Ciok S., 2009; David P.A., Hall B.H., Tolle A.A., 2000; Elk R. van, Verspagen B., Weel B., Wiel K. van der, Wouterse B., 2015; Ziółkowska W., 2016; Grabińska B., Grabiński K., 2018. These are only examples of scientific publications, but research and development expenses occur most often in the context of their impact on the financial result. The topic of R&D expenditure can also be found in monographs. For example, this topic is discussed in the book *Commercial and non-commercial organizations in the face of increased competition and growing consumer demands* (Vol. 9) by A. Ujwara-Gil (2010), A. Olechnicka (2008) *Polish science on the Internet? Space of science and innovation - research report*.

Although the subject of R&D expenditure appears quite often in the literature on the subject, it rarely appears in the context of financial statements. So there is a research gap here. The added value of this paper is to check to what extent the information on R&D contained in the published financial and non-financial reports is legible and clear to a potential investor. What are the directions of expenditure of the largest banks operating in Poland over the last 6 years?

2. Accounting recognition of r&d expenditure in the financial statements

From an accounting point of view, it is necessary to distinguish between expenditures on R&D. These are two separate concepts and refer to two successive stages, which in the end are supposed to bring some innovation. However, the terms development and research work are not defined in the Accounting Act, therefore for the purposes of practice it is necessary to use the definitions provided in International Accounting Standard IAS 38 "Intangible Assets".

Paragraph 8 of IAS 38 defines research as an innovative and planned search for solutions undertaken with the intention of acquiring and assimilating new scientific and technical knowledge. In addition, you can read examples of these works in this standard. Pursuant to § 56, research work includes, m.in:

- activities aimed at acquiring new knowledge;
- searching, evaluating and finally selecting how to use research results or other types of knowledge;
- searching for alternative materials, equipment, products, processes, systems or services;
- formulating, designing, evaluating, and finalizing new or improved materials, devices, products, processes, systems, or services.

At the research stage, the company is not able to prove the existence of an asset belonging to intangible assets that will meet the definition of assets, including generating economic benefits in the future. Therefore, expenditure incurred for research is recognized as an expense when it is incurred. This position is set out in IAS 38 and is consistent with the Polish Accounting Act.

On the other hand, development work, in accordance with paragraph 8 of IAS 38, is the practical application of research discoveries or other achievements of other knowledge in the planning or design of the production of new or significantly improved materials, equipment, products, technological processes, systems or services, which takes place prior to the commencement of serial production or application. For example, the following are included in the development work (par 59, IAS 38):

- design, manufacture and testing of prototypes and experimental models (before their implementation into serial production or use);
- design of tools, jigs, moulds and dies using new technology;
- design, construction and operation of a pilot line, the size of which does not allow for economically justified production for sale;
- designing, manufacturing and testing selected solutions for new or improved materials, equipment, products, processes, systems or services.

According to IAS 38, it is possible to capitalize development expenditure as an intangible asset, but only if the business entity is able to prove (par 57, IAS 38):

- the technical feasibility of completing the component so that it is suitable for use or sale,
- the intention to complete the asset and to use or sell it,
- the ability to use or sell an intangible asset,
- the way in which the intangible asset will produce likely future economic benefits, i.e. prove the existence of a market for the products generated by the asset or for the asset itself, or prove the utility of the intangible asset if the asset is to be used by an entity,
- the availability of technical, financial and other means to complete the development work and the use or sale of the intangible asset,
- the ability to reliably determine the expenditure incurred during development work that can be attributed to this intangible asset.

If these conditions are not met, the company reports the development expenditure as a period expense.

The Polish Accounting Act (abbreviated as the AA) takes a similar approach to recognizing expenditure on development work in the books. Pursuant

to Article 33(2) of the AA, the costs of completed development work carried out by an entity for its own needs, incurred prior to the commencement of production or the use of technology, are classified as intangible assets if:

- the product or manufacturing technology is strictly defined and the development costs associated with it are reliably determined,
- the technical suitability of the product or technology has been identified and adequately documented, and on this basis the entity has decided to manufacture these products or use the technology,
- development costs are expected to be covered by revenues from the sale of these products or the use of technology.

On the other hand, according to the AA, it is possible to recognize the costs of development works as an intangible asset only from the moment of their completion, as indicated by the name of the asset – "costs of completed development works". According to IAS 38, the completion of development works is not a condition for reporting development costs as intangible assets, but proof that the means to complete them is sufficient. Therefore, the moment of recognizing development costs as intangible assets under Polish regulations is delayed than provided for in IAS 38. However, before the costs of development work are completed, all costs related to them are accumulated in the "Accrued expenses" account, according to Polish regulations. At the time of completion of these works, the sum of the costs incurred for them is settled depending on the effect obtained. If there is no economic effect of the development work, the costs of these works are directly related to the financial result in a given period (regardless of whether they have been completed or not). If, on the other hand, the development works are completed positively and the above-mentioned requirements of Article 33(2) of the AA are met, the costs of these works are transferred from the "Accrued expenses" account to the "Intangible assets" account".

3. Recognition of R&D expenditure in non-financial reporting

Non-financial reporting is inextricably linked to the concept of CSR. The Polish Agency for Enterprise Development defines CSR as a management strategy according to which economic entities voluntarily take into account social and environmental interests and relations with stakeholders, in particular with their own employees, in their activities. Non-financial reporting is inextricably linked to the concept of CSR. The Polish Agency for Enterprise Development defines CSR as a management strategy according to which business entities voluntarily take into account social and environmental interests and relations with stakeholders, in particular with their own employees, in their activities. Being socially responsible

means investing in human resources, environmental protection and relations with the environment, as well as informing about the actions taken, as this contributes to the increase in the competitiveness of the company and is the foundation for sustainable social and economic development. The Commission accepts the claim that companies take social and environmental considerations into account voluntarily and underlines the importance of the relationship between the individual and its wider stakeholders (Bender, 2017, p. 46). The European Commission points out that only discretionary actions, i.e. those that are not obligatory and go beyond the accepted standards, can be treated as socially responsible Business entities use many ways of transmitting information in the field of social responsibility, including reports or websites (Macuda, Matuszak, Różańska, 2015, p. 117).

The most important organization disseminating the concept of an integrated report internationally is the International Integrated Reporting Council (IIRC), which was established in 2010. Integrated reports, which are an expression of the CSR concept, not only compare, but also combine and integrate financial and non-financial information (Anam, Kasprzak, 2017, p. 2). It is worth mentioning, however, that there are significant differences between generally understood CSR reporting and integrated reporting. The domain of integrated reporting is to focus on the value creation process over time, while social responsibility reports present the entity's impact on the environment and are addressed to a wider group of recipients (Krasodomska, 2015, p. 78).

In Poland, in accordance with Art. 49 section 1 of the AA, there is an obligation to attach the so-called reports on the management board's activities. The management report, prepared by the unit's manager, is, in a sense, a supplement to the financial report.

In 2014, Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU entered into force as regards the disclosure of non-financial and diversity information by certain large entities and groups. As a result, it increased the scope of compulsory disclosure of non-financial information by enterprises.

The new rules require larger companies in the European Union to disclose annually non-financial information on environmental, social and labor issues, respecting human rights and counteracting corruption (Krzysztofek, 2016, p. 338).

Pursuant to §70 of the Regulation of the Minister of Finance in Poland, the statement on the applicable corporate governance principles should include information on the diversity policy, i.e. "a description of the diversity policy applied to the administrative, management and supervisory bodies of the issuer in relation to, in particular, age, gender or education and professional experience, the objectives of this diversity policy, the method of its implementation and the effects in a given reporting period, and if the issuer

does not apply such a policy, an explanation of such a decision". This requirement applies to periods beginning after December 31, 2016.

The directive, while leaving the company free to choose the form and method of disclosing data, allows for subjective disclosures and their use in the sphere of marketing activities. Moreover, it is likely that the company will refuse to publish mandatory non-financial information due to the fact that it constitutes the entity's trade secret. The regulations imposed on individuals do not contain any specific penalty for non-disclosure of data (Fijałkowska, 2016, p. 35).

The solutions introduced by Directive 2014/95/EU and the amendment to AA result in large enterprises facing new tasks, including the need to create an appropriate information base. At the same time, it should be noted that there is no obligation to prepare a separate CSR, social or integrated report. This reporting is just one possible solution. Entities may also fulfill their obligations in the area of reporting non-financial data by disclosing the necessary minimum information in the prepared report on activities. At the same time, the information presented should be sufficient to assess the results, development, condition and impact of undertaken activities on the indicated areas, which means conscientious compliance with the principle of materiality (Tylec, 2018, p. 308).

Table 1 organizes and compares the scope of disclosures contained in the report on activities and the statement on non-financial information based on the provisions contained in the organizational structure.

Table 1. Disclosures in the management report and non-financial statement

Information included in the activity report	Information included in the statement on non-financial information
– events significantly affecting the entity's operations in the financial year and after its end, until the date of approval of the financial statements – expected development of the unit – major achievements in the field of research and development – current and expected financial situation – own shares – branches owned by the entity - Financial instruments	– a concise description of the entity's business model – key, non-financial performance indicators related to the entity's operations – description of the policies applied by the entity in relation to social and employee issues, the natural environment, respect for human rights, counteracting corruption and a description of the results of the policies applied – description of due diligence procedures – description of significant risks related to the entity's operations

Source: Own study based on: J. Błażyńska*, Standardization of non-financial reporting*, Studies and Works, College of Management and Finance, Scientific Journal 169, Warsaw School of Economics, Publishing House of the SGH, Warsaw, 2018, p. 13.

In terms of the above disclosures, entities have a lot of freedom in reporting non-financial information. Entities reporting non-financial data in the form of statements on non-financial information are subject

to the obligation to disclose such data within 15 days from the date of approval of their annual financial statements, and when preparing a separate report, optionally together with the report on activities, to be published on the website of the economic entity, within up to 6 months from the balance sheet date, the statutory auditor confirms the preparation of this statement or a separate report (Rubik, 2018, p. 212).

In the case of non-financial reporting in the form of a separate document, there is no legally regulated nomenclature for such a report. The most common names are non-financial reports or sustainability reports.

4. Results of the conducted research

The research focused on the banking sector because it was recognized that entities from this industry are characterized by high expenditure on modern technologies and innovation. This is a sector that is developing very dynamically, using the latest technological solutions. Many new products were created relatively quickly as a response to the Covid-19 pandemic. An area of particular interest was research and development work and the way banks present information on this subject in their reports.

The aim of this research paper was to find answers to the following questions:

1. How have the largest banks operating in Poland reported their research and development expenses over the last 6 years?
2. Are banks willing to boast about their research in their financial statements?
3. Have the expenditure on this type of research increased in the last 6 years?
4. What did the R&D work carried out by the analyzed banks involve?

To answer the above questions, an analysis of information published by the largest banks operating in Poland in the period 2017-2022 was carried out. The largest banks in terms of assets included: PKO BP SA, Pekao SA, Santander BP SA, ING Bank Śląski SA, mBank SA, BNP Paribas SA (balance sheet total ranged from PLN 156.87 billion to PLN 444 billion). 6 banks were selected and their financial statements (mainly balance sheet and additional information) and non-financial reports for the period from 2017 to 2022 were analyzed. The focus was only on separate financial statements.

Information available in financial statements (i.e. balance sheet and notes) regarding the value of expenditure on innovation and research and development

Expenditures on research and development work, as previously written, are shown in the balance sheet in fixed assets under intangible assets. Figure 1 below shows the carrying amount of all intangible assets. As you

can see, the PKO BP SA bank has the largest intangible assets. Other banks have intangible assets at a similar level, i.e. in 2017, the level ranged from PLN 287.9 million (in BNP Paribas SA) to PLN 648.19 million (in mBank SA). In the following years, expenditure on intangible assets increased and at the end of 2022 their value increased significantly. Bank Pekao SA increased the value of this balance sheet item to the greatest extent, by as much as PLN 777.55 million over 6 years. In turn, mBank SA increased the carrying amount of intangible assets almost twice (the difference between the end of 2017 and the end of 2022 amounted to PLN 561.58 million). BNP Paribas SA also spent over PLN 500 million over 6 years on this item. Only ING BŚ SA did not make significant expenditure on intangible assets and therefore their value at the end of 2022 decreased (mainly as a result of depreciation write-offs) and amounted to PLN 393.2 million.

It is clearly visible that in 2020 and 2021, expenditure on intangible assets increased significantly (probably due to the Covid-19 pandemic and the need to adapt IT solutions to the current situation). Pekao SA bank invested the most in this area (the balance sheet value at the end of 2020 increased by almost PLN 400 million compared to 2019, and the following year by another PLN 305.57 million).

PKO BP SA bank invests in intangible assets every year, which is why there is no such spectacular change on the chart as in the case of Pekao SA bank.

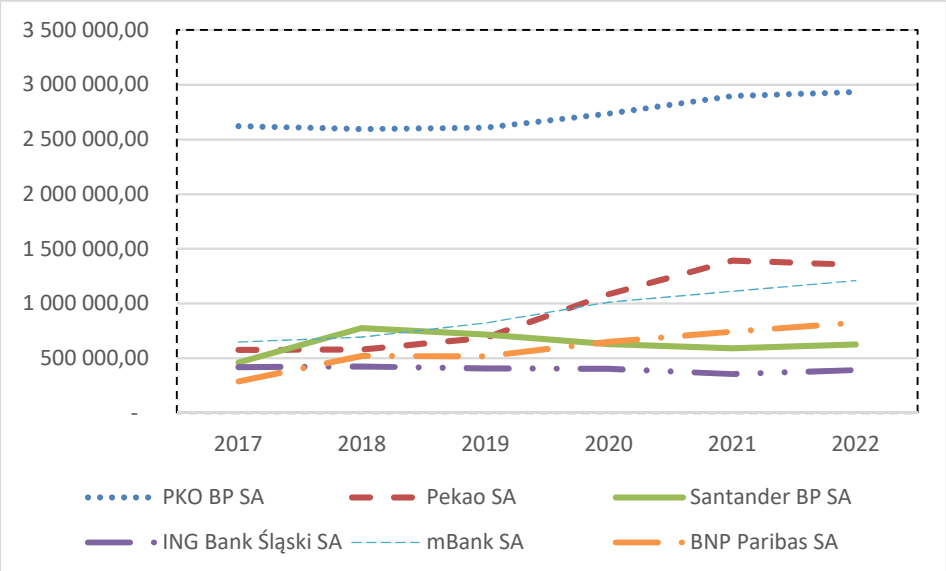

Figure 1. Carrying amount of intangible assets of the 6 largest banks operating in Poland in 2017-2022 / in thousands PLN/
Source: Own study based on financial statements of selected 6 banks from 2017 to 2022

However, analyzing the value of the balance sheet item alone is not sufficient. You should also look at the share of intangible assets in the balance sheet total. The value of the calculated indicators is presented in Figure 2.

An increase in the share of intangible assets in the balance sheet total in Pekao SA bank is clearly visible. These indicators also increased in mBank SA and BNP Paribas SA. In the remaining banks, the share of intangible assets in the balance sheet total decreased.

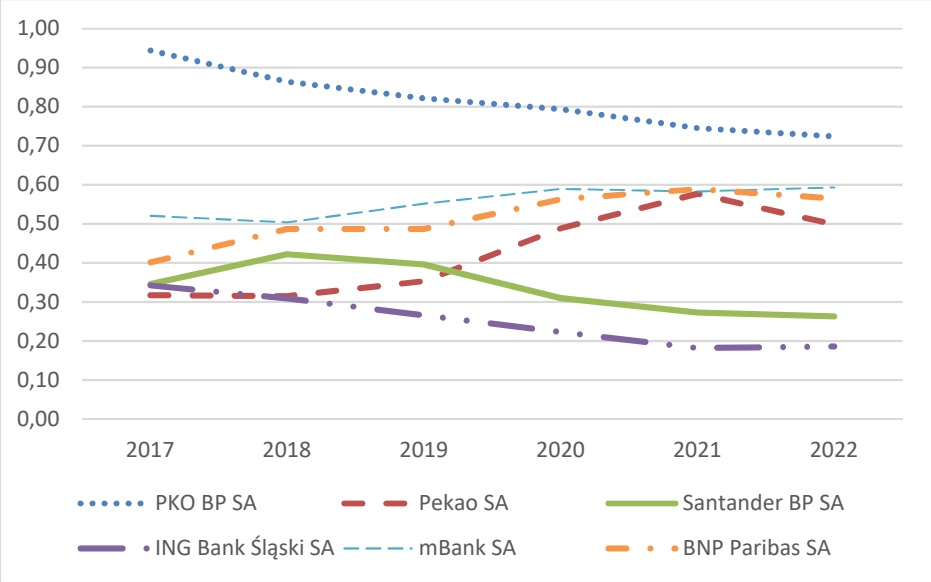

Figure 2. Share of intangible assets in the balance sheet total of the 6 largest banks operating in Poland in 2017-2022 /%/
Source: Own study based on financial statements of selected 6 banks from 2017 to 2022

Intangible assets disclosed in the balance sheet include various categories, including: goodwill. This is a position related to the takeover of another business entity. Positive goodwill occurs when the purchase price of another entity or its organized part is higher than the fair value of the acquired net assets. This category therefore has little to do with innovation and research. If we eliminated goodwill from intangible assets, the carrying value of intangible assets would be as shown in Figure 3.

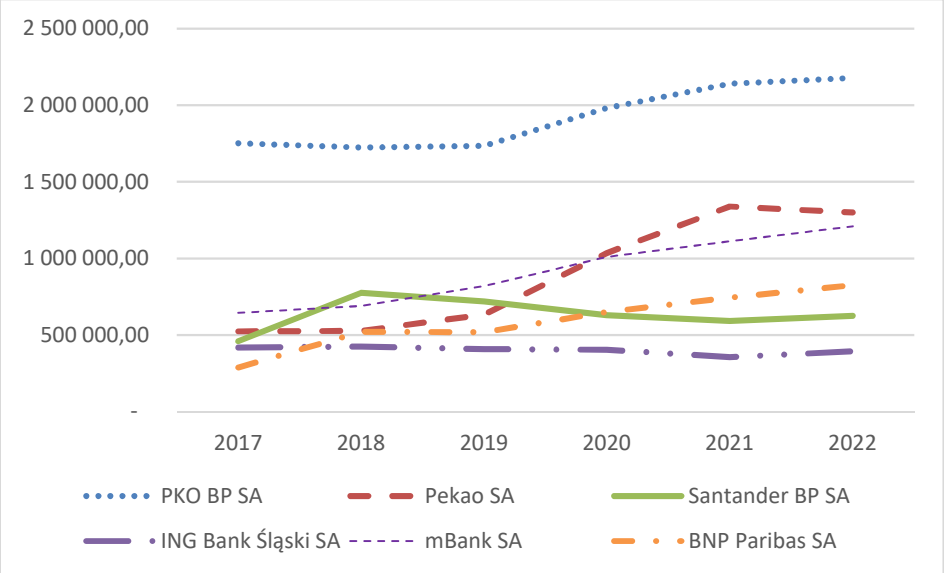

Figure 3: Carrying value of intangible assets (after eliminating goodwill) of the 6 largest banks operating in Poland in 2017-2022 / in thousands PLN/
Source: Own study based on financial statements of selected 6 banks from 2017 to 2022.

Despite the elimination of goodwill from intangible assets, the order of banks that have the most intangible assets on their balance sheets has not changed. PKO BP SA continues to dominate, and at the end of 2022, ING Bank Śląski SA still has the lowest value (Figure 3).

Of course, there are different items in intangible assets. One of them is expenditure on completed development works. When analyzing the financial statements of the 6 largest banks operating in Poland in 2017-2022, it was noticed that only Pekao SA bank showed such an item in its financial statements, which is presented in Table 2.

Table 2. Value of development costs at Pekao SA bank in 2017-2022 / in thousands PLN/

Categories	2017	2018	2019	2020	2021	2022
Development costs	1073.00	3.00	-	1276.00	2711.00	444.00

Source: Own study based on the financial statements of Pekao SA bank from 2017 to 2022

Unfortunately, Pekao SA bank did not provide detailed information in its financial statements about what these development works involved.

The next item in intangible assets concerns patents, licenses and software. They can be associated with various types of innovations (e.g. software that allows customers to perform new banking operations).

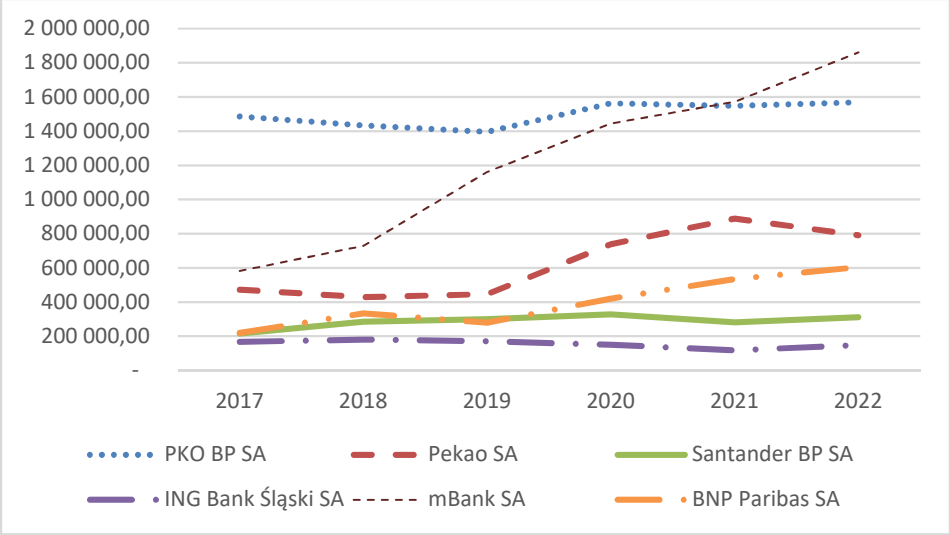

Figure 4. Carrying value of patents, licenses and software in the 6 largest banks operating in Poland in 2017-2022 / in thousands PLN/
Source: Own study based on financial statements of selected 6 banks from 2017 to 2022

Of the banks analyzed, the leader is, of course, the largest bank in Poland, PKO BP SA. In the years 2017-2022, the carrying value of its patents, licenses and software is approximately PLN 1,500 million. It is interesting that since the beginning of the analysis period, mBank SA has been constantly investing in this type of value and, as a result, in 2021 it manages to exceed the value of PLN 1,860 million.

Unfortunately, the only bank that described its intangible assets (i.e. software) was PKO BP SA. The additional information states that the bank incurred expenditure on the Integrated IT System (IS). The total value of expenditure on IS in the years 2005–2021 amounted to PLN 1,462 million. The net carrying amount of IS as at December 31, 2021 was PLN 629 million. The expected service life of the system was set at 24 years.

Other banks do not precisely inform their stakeholders about the purposes of the expenses incurred when investing in patents, licenses or software. The reader of financial statements must guess for himself what are the reasons and consequences of the bank's investment in software and licenses. This is a pity, because, as you can see, these are significant amounts and it would be good for a potential investor to find out whether

these are software necessary to provide customer service at the current level, or whether the bank is planning to implement another new service that will give it a competitive advantage over others banks.

Information available in non-financial reports regarding the value of expenditure on innovation and research

In order to verify what non-financial information banks include in their reports on management board activities and CSR documentation in the 6 largest banks were reviewed. Unfortunately, no information was found there regarding research and development activities or information on expenses related to these activities, although the financial reports clearly show that such work was carried out in banks. This is knowledge that banks should be proud of, according to the authors, because it proves that these institutions are constantly modifying their IT systems and adapting them to the ever-growing needs. It is therefore possible that banks, by publishing this type of information, would change the way they are perceived by investors and stakeholders. It should be considered whether this information should not also be a mandatory part of non-financial information published by banks.

Counclusion

The considerations presented in this research paper present only a sample of the problems related to information on research and development activities and expenditure on them occurring in economic entities. However, it should be stated that they are very important from the point of view of the interests of each enterprise and the perception of the entity by stakeholders. The aim of this paper was to present disclosed financial and non-financial information regarding R&D activities on the example of the largest banks in Poland. This goal was achieved by analyzing financial and non-financial reports published by banks in 2017-2022.

Banks are characterized by high expenditure on modern technologies and innovation. This is a sector that is developing very dynamically, using the latest technological solutions to meet the constantly growing needs of customers for new banking products and the security of their operation. Following this lead, it would seem that banks should be proud of information about R&D activities. Unfortunately, despite the high expenditure on intangible assets disclosed in the balance sheet, it turned out that banks do not boast about their research. There is no detailed information on development expenditure or the increase in expenditure on software, patents or licenses. Such information cannot be found either in the notes or in the non-financial reports.

Discussion

Answering the research questions:

1. How did the 6 largest banks operating in Poland report their R&D expenditure over the last 6 years?
   Financial and non-financial reports of the 6 largest banks operating in Poland were analyzed in terms of reporting their R&D expenses. Unfortunately, no information was found in non-financial reports regarding research and development activities or information on expenses related to these activities. On the other hand, it can be seen in the financial reports that banks make such expenditures, e.g. on IT systems.
2. Were banks willing to boast about their research in their financial statements?
   Banks incur significant expenditures on their development (mainly by investing in licenses and software). For example, in the PKO BP SA bank, in the period under review, the balance sheet value of its patents, licenses and software amounted to approximately PLN 1,500 million. It was the only bank that described its intangible assets on which it spent significant amounts of money. This concerns the Integrated Information System (SI), on which a total of PLN 1,462 million was spent in the years 2005-2021. Unfortunately, the remaining banks did not provide information on the purposes of the expenditures incurred when investing in patents, licenses or software.
3. Has there been an increase in expenditure on this type of research in these banks in the last 6 years?
   Analyzing the financial reports of banks, it can be seen that in the balance sheet the value of such intangible assets as patents, licenses and software is most often growing, which indicates that expenses are made for this purpose. Most often, these are not significant increases (except for mBank), but only in the case of Pekao SA does this value gradually decrease.
4. What was the R&D work carried out by the analyzed banks about?
   Unfortunately, there is no precise information on this subject in the banks analyzed. The only conclusions can be drawn based on the financial statements, which show that the banks make expenditures on intangible assets, mainly software. Only the PKO BP SA bank has more detailed information on the software it develops.

Due to the fact that financial and non-financial information is an important element of reporting in the field of corporate social responsibility (CSR), the research conducted leads to the following conclusions. Work is still required to improve the non-financial information provided both in Poland and in the European Union (EU) member states. The finding of a lack

of necessary information in published reporting on R&D expenditure in the banking sector may inspire relevant institutions to specify the list of mandatory information provided to stakeholders.

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ARTICLES

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Małgorzata Błażewicz[1]

IMPLEMENTATION OF ESG PRINCIPLES IN THE WATER SUPPLY SECTOR IN POLAND: AN EMPIRICAL DATA ANALYSIS

Abstract

Purpose: This study investigates the integration of ESG (Environmental, Social, Governance) principles into the water supply sector in Poland from 2021 to 2023. It explores the degree to which selected environmental and social indicators reflect strategic improvements aligned with sustainable infrastructure development and examines whether proxy indicators can be effectively used to infer governance quality in the absence of formal institutional data.

Design/methodology/approach: The research employs a quantitative, analytical-comparative methodology, utilizing statistical data sourced from the Local Data Bank of Statistics Poland (BDL GUS). ESG-related indicators were categorized, standardized, and analyzed using descriptive statistics and time series analysis. The governance dimension was evaluated through proxy indicators derived from infrastructural and operational metrics.

Findings: The study reveals consistent improvements in environmental efficiency and social accessibility within the sector, including reductions in water losses and network failures, alongside an expansion of infrastructure. Furthermore, the findings support the hypothesis that these developments are indicative of effective public governance, operational planning, and alignment with the objectives of SDG 6.

[1] M. Sc. ORCID: 0009-0008-5895-2131 Municipal Waterworks in Radom Limited Liability Company.

Practical implication: The results offer policymakers and public utility managers a structured method to assess ESG compliance in data-constrained contexts. By demonstrating the feasibility of proxy-based governance evaluation, the study provides a model for extending ESG reporting frameworks to other sectors lacking institutional transparency.

Originality/value: This work presents one of the first systematic ESG analyses of the Polish water supply sector using national public data. Its methodological innovation lies in applying governance proxies and interpreting ESG coherence across multiple dimensions. The study holds relevance for scholars, regulators, and infrastructure operators seeking to advance sustainable and accountable public service models.

Paper type: Research article.

Keywords: ESG, Water Supply Sector, Sustainable Development, Public Governance, GRI, CSRD.

JEL codes: H83, Q01, Q25.

1. Introduction

The ESG (Environmental, Social, Governance) framework is gaining strategic relevance in the public utility sector, including water supply systems. Originally developed for corporate responsibility, ESG has become a benchmark for sustainable and accountable management. In this context, this study examines the development of Poland's water supply sector from 2021 to 2023 through the ESG lens. By analyzing environmental, social, and proxy-based governance indicators, the research evaluates whether observed improvements reflect a coherent transformation aligned with sustainability goals and public governance standards.

2. Literature Review

The concept of ESG (Environmental, Social, Governance) originates from the idea of Corporate Social Responsibility (CSR); however, unlike CSR, it is characterized by a higher degree of normativity and formalization, increasingly serving as the foundation for mandatory non-financial reporting frameworks (Passas, 2024). ESG encompasses three complementary components used to assess an organization's performance: the environmental aspect, referring to the impact of operations on the climate, natural resources, and ecosystems; the social aspect, relating to stakeholder relations, equality, and inclusivity; and the governance aspect, which focuses on decision-making structures, transparency, and managerial accountability (Antonini *et al.*, 2024).

Today, ESG extends beyond corporate practices in the private sector and is increasingly applied in assessing the quality of management within public utility sectors such as energy, public transportation, and water management. The implementation of the ESG paradigm in public institutions serves not only to improve operational efficiency but also to ensure alignment with international guidelines and reporting standards, including the Corporate Sustainability Reporting Directive (CSRD) and the EU regulations on sustainable development taxonomy (Tonnarello *et al.*, 2024).

In the context of the public sector, ESG functions not only as a tool for environmental and operational audits but also as an element of institutional legitimacy for entities providing essential public services. The adoption of ESG principles contributes not only to raising service delivery standards but also to fostering long-term public trust and compliance with international development policy objectives (Nicolo *et al.*, 2023).

The concept of sustainable development constitutes both the axiological and operational foundation for the implementation of ESG policies on global and sectoral levels. The adoption of the 2030 Agenda for Sustainable Development Goals (SDGs) by the United Nations in 2015 introduced a set of 17 development goals, whose realization provides the overarching framework for public and investment policies (UNICEF, 2016). In the context of the water supply sector, Goal 6 – Ensure availability and sustainable management of water and sanitation for all – holds particular significance, as it directly correlates with the environmental and social dimensions of ESG (Campos *et al.*, 2025).

Indicators such as the availability of water supply networks, rationalization of water consumption, reduction of transmission losses, and equitable access to services in peripheral areas represent tangible expressions of SDG 6 implementation. At the same time, these indicators are reflected in ESG metrics, whose role in assessing the maturity of critical infrastructure sectors has gained particular relevance within the scope of EU policies and structural funding mechanisms (D'Amore *et al.*, 2024). Operationally, sustainable development also necessitates the implementation of a systemic approach to data and indicators, enabling not only the monitoring of SDG compliance but also the evaluation of the sector's evolution in terms of efficiency, equity, and resilience (Evaristo *et. al.*, 2023).

ESG management in institutional practice is reflected in the development and standardization of non-financial reporting frameworks (Hewawithnana *et al.*, 2023). One of the most widely recognized standards is the Global Reporting Initiative (GRI), which provides detailed guidelines for environmental (GRI 300), social (GRI 400), and governance (GRI 200) reporting. Among other requirements, the GRI framework mandates the disclosure of data on water consumption (GRI 303), service accessibility (GRI 203), anti-discrimination

policies (GRI 406), and governance structures (GRI 102, 205) (De Villiers *et al.*, 2022).

At the level of European Union law, the Corporate Sustainability Reporting Directive (CSRD), adopted in 2022, has acquired fundamental importance. Beginning in 2024, it progressively extends the obligation to report on ESG matters to broader categories of entities, including public sector institutions and municipal service operators (Hristov *et al.*, 2025). Consequently, organizations such as water utilities will be required to adhere to harmonized reporting standards (e.g., the European Sustainability Reporting Standards – ESRS), encompassing environmental impacts, social context, and governance structures (Elidrisy, 2024).

In practice, the implementation of the ESG concept within the public sector – including the water supply sector – is accompanied by specific institutional and informational barriers (Jonsdottir *et. al.*, 2022). While it is often feasible at the level of individual organizational units, such as water and sewage enterprises, to obtain data related to governance aspects (e.g., in the form of ethical policies, supervisory structures, or information on decision-making procedures), sector-wide analyses are hindered by the absence of standardized, publicly available data of this kind in official statistical databases. This gap pertains primarily to the governance dimension, whose operationalization would require systemic ESG reporting within the public sector—reporting that is only now entering its implementation phase under EU regulations (Martinez-Martinez *et al.*, 2024). As a result, conducting comparative or cross-sectional analyses at the sectoral level necessitates the use of alternative methods, particularly proxy indicators that allow for the inference of governance quality based on operational, infrastructural, and accessibility-related data (D'Amore *et. al.*, 2024).

As part of the empirical analysis, a multidimensional assessment of the water supply sector in Poland was conducted, focusing on its alignment with the concept of sustainable development through the lens of the ESG (Environmental, Social, Governance) paradigm. In particular, the study aims to determine whether the observed improvement in selected environmental and social indicators constitutes a consistent developmental trend rather than an incidental phenomenon, thereby reflecting the implementation of a strategic agenda aligned with the principles of sustainable infrastructure policy and sound public governance.

An important aspect of the study also involves exploring the potential use of selected environmental and social indicators as proxy measures for the Governance dimension-that is, corporate governance understood in terms of effectiveness, transparency, and efficiency of management within the public sector. While this approach diverges from the classical interpretation proposed by the GRI framework, it is supported by international literature and aligns with the increasingly emphasized need for an adaptive

approach to ESG reporting in non-market sectors, where data on decision-making and oversight structures are often unavailable or fragmented (Chopra *et al.*, 2024; Shalhoob *et. al.*, 2023; Chen *et al.*, 2023)

To investigate this issue, three research hypotheses were formulated and subsequently tested in the following sections of the study:

Hypothesis 1 (H1): Environmental and social indicators display an upward or stabilizing trend over the analyzed period, suggesting a positive trajectory of sectoral development;

Hypothesis 2 (H2): The observed changes are consistent with the values and objectives associated with the ESG concept, particularly in relation to Sustainable Development Goal 6 (SDG 6);

Hypothesis 3 (H3): The improvement in indicators can be interpreted as the outcome of effective public governance, reflected in attributes associated with the Governance dimension.

Accordingly, the analysis aims not only to assess the current state of the sector but also to demonstrate a causal relationship between the sector's strategic direction and its alignment with the ESG model as an integrated tool for institutional, social, and environmental evaluation.

3. Metodology

The selection of research methods in this study was subordinated to the use of quantitative statistical data obtained from public sources. Accordingly, a quantitative and analytical-comparative approach was adopted, grounded in the procedures of descriptive statistics, time series analysis, and the assessment of directional external consistency of indicators within the adopted ESG components. The following research techniques and procedures were applied throughout the study:

In the first stage, the organization and harmonization of statistical data from the Local Data Bank of Statistics Poland (GUS) were conducted with respect to environmental, social, and governance indicators of the water supply sector in Poland. This stage involved the selection of indicators meeting the criteria of temporal continuity and data completeness for the period 2021–2023, their classification within the relevant ESG categories, and alignment with the Global Reporting Initiative (GRI) non-financial reporting standards. The selection of a three-year timeframe was motivated by the need to ensure temporal consistency and the availability of complete data reported by the Local Data Bank (GUS) for each of the analyzed indicators. In the second stage, indicators were categorized according to their functional character – as absolute, relative, or derivative (synthetic) indicators – and assigned to specific levels of aggregation (systemic, operational, or user-based). This enabled the appropriate selection of data

transformation methods and value standardization procedures, including the calculation of year-over-year change dynamics for each indicator. As a result, it was possible to eliminate comparability limitations arising from input data heterogeneity, thereby enabling cross-indicator analysis within each ESG component. In subsequent stages, comparative analysis procedures were also applied between the environmental and social components, along with their interpretative reference to the governance component, based on the assumption of using proxy indicators.

4. Research Results and Discussion

As part of the analysis of the environmental aspect in the water supply sector, nine operational and infrastructural indicators were identified and interpreted, each of which holds key significance for assessing the environmental impact of the water supply system. These indicators reflect both the scale of exploitation and development of transmission infrastructure, as well as the efficiency of distribution and the rational management of water resources. The data for each of the indicators are presented in the table below.

Table 1. Environmental indicators of the water supply sector in Poland, 2021-2023

Name of Indicator	Year		
	2021	2022	2023
Water supply network failures [number]	82,010	78,905	76,231
Daily water production [thousand m³]	5,331,344	5,391,158	5,409,941
Daily water production as a share of total daily production capacity of active water supply facilities [%]	39.8	40.9	42.0
Daily production capacity of active water supply facilities [thousand m³]	13,383,683	13,166,714	12,918,055
Length of operational water supply network (distribution and transmission) [km]	334,599.2	337,724.1	341,149.1
Number of water supply network failures per 1 km of network [number/km]	0.25	0.23	0.22
Connections to residential and multi-occupancy buildings [units]	6,038,786	6,176,701	6,281,031
Water losses [thousand m³]	313,152.5	306,347.2	301,218.2
Share of water losses in total water supplied [%]	16.1	15.6	15.3

Source: Own elaboration based on data from the Local Data Bank of Statistics Poland (BDL GUS)

The empirical data collected confirm the presence of systematic modernization and optimization processes within the water supply sector, with both positive trends and stabilizing changes observed. Of particular note is the increase in the length of the operational water supply network – from 334,599.2 km in 2021 to 341,149.1 km in 2023. This indicator carries

significant structural weight, signifying the territorial expansion of the water supply system and, as such, confirming the implementation of infrastructure policy objectives aligned with the principles of GRI 203-1. This phenomenon should be interpreted not only as a physical extension of the network but also as an expression of effective spatial planning and the efficient allocation of resources for critical infrastructure.

A similar trend is observable in the number of service connections to residential and multi-occupancy buildings, which rose from 6,038,786 to 6,281,031. When interpreted through an environmental lens, this expansion of connections should not be viewed solely as a social metric (linked to service accessibility), but also as an environmental one – contributing to the reduction of alternative, often unregulated water extraction sources such as private wells or illegal intakes. This supports the rationalization of water abstraction and distribution on a local scale.

From the perspective of operational efficiency, a key metric is the number of water supply system failures and the relative failure rate per unit length of the network. These indicators show a clear downward trend – from 82,010 to 76,231 in absolute terms and from 0.25 to 0.22 failures per kilometer of network. This indicates a significant reduction in infrastructure vulnerability and an improvement in the quality of system operation, which may be interpreted as the result of more effective preventive measures and modernization investments. While not explicitly addressed in GRI standards, such trends align with the broader paradigm of environmental risk management and are consistent with OECD recommendations regarding water service governance quality.

One of the most significant environmental indicators remains water loss – understood as the volume of water lost during distribution (expressed in thousands of cubic meters) and its share in the total volume of water introduced into the system. Data from 2021 to 2023 show a distinct decline – both in absolute terms (from 313,152.5 to 301,218.2 thousand m^3) and relative terms (from 16.1% to 15.3%). This reflects an improvement in the efficiency of the entire distribution system, resulting not only from infrastructure investments but also from enhanced operational management and the implementation of technologies for leakage detection and minimization. In light of GRI 303-5, these indicators should be interpreted as evidence of more rational use of natural resources and a reduction in environmental pressure.

Subsequently, the sector's production capacity and scale were analyzed. Daily water production increased from 5,331,343.8 m^3 to 5,409,941.0 m^3, while total production capacity declined from 13,383,683 to 12,918,055 m^3. While this could initially suggest a reduction in system potential, it is noteworthy that the production-to-capacity ratio rose from 39.8% to 42.0%, which should

be interpreted as increased efficiency in the utilization of existing infrastructure. This indicator, conceptually similar to resource utilization intensity measures (capacity utilization), aligns with the logic of GRI 303-1 and demonstrates rational management of technological systems without generating excessive strain on the transmission network.

The indicators assigned to the social dimension of ESG pertain to the accessibility of water supply infrastructure, the evenness of its territorial distribution, and the inclusiveness of the water distribution system in relation to the needs of end users. This category encompasses metrics that directly relate to the fundamental human right of access to clean water, while also enabling an assessment of the advancement of public service policies in the context of infrastructural justice and efforts to eliminate technological exclusion. The data are presented in the table below and serve as the basis for further qualitative interpretation.

Table 2. Social indicators of the water supply sector in Poland, 2021-2023

Name of Indicator	Year		
	2021	2022	2023
Population using the water supply network [persons]	35,011,460	34,920,089	34,832,724
Rural population using the water supply network [persons]	13,132,049	13,165,737	13,181,386
Urban population using the water supply network [persons]	21,879,411	21,754,352	21,651,338
Water supplied to households [dam³]	1,279,793	1,286,530	1,296,355
Public water fountains [units]	3,597	3,555	3,426

Source: Own elaboration based on data from the Local Data Bank of Statistics Poland (BDL GUS)

The empirical data indicate that the overall number of people connected to the water supply network in Poland showed a declining trend – from 35.01 million in 2021 to 34.83 million in 2023. However, this decrease should not be interpreted as a deterioration in infrastructure accessibility indicators, but rather as a consequence of broader demographic trends, including a declining urban population and changes in settlement structures. Notably, when this indicator is analyzed by territorial breakdown, divergent trends emerge between urban and rural areas. The number of users connected to the water supply network in urban areas decreased from 21.88 million to 21.65 million, while in rural areas it increased from 13.13 million to 13.18 million. Although modest in absolute terms, this increase may be interpreted as evidence of continued efforts to integrate peripheral areas into water infrastructure networks and to reduce the development gap between core and peripheral regions.

Indicators concerning the number of public water fountains – an element of publicly accessible infrastructure – demonstrate a downward trend: from 3,597 units in 2021 to 3,426 in 2023. This phenomenon can be interpreted in two ways. On the one hand, the decline may reflect efforts to reduce the maintenance costs of public infrastructure due to budgetary constraints or a shift toward alternative solutions (e.g., automated water dispensers). On the other hand, the continued reduction in the number of public water access points may negatively impact the social inclusiveness of the water supply system, especially in the context of individuals not affiliated with households (e.g., homeless persons, tourists, mobile workers), a factor that warrants consideration in future recommendations.

An analysis of the volume of water supplied to households reveals an increase from 1,279,792.7 dam³ to 1,296,355.1 dam³, corresponding to a growth of approximately 1.3%. When considered alongside the decline in the total number of urban users and the slight increase in rural users, this trend suggests a rise in per capita water consumption. Several factors may account for this: changing lifestyles, improved availability of internal infrastructure (such as bathrooms, washing machines, dishwashers), and enhanced service quality and network pressure. In the context of GRI Standard 303-5 on water consumption, this indicator may be considered neutral: it does not necessarily point to increased environmental pressure, provided it is accompanied by parallel improvements in the system's technical efficiency – as demonstrated in the environmental aspect analysis.

In contrast to the environmental and social dimensions, the governance component in the water supply sector lacks directly accessible data of a managerial nature as understood in the classical GRI framework (such as supervisory structures, decision-making procedures, or ethical policies). Consequently, this analysis adopts an adaptive methodological approach based on the use of so-called proxy indicators, which enable the reconstruction of governance quality and operational efficiency using infrastructural, operational, and accessibility-related data. Although these indicators are originally classified under the environmental or social categories, they effectively serve as measures of organizational performance, technical risk management effectiveness, and the coordination of water infrastructure development. They are presented in the table below and serve as a point of departure for further interpretation.

Table 3. Governance indicators of the water supply sector in Poland, 2021-2023

Name of Indicator	Year		
	2021	2022	2023
Daily water production as a share of the total daily production capacity of active water supply facilities [%]	39.8	40.9	42.0
Length of operational water supply network (distribution and transmission) [km]	334,599.2	337,724.1	341,149.1
Number of water supply network failures per 1 km of network [number/km]	0.25	0.23	0.22
Connections to residential and multi-occupancy buildings [units]	6,038,786	6,176,701	6,281,031
Share of water losses in the total amount of water supplied [%]	16.1	15.6	15.3
Rural population using the water supply network [persons]	13,132,049	13,165,737	13,181,386
Urban population using the water supply network [persons]	21,879,411	21,754,352	21,651,338
Public water fountains [units]	3,597	3,555	3,426

Source: Own elaboration based on data from the Local Data Bank of Statistics Poland (BDL GUS)

The analysis of the collected data reveals several trends that may be interpreted as indicators of the sector's institutional maturity and its alignment with the principles of good governance. Of particular note is the consistent increase in the indicator reflecting the ratio of daily water production to daily production capacity. The rise from 39.8% in 2021 to 42.0% in 2023 demonstrates a rationalization of production resource management and improved alignment of operational capacity with actual demand. Maintaining this ratio below the threshold of infrastructure saturation simultaneously indicates the preservation of a safe margin of system reserves – an essential characteristic of resilient and effectively managed systems.

In this context, the data on the number of water supply system failures per unit length of the network are particularly significant. This indicator declined from 0.25 failures/km in 2021 to 0.22 in 2023, which should be interpreted as a sign of improved operational oversight and the effectiveness of maintenance and modernization activities. Although this indicator is not formally included in the GRI framework, it serves as an equivalent to the category of "operational infrastructure risk," widely applied in regulated sectors and featured in governance quality assessment frameworks such as the OECD Water Governance Indicator Framework (Ben-Daoud *et al.*, 2021).

Other infrastructural and accessibility indicators likewise serve as useful proxy measures of governance efficiency. The consistent increase in the length of the water supply network (from 334.6 thousand km to 341.1 thousand km) and the number of connections to buildings (from 6.04 million to 6.28 million) reflects a planned and effectively

coordinated expansion of core infrastructure. This process not only aligns with the logic of public investment management but also confirms the existence of coherent strategies implemented by local operators functioning within municipal systems and public utility enterprises.

Special attention should be paid to indicators concerning the territorial accessibility of water supply services – the number of users in rural areas increased by nearly 0.5% over the analyzed period, while the number of urban users experienced a slight decline. These data, when considered within the context of the country's overall demographic structure, may suggest not only the inclusion of new users but also a geographical redistribution, highlighting the need for flexible management of the public service system. The increase in service accessibility in peripheral areas demonstrates the system's capacity to respond to social needs in a sustainable manner, consistent with the principle of infrastructural justice.

5. Conclusions, Proposals, Recommendations

Based on the collected data and the qualitative interpretation of the three ESG components – environmental, social, and governance – it is possible to formulate an assessment of the extent to which the water supply sector has progressed toward a sustainable operational model and institutional quality aligned with the guidelines of international non-financial reporting frameworks.

With regard to Hypothesis 1 **(H1)**, which assumes a systematic improvement in environmental and social indicators over the analyzed period, the results unequivocally confirm its validity. In the case of environmental indicators, not only was an increase observed in the length of the operational water supply network and the number of service connections, but also a marked reduction in water losses and a decrease in the failure rate per unit length of the network. Simultaneously, the rise in the ratio of daily water production to system capacity, while maintaining a safe operational margin, reflects improved efficiency in water resource management. From the social perspective, despite the decline in the overall number of users connected to the network (driven by demographic factors), there was an increase in the share of rural population covered by water services, as well as a rise in the volume of water delivered to households. These developments clearly indicate the continued expansion of water infrastructure and the sustained provision of high-quality public services, even amid shifting socio-economic pressures.

In relation to Hypothesis 2 **(H2)**, which posits that the observed changes align with the directions outlined by the ESG paradigm and the Sustainable Development Goals, confirmation can be described as multifaceted. On the environmental side, the indicators are fully consistent with

the requirements of GRI 303 (Water and Effluents) and contribute to the implementation of Sustainable Development Goal 6 (SDG 6: Clean Water and Sanitation). The social indicators, including the level of access to services in rural areas and overall infrastructure availability, correspond to the objectives of GRI 203 (Indirect Economic Impacts), particularly in terms of promoting equitable access to municipal services. From an integrative perspective, it may be noted that infrastructure development efforts are not conducted in isolation from social and environmental goals; rather, they serve as functional complements, as evidenced by the coherence of observed trends across ESG dimensions.

Hypothesis 3 **(H3)**, which postulates that improvements in indicators are the result of effective management of the water supply sector, was positively verified based on proxy indicators associated with the governance (G) dimension. The application of an adaptive methodology – drawing on measures derived from environmental (E) and social (S) indicators – enabled an assessment of investment planning quality, technical prevention, operational oversight, and organizational flexibility. The maintenance or improvement of the production-to-capacity ratio, the reduction of failure rates, the increased accessibility of services in peripheral areas, and the ongoing expansion of the water supply network all point to the existence of coherent, long-term governance strategies effectively implemented by entities responsible for water management at both national and local levels.

The empirical study in question is subject to several limitations that affect both the full validation of its findings and the potential for generalization. In the case of this paper, which aimed to assess the development trajectory of the water supply sector in Poland within the context of the ESG framework, the primary limitations stemmed from both the nature of the available data and the relative novelty of the research topic.

The first and most significant limitation was the limited availability of quantitative data describing the water sector at the national level. Despite the existence of well-developed public statistical registers – such as the Local Data Bank of Statistics Poland (BDL GUS) – many indicators relevant from an ESG perspective are only available in aggregated form at the municipal or regional level, rendering them difficult to apply in sector-wide cross-sectional analyses. Moreover, a substantial number of indicators have only been standardized in recent years, which significantly restricted the ability to include them within a broader temporal scope. For this reason, the temporal range of the study was deliberately narrowed to the years 2021-2023, which constituted the only period guaranteeing full consistency and comparability of statistical data for the analyzed indicators.

Another important limitation was the necessity to exclude several archival datasets recorded under earlier classification schemes or covering only

a single measurement year. To ensure methodological coherence, all variables with limited time series were eliminated from the analysis, which reduced the potential breadth of the indicator spectrum. As a consequence, many metrics with potential informational value but lacking completeness over the study period were omitted.

A specific challenge was also associated with the use of proxy indicators for the governance dimension (G). In the absence of institutional data (e.g., supervisory structures, audit practices, ethical mechanisms), the decision was made to use infrastructural-operational proxy indicators that serve as indirect reflections of governance quality. Although this approach is supported by the literature (e.g., OECD, UNDP), its application in a sectoral context required the adoption of specific assumptions and was of an inductive nature. Given the lack of broad access to governance-related data or industry-level corporate reports, it was not possible to directly measure the G component, which limited the full operationalization of this dimension.

From a methodological standpoint, the study was further constrained by its sectoral structure and the aggregated nature of the data. While cross-sectional analysis allows for the identification of dominant macro-level trends, it does not enable the full recognition of intra-sectoral differences stemming from local contexts, enterprise-specific characteristics, or ownership structures. In this sense, the results obtained are not exhaustive but rather contextual – they serve as a foundation for further, more targeted research efforts.

Despite the aforementioned limitations, the conducted study opens up promising research avenues with significant cognitive and practical potential. Firstly, this work can be considered a preliminary step toward further, in-depth individual and comparative analyses using qualitative methods and case studies. For instance, ESG data analysis at the level of selected water utility operators could encompass not only infrastructural indicators but also non-financially reported data (in line with the CSRD Directive), such as environmental policies, codes of ethics, and governance structures.

Secondly, an important direction for future research involves the development of sector-specific ESG indices based on aggregated and standardized indicators. Such indices would not only allow for the evaluation of a given sector’s compliance with sustainable development requirements but would also enable intersectoral comparisons. As public data repositories continue to expand and as more entities become subject to ESG reporting obligations, it will become feasible to construct dynamic indices with high interpretive sensitivity.

Thirdly, this study may serve as a point of departure for long-term analyses incorporating a broader temporal horizon, provided that sufficiently comparable data are made available by public institutions in a standardized format. The ongoing digitalization and the development of public data warehouses support the creation of an environment conducive to such exploratory research.

Despite certain structural, technical, and data availability limitations, this study represents not only the first attempt at a systematic analysis of the compliance of the water supply sector in Poland with the ESG framework, but also a foundation for future in-depth, comparative, and model-based research. In the context of the growing importance of sustainability reporting and the implementation of EU regulations in this domain, such research is not only timely but indeed essential from the perspective of institutional accountability and the strategic management of public service development.

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ARTICLES

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Jarosław Prońko[1]

RATIONALIZATION OF SUPPLY

Abstract

The article presents the fundamental problems of optimizing supply processes. It presents: theoretical foundations of optimization, structure of the supply process, cost structure and methods of their estimation, as well as basic methods of optimizing supply costs. The use of the indicated methods does not provide immediate effects. However, it allows for a permanent reduction of costs in the future related to the size of the required warehouse space or capital frozen in inventories.

The fundamental dilemma is the correct estimation of the costs of a single delivery and unit costs of maintaining the inventory. The article describes the methodology for their estimation in several variants. It seems the most logical, but its practical application can be quite complicated.

The issue of optimizing supply costs should be viewed holistically. Because improving the efficiency of one sub-process can lead to a deterioration in the efficiency of the others.

Keywords: optimization, supply process parameters, supply models, supply cost optimization methods.

JEL classification: C610, D240, L230.

Introduction

An important problem in enterprise management is its supply of: necessary materials and semi-finished products intended for production, consumables and spare parts for machines, work clothes and other products related

[1] PhD, DSc, Institute of Management, Jan Kochanowski University in Kielce.

to occupational health and safety and social security of employees. The huge variety of assortment necessary for the functioning of the enterprise causes many problems related to its supply. In addition to organizational problems, there is also the question: how to do it cheapest? This article presents basic supply models and methods of its rationalization in terms of the costs of planning and implementing these processes. Currently, planning of these processes is often carried out using more or less advanced IT systems. However, it is worth knowing what optimization algorithms are used in these systems. And whether they really meet our expectations. It should also be remembered that advanced systems are most often designed for a specific enterprise according to the requirements set by its management. Therefore, in my opinion, general knowledge about the optimization of supply processes is necessary to select the right IT system for a given enterprise or to know what requirements to set for its designers.

1. Basic optimization issues

Optimization is the process of searching for solutions that best meet specific criteria. It begins with defining optimization criteria and indicators assessing the degree of their fulfillment. The next step is to construct a model containing optimization criteria, most often described in mathematical language, although this is not a necessary condition. The last step is to search for solutions: feasible and best meeting optimization criteria. Hence, optimization problems can be classified in terms of: the number of optimization criteria (single and multi-criteria); the model of the phenomenon (process) and related methods of searching for optimal solutions; the strategy of searching for solutions.

The last criterion is related to the division of optimization into static and dynamic. Static optimization is based on the search for optimal solutions based on the overall model. On the other hand, dynamic optimization is most often used in situations where there is no reliable overall model or complicated methods of searching for its solutions. We then assume that the process composed of optimal subprocesses is also optimal. This assumption allows us to decompose the optimization problem into partial problems with respect to several parameters. Solve each of them and, as a result, achieve the optimal solution of the entire problem. Richard Bellman is considered to be the creator of this method (Bellman, 1952). An alternative to dynamic programming are the so-called greedy algorithms. They consist in solving the problem in stages, choosing the most promising solution at each of them at a given moment of choice (Cormen, Leiserson, Rivest i Stein, 2007). Therefore, we make the optimal choice locally. Using these algorithms does not always lead to the optimal solution. However, a number of problems cannot be solved by other methods due to the lack or complexity of the model. The solution by this method is always optimal

in the case of models constructed in the form of graphs. There is no general rule indicating that for a given problem the greedy solution always leads to the optimal solution. However, there are certain criteria that allow us to assume that a given problem can be solved using this method (Cormen, Leiserson, Rivest i Stein, 2007).

An important optimization problem, as indicated above, is the selection of criteria. In complex problems, such as the supply process, there is usually more than one criterion for assessing the optimality of the solution, e.g.:

- the costs of implementing the process within a specified period of time;
- use of the transport capacity of means of transport;
- use of drivers' working time;
- utilization of warehouse working time and the ability to receive and issue goods.

There are many more optimization criteria. All of them can be converted into money, i.e. costs incurred. This is extremely important when reducing multi-criteria tasks to single-criteria tasks, which provide one solution instead of a set of solutions. In many cases, individual criteria are mutually exclusive, which requires finding a compromise in the scope of the solutions used. For example, planning deliveries without taking into account the ability of warehouses to receive goods can lead to an extension of working time (overtime work) in certain periods of time. In other cases, it can lead to the underuse of the labor fund available to the warehouse. The same applies to the use of means of transport and drivers' working time. Often, the optimization of warehouse work ruins the optimization of the use of means of transport. Therefore, the search for optimal solutions for the supply process often requires compromise solutions that do not optimize individual sub-processes, but the entire supply process.

By performing a multi-criteria analysis of the supply process, we obtain a set of solutions from which non-dominated solutions should be selected. That is, a set of decisions, each of which is better than the others in terms of some criterion, but worse than the others in terms of the remaining criteria. The next step is to select a strategy for searching for the optimal solution among the Pareto optimal solutions – non-dominated.

To determine the set of non-dominated decisions, you can be used the Hasse Diagram – a directed graph showing the order in the set: $P = (S, \leq)$. Where S denotes an element of the set, $\leq$- denotes the order in the set. An example of using this tool is shown in Figure 1. The Diagram used in Figure 1 is a modification of the original Hasse Diagram, which should indicate the order through the proper arrangement of elements, not directed edges.

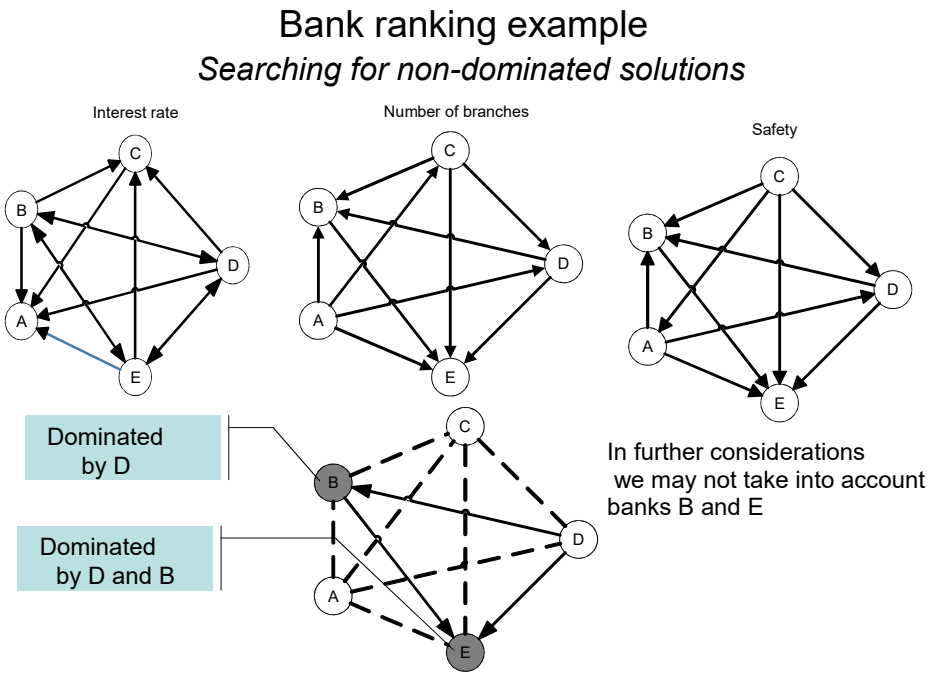

Figure 1. Example of using the Hasse Diagram to find non-dominated solutions Source: own work

The example presented in Figure 1 concerns the selection of the best bank for us in terms of the following criteria: interest rate, number of branches, security. The relationships between individual banks are presented in the upper row of diagrams. The arrow indicates the bank with worse parameters in terms of a given criterion. The lower diagram shows the combination of criteria. The dashed lines indicate a non-dominated relationship, while the arrows indicate a dominated relationship. It is clear from the diagram that only banks A, C and D should be taken into account in further analyses. Each of them is better in terms of one criterion than the others. A is the best in terms of the number of branches, C – in terms of security, D – in terms of interest.

Selecting the optimal solution from non-dominated solutions usually involves reducing a multi-criteria task to a single-criteria one by:

- maximizing the main goal;
- creation of meta-criterion:
- weighted sum of criteria;
- weighted sum of the degrees of criterion realization;
- minimizing the distance from the ideal point.

Maximization of the main goal – we strive to maximize the goal considered to be the most important, with a satisfactory level of the remaining criteria. The remaining criteria are included in the set of constraint functions, defining the area of feasible solutions.

Weighted sum of criteria – we aim to maximize the objective function, which is a linear combination of partial objectives. The sum of the weights of individual criteria must be equal to one. This methodology makes sense if all criteria are expressed in the same units of measurement.

$$u(x) = \sum_{i=1}^{k} w_i f_i(x)\,, w_i \geq 0$$
$$\sum_{i=1}^{k} w_i = 1$$

Weighted sum of the degree of criteria realization – the same as before, but instead of the objective function we insert the quotient of the objective function by the maximum value of this function

$$m(x) = \sum_{i=1}^{k} w_i \frac{f_i(x)}{f_{max}}$$
$$\sum_{i=1}^{k} w_i = 1$$

Minimizing the distance from the ideal point – we are looking for a solution that maximizes all criteria (it may lie outside the set of feasible solutions). In the next step, we are looking for a solution for which the distance from this point is the smallest.

The problem of process optimization is a complex issue, sometimes very difficult in the sphere of modeling and searching for solutions. Despite the development of many tools for solving such issues, many decision-making problems have still not been solved. In many cases, an individualized approach must be used, which significantly hinders the development of model solutions and their reproduction in practice. Problems related to optimization, despite the striving of almost all decision-makers to make optimal decisions, result from several reasons:

- difficulties in constructing models of real processes;
- selection of criteria, often these are qualitative criteria that are difficult to clearly reduce to quantitative criteria;
- selection of indicators measuring the degree of achievement of the intended goals;
- difficulties in solving the constructed models.

2. Models and parameters of the supply process

In the supply process we can distinguish three main sub-processes:

- searching for suppliers and concluding contracts;

- organization of transport;
- warehousing - receiving goods from suppliers, storing and issuing for current tasks for individual departments of the company.

Each of these sub-processes can be optimized individually or the entire supply process can be optimized. Individual optimization can lead to the optimization of the entire process. However, similarly to trade, subsequent optimization steps lead to the determination of the Pareto optimum of the supply process. It is characterized by the fact that the next improvement in the functioning of one element (the implementation of one sub-process) causes a deterioration in the quality of the functioning of the others. From this point on, further optimization of the supply process must include all of its sub-processes simultaneously.

Another problem related to supply is the multitude of materials that are covered. These materials are characterized by different value (in the cost sense) for the company and different regularity of consumption. This diversity means that almost every material should have a separate supply strategy. In practice, these materials are most often divided into groups using ABC and XYZ analysis. The first divides materials in terms of their share in costs, the second in terms of regularity of consumption, and thus the reliability of demand forecasts. Combining the results of these two analyses, we obtain 9 different groups of materials. [see 3] For each of them, we can develop a separate supply strategy and select separate optimization methods.

Regardless of the affiliation of a given material to a specific group, the organization of the supply process comes down to determining: the size of a single delivery, the delivery cycle (the time between subsequent deliveries) and the average inventory level, which is the result of the other two parameters.

Taking into account two basic parameters: the size of a single delivery and the delivery cycle, we can construct four models for supplying a company with a given material (group of materials):

- constant volume and delivery cycle;
- fixed delivery volume and variable delivery cycle;
- variable supply volume and fixed cycle;
- variable supply volumes and delivery cycles.

We can evaluate each of these models in terms of:

- ease of supply planning;
- possibilities of optimizing transport processes;
- possibilities of optimizing warehouse processes;
- influence on the size of average stocks depending on the stability of material consumption;
- impact on the ability to optimize supply costs;

Taking into account the following criteria: the size of inventories (we strive to minimize them), the use of transport and warehouse work (we strive to maximize the efficiency of work and equipment), we can indicate the possibilities of optimizing individual components of the supply process depending on the adopted supply model, as shown in Table 1.

Table 1. Possibilities of optimizing the components of the supply process depending on the adopted model. Q – delivery volume, T – supply cycle

	Q - constant T - constant	Q - constant T - variables	Q – variables T - constant	Q – variables T - variables
Transport	It favors	It favors	It is not conducive	It is not conducive
Warehouse work	It favors	It is not conducive	It favors	It is not conducive
Inventory size	It is not conducive	Partially favorable		It favors

Source: Own study

As can be seen from the table, the model of constant size and delivery cycle is conducive to optimizing transport and warehouse operations, but it is not conducive to reducing average stocks. In turn, the model of variable size and delivery cycle is conducive to reducing average stocks, but it makes it difficult to optimize the functioning of transport and warehouse operations. Moreover, this is not indicated in the table, the first model is easy to plan – it requires a small number of people to forecast demand and determine the size and dates of deliveries. On the other hand, the last model requires significant organizational outlays in the form of an increased number of people involved in planning and a greater number of problems in the sphere of transport planning and organization of warehouse operations. Currently, most planning and forecasting issues are solved using computers, but this does not reduce the number of people employed. It seems that the introduction of computer systems supporting planning processes in logistics should reduce employment in administration, but practice indicates a reversal of this trend.

3. Supply costs

One of the basic criteria for optimizing economic processes is the criterion of management rationality, which can be expressed in two ways:

- the greatest effect for a given input.
- the least number of resources to achieve a given effect.

$$Efficiency = \frac{E}{N} \rightarrow max$$

Comparing the achieved effects of economic activity to the costs incurred is called economic calculation. In order to use it, the effects and costs must be measurable, their measure must be expressed in the same units, and it must be possible to precisely determine the effect of specific actions. In supply processes, this problem can be reduced to a simpler form: achieving the same effect – supply that meets needs – with minimal costs. Most often, we express costs in the form of costs, although this is a significant simplification of the problem (Prońko, Soboń and Zamiar, 2008). However, assuming this simplification, the basic criterion for optimization will be minimizing the costs of supplying the enterprise, which is to express the maximum efficiency of supply processes.

It is therefore worth considering what generates costs and how to divide them (what groups to create from them) in order to optimize the process under consideration. As stated above, this process includes two main sub-processes: delivery and storage. Therefore, supply costs should be divided into two groups: delivery costs and storage costs. In further considerations, the issue of logistics marketing, which is of no small importance for logistics costs, has been omitted. However, taking this issue into account requires an individualized approach. This is determined by several aspects:

- strategic (basic) materials – different for different entities;
- transport infrastructure of the area connecting sources of strategic materials with the entity;
- the possibility of negotiating the price of these materials;
- quantitative and qualitative reliability of suppliers;
- financial and information infrastructure ensuring – speed and reliability of money and information flows;

Focusing only on the issues of delivery and storage, the costs of these processes are generated by:

- administrative units responsible for supply planning and the administration of warehouse management and transport;
- warehouses;
- transport.

Dividing them into two main groups, we can conclude:

- delivery costs are generated by:
- administrative units responsible for planning deliveries and implementing administrative projects related to it;
- transport
- storage costs are generated by:

- administrative units responsible for managing warehouse management;
- warehouses.

The correctness of separating these costs is of fundamental importance for the quality of future optimization, because the main criterion of optimization is the minimization of these very costs. Any incorrect classification of supply costs into one of the groups will affect the value of independent variables, which include the size and terms of deliveries. In known methods of supply cost optimization, the basic parameters of incurred costs are: the cost of a single delivery and the unit cost of storage.

As a rule, it is assumed that the cost of a single delivery for a given material is constant over a considerable period of time, independent of the size of the delivery (within the limits defined by the capacity of the means of transport) and dependent on the distance from the supplier. Hence, the cost of a single delivery can be estimated as:

$$k_d = \frac{K_{\acute{S}R(T+A)}}{ID}$$

where:

$K_{\acute{S}R(T+A)}$ – average monthly cost of maintaining transport and administration planning deliveries.

ID – average number of deliveries made per month (regardless of their size).

or:

$$k_{d_1} = \frac{K_{\acute{S}R(T+A)}}{IK} \cdot odl_1 \cdot 2$$

where:

$K_{\acute{S}R(T+A)}$ – average monthly cost of maintaining transport and administration planning deliveries.

IK – average number of kilometers covered by means of transport per month.

odl_1 – distance from the supplier.

A slightly more complicated problem concerns storage costs, because in a very short period of time, changing the amount of stored goods does not affect the amount of storage costs. However, minimizing the size of inventories can contribute to reducing storage costs in the future. Reducing inventories currently will result in the separation of free storage space, which can be used somewhat differently in the future or its maintenance can be discontinued. However, the amount of stored materials certainly affects the amount of capital frozen in them, which is not without significance for the financial liquidity of the company. Hence, unit storage

costs can be estimated in two ways: as an explicit cost – maintaining storage space or as an implicit cost – frozen capital.

The procedure for calculating unit storage costs explicitly can be carried out as follows.

- we determine the average monthly stock of individual materials (Zi);
- we estimate the amount of necessary storage space for each of them (PMi);
- we estimate the amount of storage space needed for all materials (PM= Σ PMi);
- we calculate the indicator of the use of the space stored by individual materials (Wi = PMi /PM),
- we estimate the monthly costs of maintaining warehouses and administration supporting warehouse management (K).

The unit storage costs of a given material can be determined using the formula:

$$kp_i = \frac{K \cdot W_i}{Z_i \cdot l}\left[\frac{j.p.}{j.m.\cdot j.t.}\right]$$

where:

kp_i – unit cost of storing a given material expressed in: monetary units per unit of measurement and unit of time (e.g. day),

l – average number of days in a month, if W_i and Z_i were also estimated on a monthly basis.

The implicit costs (capital freezing) can be determined from the following relationship:

$$Kp_i = Z_i \cdot C_i \cdot p \cdot l$$

where:

p – value of the daily interest rate of the most stable and advantageous financial instrument, these may be bonds, deposits, etc.

Zi – average stock level of a given material in a month;

Ci – purchase price of a given material;

l – number of days in a month.

Hence, the unit cost of freezing capital in a given material can be determined using the formula:

$$kp_i = C_i \cdot p$$

4. Optimization of supply costs

To sum up the previous considerations, the problem of optimizing the supply process can be simplified to the problem of minimizing its costs. However, it should be realized that this is only one aspect of optimizing this process. It is certainly very important and comprehensively covers the supply issue, but not the only one. Its main advantage is the comprehensive approach to the supply problem. As a reminder, the optimization of individual subprocesses must take into account the impact of changes made on the functioning of other subprocesses. This results from the broadly understood Pareto optimum. Mutual adjustment of the functioning of individual subprocesses leads to a stable state, in which the improvement of one subprocess entails a deterioration in the functioning of other subprocesses. In the case of minimizing the costs of the entire process, we improve its efficiency by taking into account the mutual dependence of subprocesses.

We reduce the optimization of the supply process to minimizing the costs of its implementation. The independent variables are: the size and terms of deliveries. The main indicators are: the cost of a single delivery and the unit cost of storage.

Economic Order Quantity (EOQ*) model* presented in 1913 by F.W. Harris (Harris, 1913). This model is better known as *the Wilson EOQ Model* or *Wilson's Formula*. It has a very versatile application, therefore its slightly modified version will be presented below.

Let us assume that the consumption of a given material is stable in a predictable time perspective (e.g. 1 month, quarter, year), hereinafter referred to as the planning period, and amounts *to a* units [MU] in the settlement period (e.g. 1 day, week). Hence, the needs *D* for the entire planning period are: $D = a \cdot n$, where *n* is the number of settlement periods in the planning period.

If we deliver the material at once for the entire planning period, the average stock for the entire planning period will be $\frac{1}{2}D$. If we make two deliveries of the same size for the entire planning period, the delivery quantity *Q* will be $\frac{1}{2}D$; average stock: $\frac{1}{2}Q = \frac{1}{4}D$. If we make 4 identical deliveries during the planning period, the delivery quantity *Q* will be $\frac{1}{4}D$; average stock: $\frac{1}{2}Q = \frac{1}{8}D$. We can therefore write:

- quantity of deliveries $k = \frac{D}{Q}$;
- average daily inventory in the planning period $Z_{śr} = \frac{1}{2} \cdot Q$

Hence the delivery cost will be:

$$K_d = \frac{D \cdot A}{Q}$$

where
A – cost of a single delivery.

The cost of maintaining inventories will be:

$$K_u = \frac{1}{2} \cdot Q \cdot h \cdot n$$

where:
h – unit cost of maintaining the inventory;
n – number of settlement periods in the planning period.

Therefore, the total cost of supply will be:

$$K = K_d + K_u = \frac{D \cdot A}{Q} + \frac{1}{2} \cdot Q \cdot h \cdot n$$

The above equation is a mathematical model of supply costs with the assumptions made earlier. It combines the optimization criterion – supply costs, with the decision variables – the size of a single delivery Q. The optimization problem is therefore reduced to finding the minimum of this function. This can be done graphically or by using differential calculus. The graphical method is more illustrative, so it will be presented. The total cost function is the sum of the supply cost function (hyperbolic function) and the inventory holding cost function (linear function). The solution to the problem is shown in Figure 2.

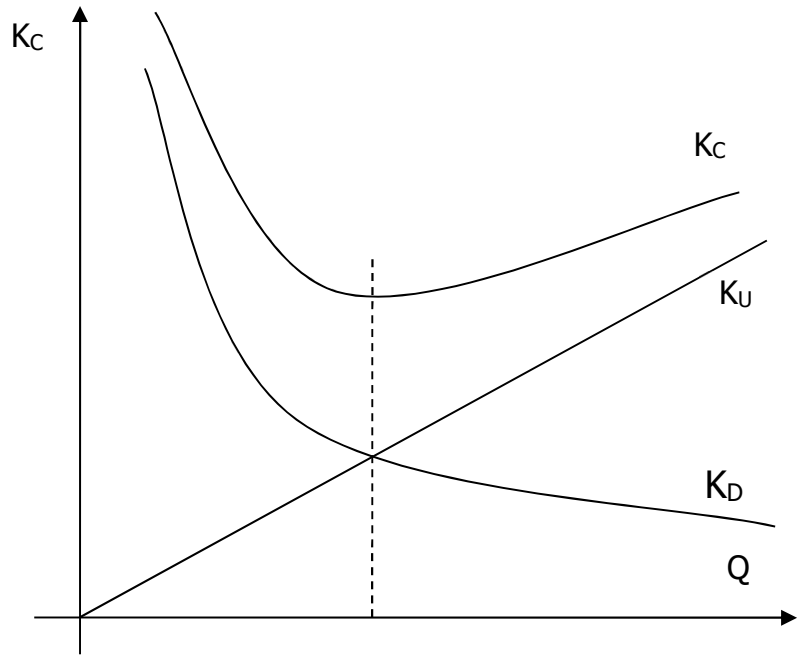

Fig. 2. Graphical solution of the supply costs problem
Source: Own study

Figure 2 shows that the total cost function has a global minimum and it is located at the intersection of the functions describing the costs of delivery and storage. Therefore, the minimum of supply costs occurs when the costs of delivery are equal to the costs of storage. This relationship has a much wider application. It has become the basis for all subsequent methods of solving the problem of minimizing supply costs. It can also be used to solve the replacement problem: when to replace a vehicle or other fixed asset so that the costs associated with its operation and purchase are the lowest?

Taking into account the relationships presented in the figure, the lowest total supply cost will be achieved when:

$$\frac{A \cdot D}{Q} = \frac{1}{2} \cdot Q \cdot h \cdot n$$

Solving the above equation we get:

$$Q(EOQ) = \sqrt{\frac{2 \cdot A \cdot D}{h \cdot n}}$$

We will obtain the same result by finding the minimum of the total cost function using differential calculus.

Taking into account that: $\frac{D}{n} = a$ - average daily material consumption, we get:

$$Q(EOQ) = \sqrt{\frac{2 \cdot A \cdot a}{h}}$$

With even material consumption, subsequent deliveries should take place at the following time intervals:

$$l(POQ) = \frac{n}{k} = \frac{n}{\frac{D}{Q}} = \frac{n \cdot Q}{D} = \sqrt{\frac{2 \cdot A \cdot n}{h \cdot D}} = \sqrt{\frac{2 \cdot A}{h \cdot a}}$$

With even material consumption, it does not matter what we determine: *Q* or *l*, but it does matter when material consumption is not even. With this assumption, we determine EOQ analytically, and we estimate delivery dates based on forecasts. Or we estimate POQ (constant delivery cycle), and we estimate the delivery size based on consumption forecasts. In the case of uneven consumption of a given material, planning deliveries based on POQ is more economical than based on the EOQ method. When using these methods, it is also worth remembering to take into account: the order fulfillment cycle (the time from placing an order to its fulfillment) and warehouse operation schedules.

For some materials, the batch-by-batch supply method is often used. Considering the above formulas, this method is profitable when POQ is less than 2, hence:

$$POQ = \sqrt{\frac{2 \cdot A \cdot n}{h \cdot D}} < 2 \Rightarrow \frac{2 \cdot A \cdot n}{h \cdot D} < 4 \Rightarrow D > \frac{A \cdot n}{2 \cdot h} lub\ a > \frac{A}{2 \cdot h}$$

As can be seen from the above formula, this strategy is profitable if the average daily material consumption is greater than half the ratio of delivery costs to unit storage costs. That is, for example, in the case of expensive materials, if the storage costs are associated with frozen capital. However, it is not necessarily a good strategy in the case of materials used occasionally but cheap to store.

In order to optimize supply costs, in addition to the static optimization model indicated above, the dynamic optimization algorithm formulated by HW Wagner and TM Whitin in 1958 [6] can also be used. The essence of this algorithm is to search for the minimum value of the total supply costs by analyzing all possible supply variants. We assume that the following are known: the size of material requirements for subsequent settlement periods (e.g. days), the cost of a single delivery and the unit storage cost. The supply cost for the first settlement period is equal to the material delivery costs, because it is not stored. In the case of supply for two subsequent settlement periods, the supply cost may be equal to twice the delivery cost or the delivery cost and the cost of maintaining the stock for the second settlement period for one settlement period. In the case of supply for three settlement periods, the supply cost may be equal to: the minimum supply cost for two settlement periods plus the delivery cost in the third settlement period or the cost of storing the stock for the third settlement period. Considering different supply options for the planning period, the supply costs can be presented in a matrix:

$$\begin{matrix} K_{1,1} & K_{1,2} & K_{1,3} & K_{1,4} & K_{1,5} \\ 0 & K_{2,2} & K_{2,3} & K_{2,4} & K_{2,5} \\ 0 & 0 & K_{3,3} & K_{3,4} & K_{3,5} \\ 0 & 0 & 0 & K_{4,4} & K_{4,5} \\ 0 & 0 & 0 & 0 & K_{5,5} \end{matrix}$$

where:

$K_{i,i} = A + min(K_{j,i-1})$ where $j = 1,2,3, \dots i-1$

$K_{j,i} = K_{j,i-1} + (i-1)d_i$, where d_i material requirements for a given billing period.

After constructing such a matrix, we search for the smallest value in its last column, which determines the cost of purchasing and maintaining inventories in the entire planning period. The row containing this value determines the sub-period in which purchases should be made. Then, in the column preceding the purchase date, we search for the smallest value. The row containing it determines the purchase date. We repeat the procedure until we reach the first column. In this way, we determine

the delivery dates. We determine the size of deliveries by summing up the demand in the period between subsequent delivery dates. The method of using this algorithm is presented in Table 2.

Table 2. Example of the Wagner–Whitin algorithm application. (A=100 CU; h=0.4 CU/ (CU*CU))

Dni	1	2	3	4	5	6	7	8	9
Potrzeby	50	10	60	70	30	10	20	60	60
	100	104	152	236	284	304	352	520	712
		200	224	280	316	332	372	516	684
			304	332	356	368	400	520	664
				252	264	272	296	392	512
					336	340	356	428	524
						364	372	420	492
							372	396	444
								396	420
									492
Dostawy	120			110				120	

Source: Own study

Simpler dynamic programming algorithms are the lowest total cost (LTC) and lowest unit cost (UTC) algorithms. They are a certain simplification of the algorithms proposed by Wagelmans, Hoesel and Kolen (Wagelmans, Hoesel and Kolen, 1992) and EA Silver and HC Meal (Silver and Meal, 1973). Both of these algorithms involve searching for supply periods for which the total cost or unit total cost is the lowest. The procedure is similar to the Wagner– Whitin algorithm, but much simpler. In both cases, we calculate supply costs for subsequent settlement periods as if the delivery took place only in the first period. The calculation procedure is finished when the total cost or unit total cost reaches a minimum. Then it is most profitable to deliver the material for the entire period. However, from the next settlement period, we repeat the entire procedure anew.

Each of the presented supply cost optimization models has its advantages and disadvantages. Their application for the same material requirements systems often leads to different results. It can be stated with great probability that the best is the Wagner-Whitin algorithm, while the results obtained using the other dynamic algorithms and the POQ method are comparable. With a strongly diversified demand, the worst results are obtained using the EOQ method. However, analyzing the results of using different methods for the same material requirements systems, it should be stated that all of them, with greater or lesser success, approach the basic condition: minimizing

supply costs – delivery costs similar (should be equal) to the costs of maintaining the inventory.

5. Summary

The issue of optimizing supply costs is very complex due to the number and type of criteria that can be indicators of the optimality of the adopted solutions. In search of a single solution, we must reduce the multi-criteria issue to a single-criteria one. Economic calculation suggests that the basic criterion for optimizing supply processes should be costs. They roughly represent the costs incurred for this process. Therefore, optimization should lead to an increase in supply efficiency. Therefore, we should look for solutions that minimize the costs of the entire supply process. For this purpose, we can use the methods indicated in this article.

Pareto optimum, i.e. the impact of changes in a given sub-process on other components of the supply process.

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ARTICLES

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Jakub Steblik

OKUN'S LAW REVISITED ON EXAMPLE OF CHINA AND SELECTED NEIGHBORS' COUNTRIES

Abstract

This paper examines the unemployment-output relationship in China and neighbors' countries (Vietnam, Indonesia and Philippines) from 1991 to 2023 to verify Okun's Law validity by using a coefficient for various periods and impulse response analysis of VAR models. The estimates show that the correlation result is either positive or negative and varies considerably between the countries studied and period selected. Impulse response analysis provides also non conclusive results. Based on analyzed data and conclusions from selected literatures (e.g. asymmetric reaction of unemployment from production output shocks, specific employment patterns) the Okun' law could be treated more as benchmark rather than objective rule.

JEL Classification: C32, E23, E24.

Keywords: Okun's law, unemployment, impulse response analysis of VAR models, China.

Introduction

Okun's observation (1962, pp. 98-103) of the negative relationship between economic growth and the level of unemployment, made in the 1950s of the previous century, has become one of the fundamental pillars of macroeconomics. At the same time, since its formulation it has also been the subject of theoretical analysis and empirical verification in different time periods and geographical areas. The simple relationship between

the level of economic activity and unemployment allows for a variety of research approaches and the use of different econometric tools. It is therefore possible to exploit the relationship in many ways.

The original subject of the observation, later translated into "economic law", was the quarterly data of the United States from 1947 to 1960. The fundamental and original purpose was to address one of the major economic issues of the time, which was the nature of full employment, and to examine the size of the GNP gap caused by the absence of full employment. Within the output gap, a 1 percentage point increase in GNP leads to a 0.3 percentage point reduction in unemployment. The proposal was in line with the prevailing welfare economics of the time. At the same time, the conclusions supported the government's active economic policy aimed at achieving full employment.

The People's Republic of China has made an undeniable civilizational leap in recent decades, becoming the manufacturing centre of the world. Similar to the United Kingdom, the United States, the Federal Republic of Germany, South Korea or Japan in the past. China's economic achievements have been accompanied by an increase in its political importance and, in particular, its desire to exert an even greater influence on the international stage. The fundamental argument for the rise of the middle state is its economic power. Its economic development in recent decades has been impressive. At the same time, it has provided an opportunity to analyse the relationship between economic growth itself and unemployment. Secondly, additional motivation (particularly for China) has been the political decision to temporarily suspend the publication of unemployment data for 16-24 year old (Oi and Marsh, 2023).

The article was written for two reasons. First, in a few decades China has become the world's second largest economy, with a high degree of integration with other economies. In this context, it is interesting to see whether, in the course of its rapid development, a relationship similar to that of the US can be observed in China. Okun's observation is particularly interesting as it illustrates the fundamental relationship between economic growth and unemployment.

The first hypothesis is that there is a negative relationship between economic growth and the level of unemployment in China after 1990. The selected neighboring countries are used as reference points for the relationship under investigation. An additional question related to the hypothesis is whether and how the magnitude of the correlation has changed over time.

1. Okun’s law application in selected literature

Contemporary economic studies exploit the basic relationship between the level of economic activity and unemployment, but without such strong

implications for policy makers. They focus on statistical correlations or specific circumstances, making the relationship itself stronger or weaker. At the same time, the geographical scope of the studies covers virtually all countries. Generally speaking, Okun's original work has been a source of inspiration for a huge number of works. They are mainly concentrated around the following topics:

Firstly, the study of the relationship between two variables within a single country or group of countries in a panel study. It is worth to mention, that almost all countries have become the subject of some kind of analysis regardless of their level of economic development or type of political system. Andreescu (2024) conducted extensive research on Central and Eastern European countries. She confirmed the significance of the Okun's coefficient using gap model for following countries: Czech -1, Hungary -0.5, Bulgaria -0.36, Poland -0.27 and Romania -0.15. Pizzo (2023) presented an extensive analysis covering South American countries, for which the correlation varied between -0.2 and -0.1. The result is lower than the correlation for the US however, it is similar to some European countries and Japan. The low correlation may be due to the peculiarities of these countries, where many people are self-employed, agriculture has a large share and people work in the informal sector. The author also emphasises the asymmetric nature of the relationship, which is different in prosperity and recession. Similar results can be found on the effect of the number of self-employed in different regions of Spain on the correlation (Porras and Martín-Román, 2019). There is also an interesting example of examining low-income countries using various methods including also reference to Okun's law (Mishr, Grima and Ozen, 2024).

Secondly, two economic events in recent years have also been a frequent source of inspiration: the 2008 economic crisis and the COVID-19 pandemic, which had a huge impact on economic activity and thus on unemployment. Daly and Hobijn (2010), analyse the resilience of the economy to shocks and conclude that, using the crisis shock as an example, they verify the theoretical relationship and conclude that productivity growth mitigated the negative effects of the 2008 economic crisis. A detailed analysis of the relationship during the crisis period is provided by Cazes at al. (2013), who argue that the increase in unemployment at that time was due to a larger output gap, rather than a structural change in trend. In addition, they highlight the fact that the results are highly dependent on the methodology used and the period considered.

Thirdly, Theoretical reflections on the relationship itself and its nature. An example of this is Kaufman's (1988) work, written almost half a century ago. The author studied the most developed economies and found that the relationship varied dramatically from country to country. Cuaresma (2003) showed, in particular, the existence of this relationship, further

demonstrating its asymmetric nature. The level of unemployment reacted more sharply to an economic slowdown or recession than to economic growth. Aaronson *et al* (2019) used regression models and data for the US economy to break down the unemployment category into subgroups by ethnicity, race, educational attainment or gender. Less advantaged groups show greater vulnerability to cyclical changes in unemployment. The final conclusion is that Okun's law affects different groups to different degrees. Donayre (2020) analyses the incidence and strength of the correlation between unemployment and output changes in "three endogenously determined regimes, closely matching expansions, mild recessions and deep recessions". An additional observation concerned the link between the strength of the Okun's law correlation and the wage level. A corollary of these observations is the conclusion that Okun's law is asymmetric. Knotek (2007) considers the general usefulness of the law itself and concludes, as in the previous case, that the usefulness of this relationship depends very much on the point in the economic cycle in which the economy finds itself. Karfakis at al. (2014) analyse Greece's recent history and the negative shock experienced in the context of the adjustment programme, which contributed to keeping unemployment high. They also confirm the conclusion that the relationship between output and unemployment is itself asymmetric. The paper of Pehlivanoğlu and Tanga (2016) ends with an interesting conclusion: according to the authors' calculations in Brazil, South Africa and Turkey, they did not observe a relationship that could be considered Okun's law. The authors argue that Okun's law may not be applicable to developing countries, so that economic growth does not necessarily translate into a decrease in unemployment. An article analysing data from China comes to the opposite conclusion (Liu *et al.*, 2018) enriching basic data on output and unemployment with the context of internal migration and, in particular, the potential ambiguity of data related to the hukou registration system, which formally links citizens to their place of residence. The flow of labour between rural and urban areas is a key element in understanding the Chinese labour market, and therefore in interpreting unemployment rates, which may not reflect the true number of unemployed. The hokou system itself significantly reduces economic growth and contributes to the persistence of economic inequalities between urban and rural areas (Sangild, 2024). It is estimated that around 200 million Chinese have left the countryside to work in cities, but according to the hukuo system they are still rural residents (Ruwitch and Li, 2024) and (Song, 2023). Other estimations put the number of internal migrants at around 270 million (Meng, 2012). (Boďa and Považanová, 2025)

All in all, an exploration of the topic brings some discrepancies, and the relationship itself ceases to be obvious if we compare different economies and analyze the variability in business cycles. Collecting

the author's observations in synthetic form, we can say that the relationship between the level of unemployment and GDP dynamics is complex in nature and depends on many factors. The unemployment rate fluctuates less than GDP dynamics, and their relationship changes over time. Unemployment responded more strongly to reductions in domestic product during the recession phase than to periods of economic growth during the recovery phase. In addition, the relationship between output dynamics and the unemployment rate varies from country to country (Maleszyk, 2024).

As a summary, one can refer to the impressive meta-analysis of scientific articles on Okun's Law by 2020, carried out by (Boďa and Považanová, 2025), led to a number of conclusions. The authors grouped articles by type of analysis or geographical coverage. Overall, they created an impressive universe of Okun's law articles to navigate among them and among various methodologies.

2. China case of Okun's law

The relationship becomes more complicated as one delves into the nuances and contexts, but the starting point remains the general assumption of a negative correlation between global output and unemployment. The specific purpose of this article is to see how this relationship played out in China between 1991 and 2023, using World Bank data. For the sake of comparison, I have included three countries, Indonesia, the Philippines and Vietnam. The chart below shows China's economic growth and unemployment rates. I would like to examine the relationship in three ways.

Firstly, most typical, we will collate changes in GDP and changes in unemployment. From the beginning of available data until COVID-19, we can see a dynamic increase in GDP and a minimal but almost continuous increase in the level of unemployment. Only with the pandemic can we see a negative relationship between GDP and unemployment. From 1991 to 2019, we see an average annual GDP growth of 9.5% and an average annual increase in unemployment of 0.08%.

3. Methodology

The article uses unemployment and GDP data for China, Indonesia, the Philippines and Vietnam for the period 1991 to 2023 which are used in two approaches. Initial graphical representation of date is used as an introduction and exemplification of various trends among countries. The first approach compiles the above data in the form of correlations in three different ways.

- The 5-year periods seem to be the smallest possible time range within which to calculate correlations. However, this is an arbitrary choice. By extending the periods to a larger number of years, we obtain results

that are more flattened and with fewer extreme values. On the other hand, presenting the data in groups of 5 years periods clearly shows the changes in the correlations over the period considered.

- The second way to divide the data is by lengthening periods. The first would be 2019-2023, the next 2018-2023 and so on until 1991-2023. The basis for this approach is the assumption that the available data period between 1991 and 2023 could vary, depending on when the data recording began; if, for example, the World Bank had been collecting data since 2000.
- The first period covers the years 1991 to 1995, the second 1991 to 1996 and finally the entire period.

Second approach attempt to verify the functionality of Okun's law by using the VARs, and particularly the Impulse Response tool, which reflects the effect of deviation shock of GDP onto unemployment. All modulus of all models are smaller than one (all inside the unit circle). Therefore, the system is stationary. All countries have lag of one, except China, where lag is two for period 1990-2023. Stochastic tests are presented in Appendix.

4. Okun's law application in selected countries

In particular, the data for this period is puzzling. The historic increase in output was accompanied by a creeping rise in unemployment. As a reference, relevant graphs for the 3 selected countries have been added.

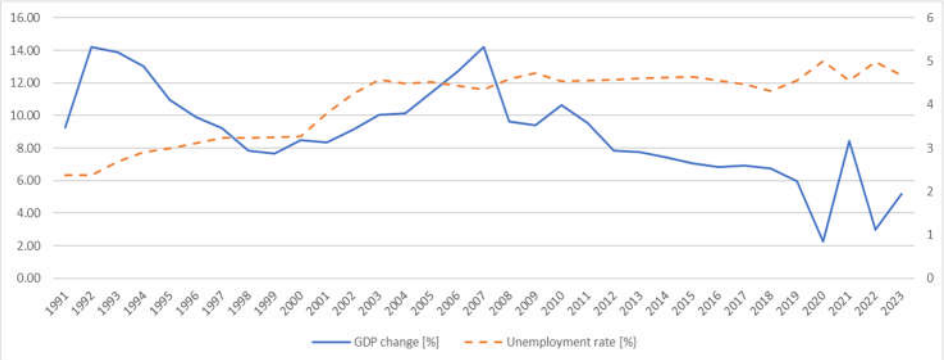

Figure 1. GDP dynamics and unemployment changes for China
Source: Authors' estimates, using data from World Bank

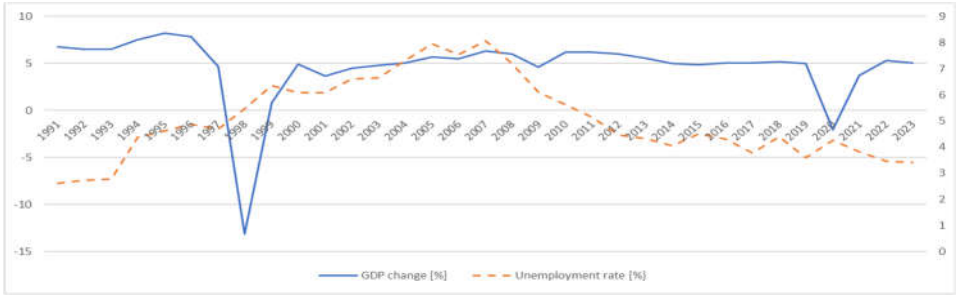

Figure 2. GDP dynamics and unemployment changes for Indonesia
Source: Authors' estimates, using data from World Bank

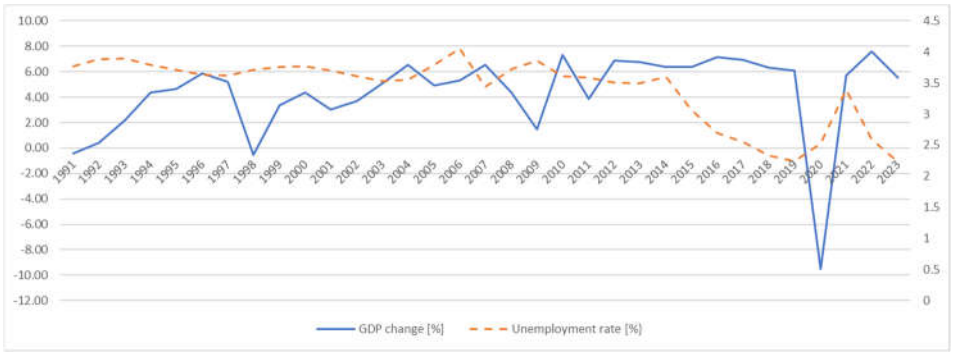

Figure 3. GDP dynamics and unemployment changes for Philippines
Source: Authors' estimates, using data from World Bank

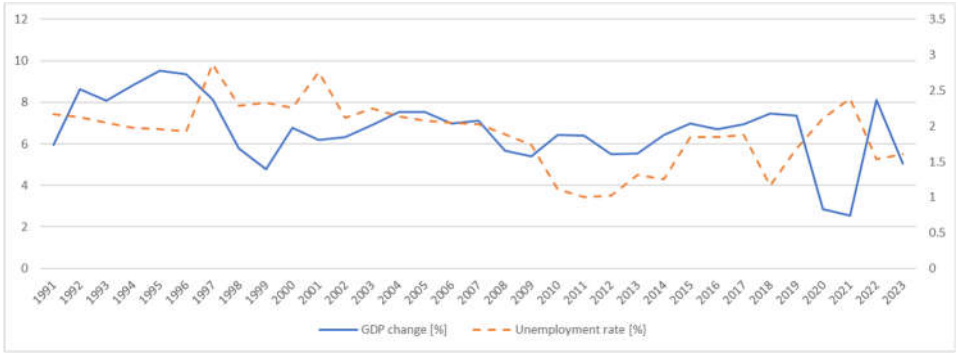

Figure 4. GDP dynamics and unemployment changes for Vietnam
Source: Authors' estimates, using data from World Bank

The same data in a slightly modified form can be seen in the chart below. Annual change in GDP in percentage points (left axis) and annual change in unemployment also in changes

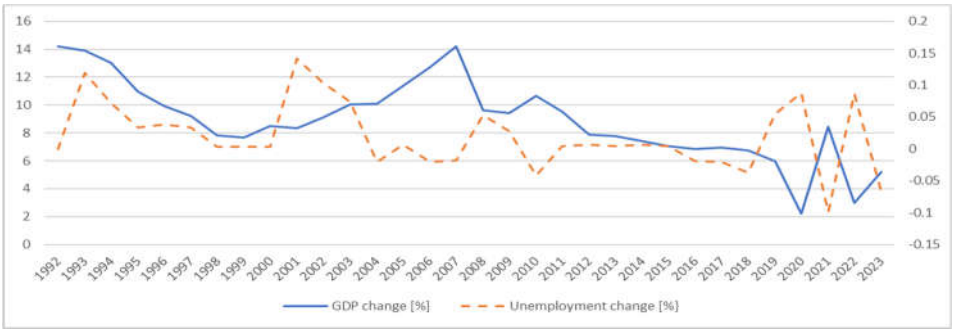

Figure 5. GDP and unemployment change for China
Source: Authors' estimates, using data from World Bank

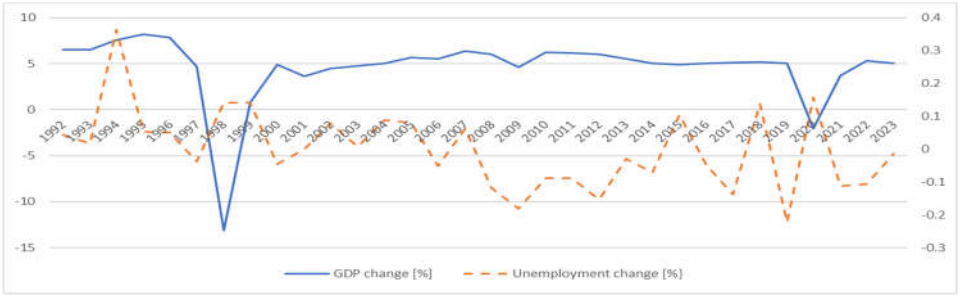

Figure 6. GDP and unemployment change for Indonesia
Source: Authors' estimates, using data from World Bank

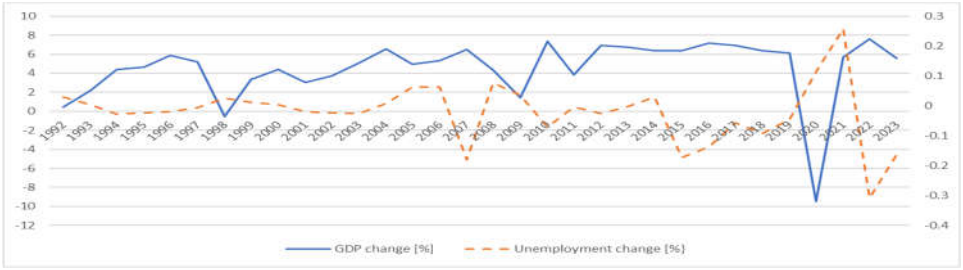

Figure 7. GDP and unemployment change for Philippines
Source: Authors' estimates, using data from World Bank

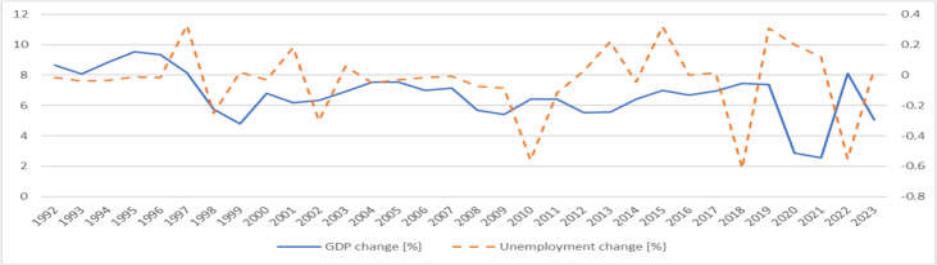

Figure 8. GDP and unemployment change for Vietnam
Source: Authors' estimates, using data from World Bank

The first and observation is that the level of unemployment had been rising steadily for the past thirty years until the COVID-19 epidemic, when there was a sharp increase followed by fluctuations in the opposite direction. At the same time, there was a historic increase in the level of GDP, which also experienced fluctuations during the pandemic period. Since the early 1990s there has been a dynamic increase in GDP and a minimal increase in unemployment. This observation is surprising in that it contradicts the general belief in the relationship between GDP and unemployment.

However, this statement itself is general and provides a starting point for verifying the data in two directions. First, by comparing the above data with the economic performance of Indonesia, Vietnam and the Philippines. The second is to look more closely at the correlation between GDP and unemployment in these four countries by breaking down the available data into shorter intervals in order to answer the question of whether the correlation coefficient for these countries looks similar in different periods or whether significant differences can be observed. Moreover, the changes in the level of unemployment itself over three decades (up to the COVID-19 pandemic) are practically cosmetic.

Paradoxically, these data would have a twofold implication: an increase in GDP generates an increase in the level of unemployment, or a sharp increase in GDP leads to a minimal increase in unemployment. However, in no way are these statements defensible.

The charts above show that the correlation between the level of GDP and unemployment over the maximum 30-year period is 0.74. However, it was found more interesting to divide the long period into smaller parts and look at what the correlation looks like in each time segment.

The following graphs show the correlation between unemployment and economic growth for each country, divided into consecutive 5-year periods.

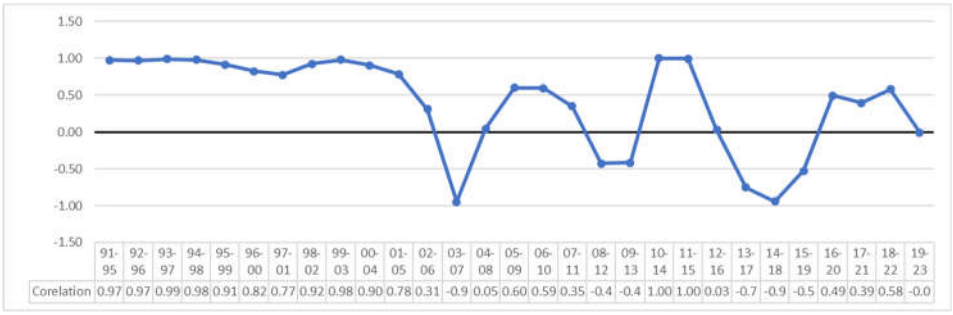

Figure 9. Moving correlations (5-year periods) for China.
Source: Authors' estimates, using data from World Bank

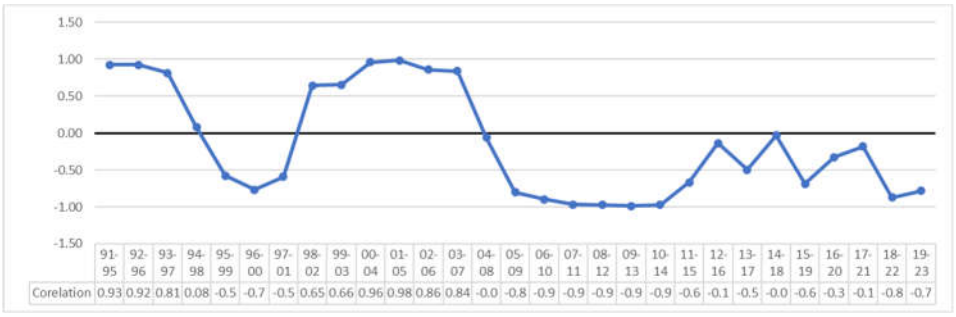

Figure 10. Moving correlations (5-year periods) for Indonesia
Source: Authors' estimates, using data from World Bank

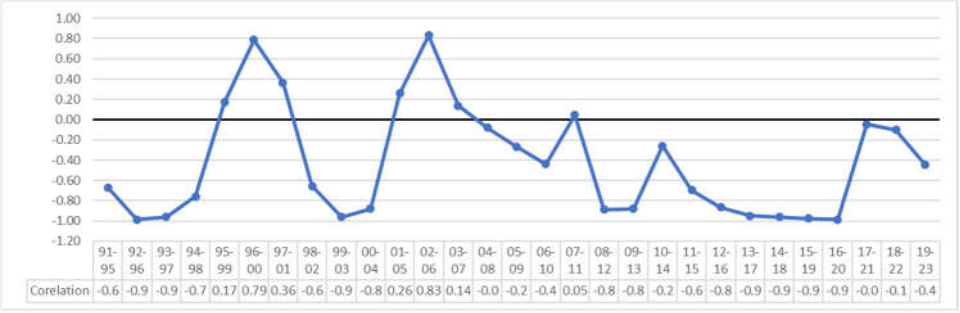

Figure 11. Moving correlations (5-year periods) for Philippines
Source: Authors' estimates, using data from World Bank

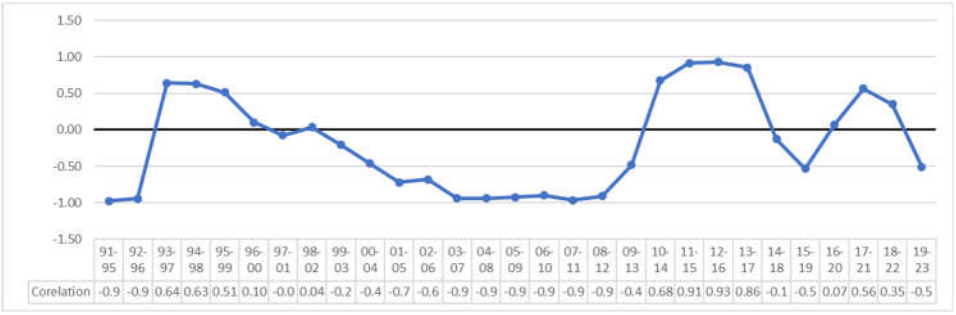

Figure 12. Moving correlations (5-year periods) for Vietnam
Source: Authors' estimates, using data from World Bank

The above comparison between the four countries is decidedly inconclusive. They all have 5-year periods in which the relationship studied had extremely positive as well as negative correlation. The only outstanding period for the PRC concerns the first fifteen years, during which the correlation remains virtually unchanged, oscillating around 0.9.

The following four graphs show the correlation between unemployment and economic growth for each country, divided into lengthening periods. The graphs shows that the relationships, is arranged in a certain direction (observations are available below the figure no. 20).

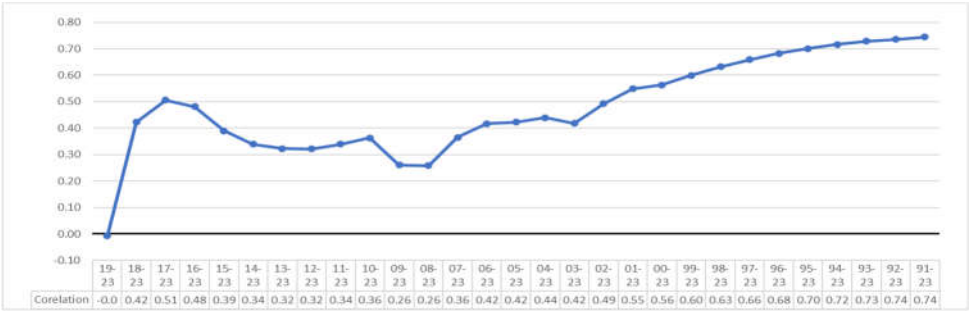

Figure 13. Correlations in following periods from 2019-2023 to 1991-2023 in China
Source: Authors' estimates, using data from World Bank

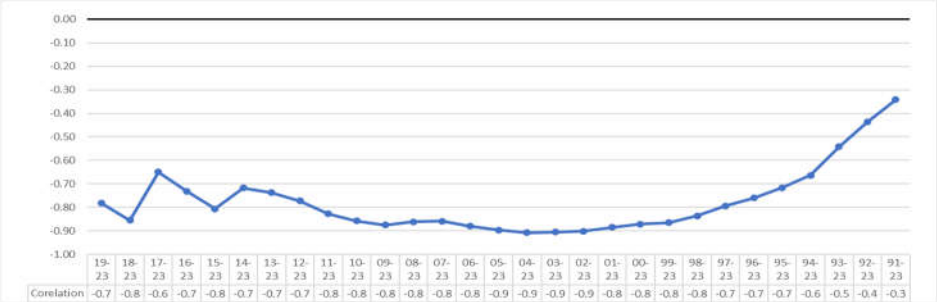

Figure 14. Correlations in following periods from 2019-2023 to 1991-2023 in Indonesia

Source: Authors' estimates, using data from World Bank

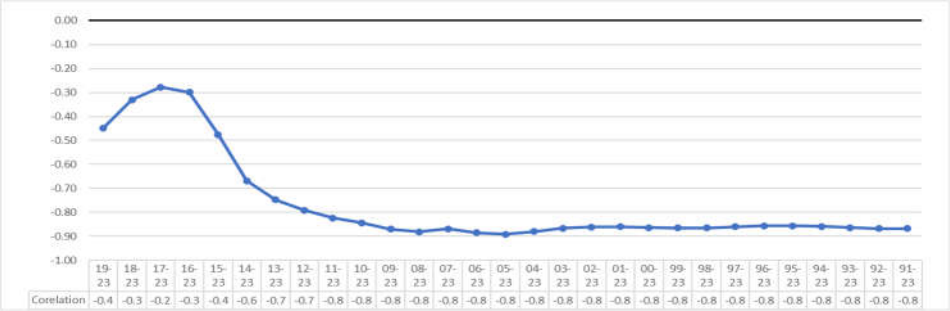

Figure 15. Correlations in following periods from 2019-2023 to 1991-2023 in Philippines.

Source: Authors' estimates, using data from World Bank

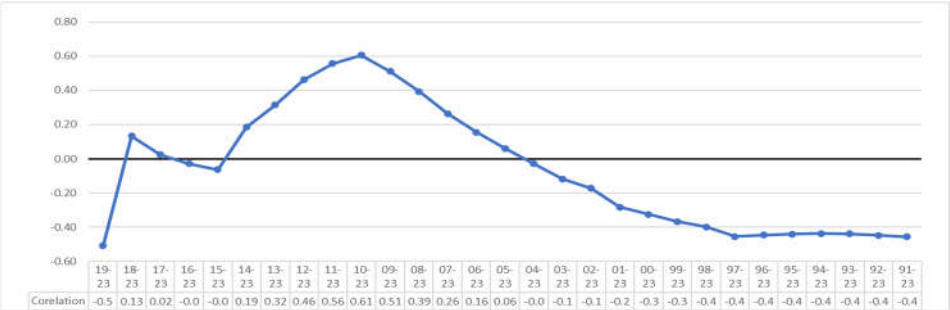

Figure 16. Correlations in following periods from 2019-2023 to 1991-2023 in Vietnam

Source: Authors' estimates, using data from World Bank

The same approach, but applied from the opposite perspective, we can observe if the first period is 1991-1995 and the last 1991-2023.

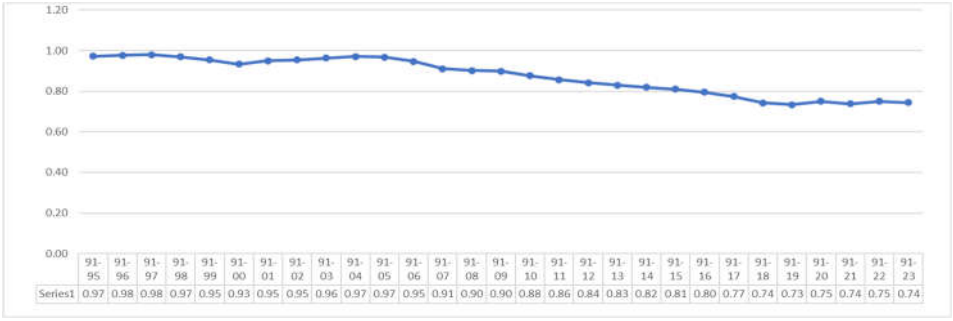

Figure 17. Correlations in following periods from 1991-1995 to 1991-2023 in China

Source: Authors' estimates, using data from World Bank

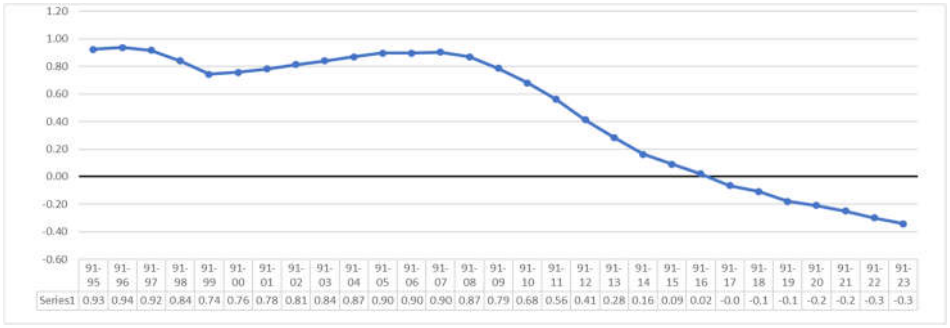

Figure 58. Correlations in following periods from 1991-1995 to 1991-2023 in Indonesia

Source: Authors' estimates, using data from World Bank

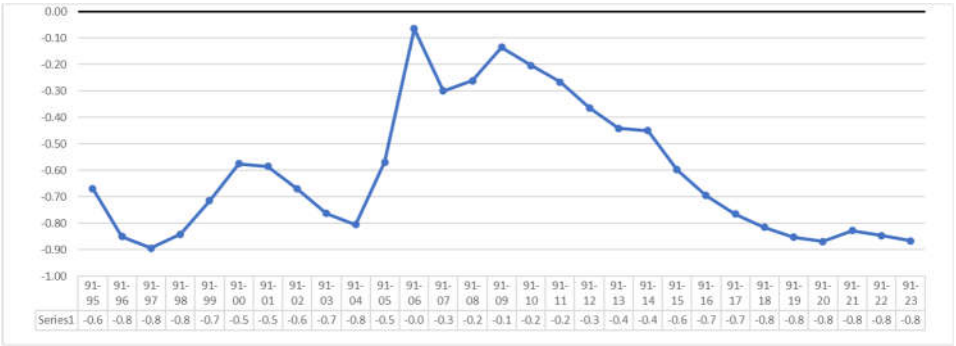

Figure 19. Correlations in following periods from 1991-1995 to 1991-2023 in Philippines

Source: Authors' estimates, using data from World Bank

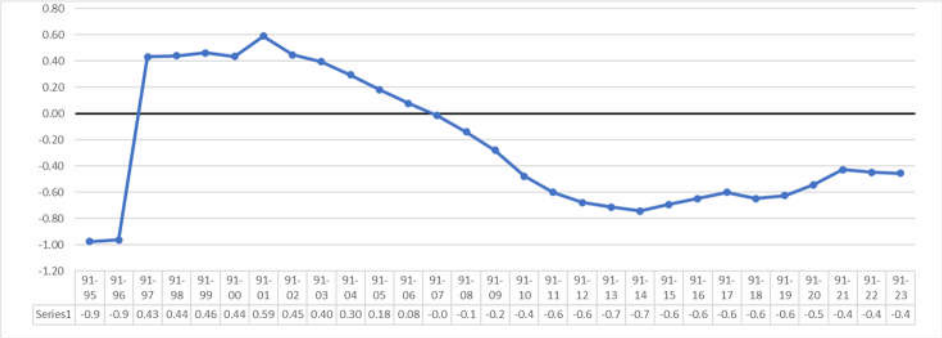

Figure 60. Correlations in following periods from 1991-1995 to 1991-2023 in Vietnam

Source: Authors' estimates, using data from World Bank

The two approaches above present similar conclusions. Therefore, I will consider them together. First, the correlation for the PRC takes values much closer to 1 than for the other countries studied. Second, the correlation for the PRC is closer to 1 in the early 1990s and then decreases over time. Third, while the correlation for the compared countries takes on negative values in some periods and positive values in others, for the PRC this correlation is virtually all the time positive and very high. Fourth, in connection with the above observations, it seems that the further we go back in time to the 1990s, the less reliable the Chinese data seems to be. However, based on the assumption that they are interrelated, one would expect in the long run the presence of a negative correlation between the two. Such a relationship, yet, only emerged with the pandemic, when there was a sharp collapse in production and a consequent increase in unemployment.

The data visualization methods presented are intended to show a trend. It can be seen that the correlation becomes increasingly negative as the analysis period increases. It can be inferred from this observation that more mature economies have a more negative correlation. However, this is only an assumption and requires further research.

The selection of the period in which the correlation is studied has a decisive impact on the result of the correlation between the GDP and the level of unemployment. At the same time, each of the selected periods is selectable. The extremes for individual countries range from (-1) to (1). The choice of the period in which the correlation is checked is critical to the result.

Having analyzed the correlation, the next step is the VAR model and its impulse response function. The results of the estimation of each model and the estimation of these models can be found in the Appendix.

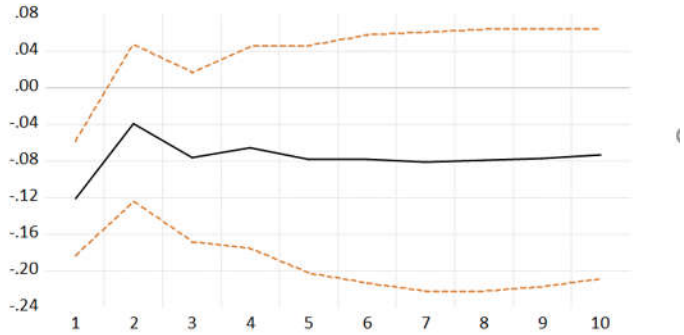

Figure 21. Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in China

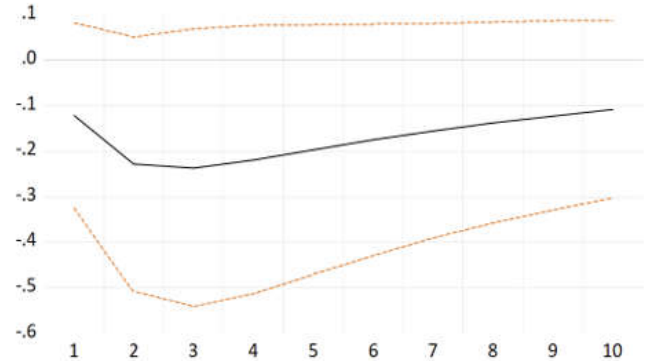

Figure 72. Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in Indonesia

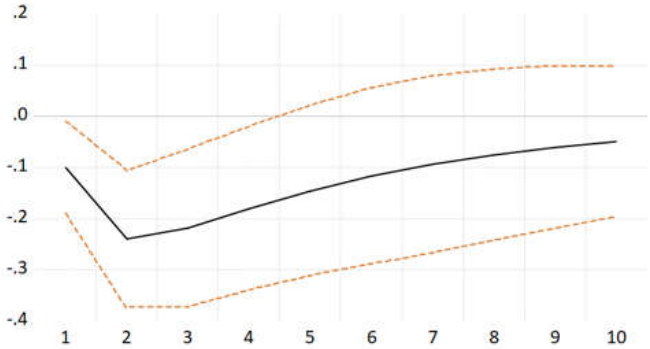

Figure 23.8 Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in Philippines

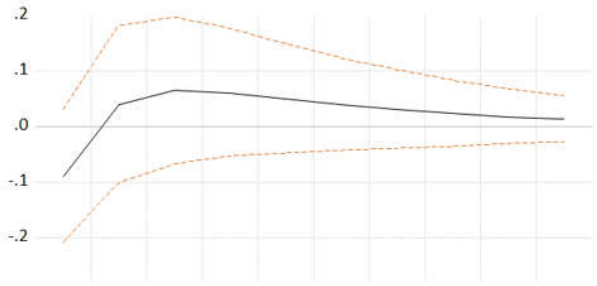

Figure 24.9 Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in Vietnam

Interestingly, if we narrow the period to 1991 till 2019 (before the COVID-19) we get following results:

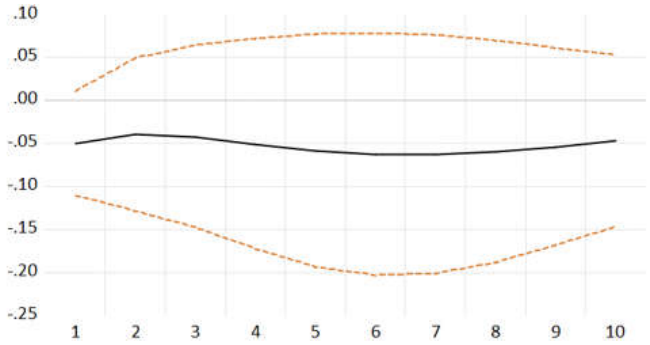

Figure 25. Figure 16 Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in China

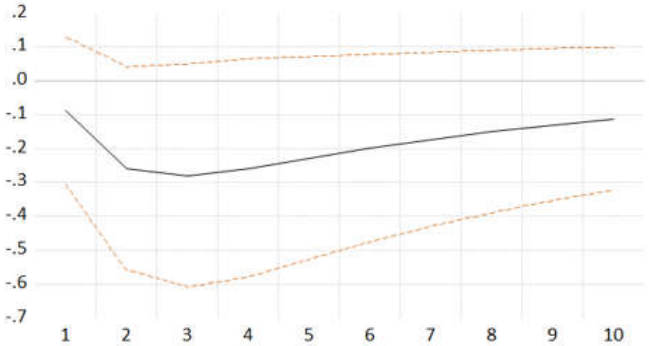

Figure 26. ***Figure 16 Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in*** **Indonesia**

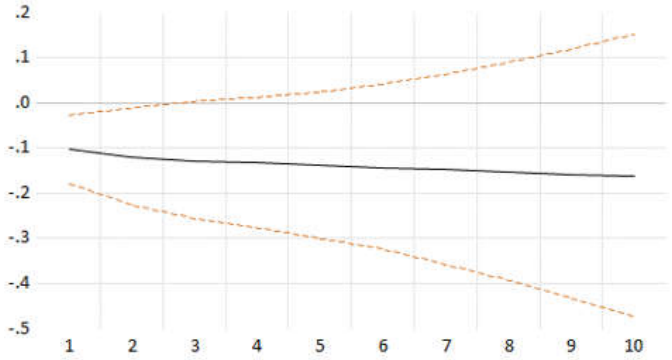

Figure 27.10 Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in Philippines

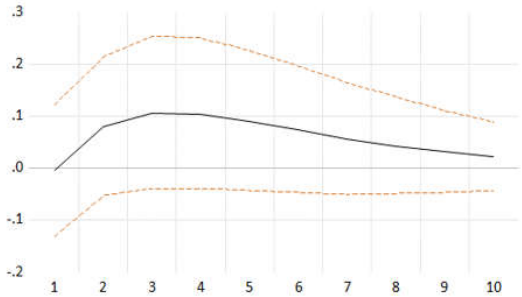

Figure 28. **Response of unemployment to GDP Cholesky one standard deviation (d. f. adjusted) innovation ± 2 analytic asymptotic S.E.s in Vietnam**

First of all, we can see how COVID-19 period has significant impact on overall relation between GDP and unemployment. Additionally, the graphs look similar but are shifted upward compared to the 1990-2023 period. For all countries and periods, the impulse score falls on either side of the X axis, suggesting that it is not statistically significant. Only the Philippines for the first couple of periods has a statistically significant impulse result.

Impulse response results are therefore inconclusive not conclusive, which would be consistent with the correlation results presented in rolling windows. Depending on the period selected, the correlation took on a very different value.

Going to the details, however, and concentrating on China as the subject of the analysis for the period 1990-2023, it is noticeable that there is initially a slightly negative impact of the GDP shock on unemployment, which fades out with time. The negative impact on unemployment persists for all 10 periods, but appears statistically insignificant.

The lack of statistical significance seems to be in line with the first part of the analysis, where dramatic changes in the correlation result could be observed depending on the period selected.

Attempting to answer the question of the validity of Okun's Law in China, one can go beyond macroeconomic data and look at the structures of how the Chinese state operates, in particular the Hukou registration system, a regulation that 'restricts a citizen's employment opportunities to his place of birth. The hukou system prevents immigrant workers living in cities, but registered in their places of origin, from receiving public services'. This registration system is itself a source of potential abuse and manipulation (Feng, Hu and Moffitt, 2017). People from rural areas going to cities cannot be registered as unemployed (even for a short time). In addition, the status of the rural unemployed is not clear-cut, as the nature of rural unemployment is non-obvious: those working on the family farm or in lower-paid jobs are not necessarily formally registered as unemployed. In the hukou system, the transition from rural to urban work involves a change in economic status, access to social services, but due to restrictions, the change of status from rural to urban requires meeting certain criteria that are difficult for most labor migrants to meet. In many cases, it is necessary to have a stable job, an apartment in the city, and sometimes a high level of education. With such stringent criteria, formally only a small part of the population succeeds in obtaining a change of status, however, publicly available data confirms the continuous and huge labor migration from the countryside to the cities, which clearly and significantly must affect official unemployment figures. After all, people from the countryside take up a variety of jobs after arriving in the city without changing their hukou status; they cannot register as unemployed, while working they still contribute to production and thus GDP. The operation of such a pattern would translate into the analyzed data, that is, very dynamic growth with virtually unchanged unemployment.

Conclusions

Okun's observation about the relationship between economic growth and unemployment levels, which was then turned into one of the basic economic laws. Using only economic benchmark and econometric tools, the results would suggest that the relationship in China's case is dubious, or at least questionable over certain time periods. Therefore, on the one hand, one can conclude that Okun's law would not be relevant. On the other hand, adding local context to the analysis makes the raw data themselves less reliable. It is not possible to say unequivocally whether, for China during the period under study, the law itself is still valid.

An additional point of reference may be the reliability of the data itself for the countries studied. This is particularly the case for China, which as a non-democratic country provides data that may not be fully reliable

or difficult to verify. Suspicions about the influence of the political system on the reliability of official data were tested by a clever juxtaposition of official GDP data with publicly available satellite imagery showing the intensity of night lighting and hence human activity (Hu and Yao, 2022). The conclusions were clear: countries with non-democratic regimes reported inflated GDP figures relative to the observed intensity of nighttime light consumption. According to the authors' calculations, China's real GDP may have been 3.6 percentage points lower per year between 1992 and 2013.

The general conclusions drawn from the above analyses and the review of the selected literature lead to a general question. What are the determinants of the correlation? Based on literature review and observations we assume that it may depend on the type of economy (agricultural, industrial, services), labour market regulation, socio-cultural conditions or other significant factors. Furthermore, if we assume that asymmetry is widespread, then comparability over time and space becomes questionable. Interpreting the results across countries and time periods could lead to the conclusion that there is no 'one' Okun's law. On the other hand, various results could be treated as a suggestion to talk rather about Okun's benchmark than Okun's law. Having read Okun, it seems that him main aim was to answer the question, what effort need to be taken to ensure full employment. Given the passage of time and the changes in the economy, it can be considered to move the emphasis can be shifted from an objective and universal law to a benchmark describing the nature of the economy.

Further research can use other research methods, such as Granger causality or Johansen cointegration test. Additionally, the analyses can be extended with more countries to compare or even compare with countries that have experienced similarly rapid changes in the past (e.g. South Korea or Japan).

Appendix

Vector Autoregression Estimates
Date: 01/03/25 Time: 10:39
Sample (adjusted): 1993 2023
Included observations: 31 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	GDP_CHN	U_CHN
GDP_CHN(-1)	0.707872	0.049801
	(0.20207)	(0.02163)
	[3.50304]	[2.30224]
GDP_CHN(-2)	0.125958	-0.053552
	(0.20376)	(0.02181)
	[0.61816]	[-2.45508]
U_CHN(-1)	3.601619	1.067540
	(2.07770)	(0.22241)
	[1.73347]	[4.79978]
U_CHN(-2)	-3.406563	-0.168650
	(1.91375)	(0.20486)
	[-1.78005]	[-0.82323]
C	0.103847	0.518203
	(3.14307)	(0.33646)
	[0.03304]	[1.54016]
R-squared	0.627498	0.930415
Adj. R-squared	0.570190	0.919710
Sum sq. resids	85.20680	0.976416
S.E. equation	1.810300	0.193790
F-statistic	10.94959	86.91125
Log likelihood	-59.65905	9.609636
Akaike AIC	4.171552	-0.297396
Schwarz SC	4.402840	-0.066108
Mean dependent	8.764660	4.162903
S.D. dependent	2.761293	0.683911
Determinant resid covariance (dof adj.)		0.074903
Determinant resid covariance		0.052690
Log likelihood		-42.35244
Akaike information criterion		3.377576
Schwarz criterion		3.840153
Number of coefficients		10

Table 1. VAR model for China
Source: Authors' estimates, using data from World Bank

Vector Autoregression Estimates
Date: 01/03/25 Time: 11:07
Sample (adjusted): 1992 2023
Included observations: 32 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	GDP_IDN	U_IDN
GDP_IDN(-1)	0.272018	-0.032420
	(0.17806)	(0.02787)
	[1.52768]	[-1.16341]
U_IDN(-1)	0.167858	0.895138
	(0.43665)	(0.06833)
	[0.38443]	[13.0995]
C	2.450772	0.711596
	(2.52803)	(0.39563)
	[0.96944]	[1.79864]
R-squared	0.076558	0.858830
Adj. R-squared	0.012872	0.849094
Sum sq. resids	398.4376	9.758330
S.E. equation	3.706646	0.580081
F-statistic	1.202116	88.21297
Log likelihood	-85.75507	-26.40420
Akaike AIC	5.547192	1.837762
Schwarz SC	5.684605	1.975175
Mean dependent	4.567032	5.143969
S.D. dependent	3.730735	1.493260
Determinant resid covariance (dof adj.)		4.423152
Determinant resid covariance		3.632686
Log likelihood		-111.4516
Akaike information criterion		7.340727
Schwarz criterion		7.615552
Number of coefficients		6

Table 2. VAR model for Indonesia
Source: Authors' estimates, using data from World Bank

Vector Autoregression Estimates
Date: 01/03/25 Time: 11:08
Sample (adjusted): 1992 2023
Included observations: 32 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	GDP_PHI	U_PHI
GDP_PHI(-1)	0.087003	-0.046520
	(0.17745)	(0.01405)
	[0.49030]	[-3.31171]
U_PHI(-1)	1.048743	0.873832
	(1.19207)	(0.09437)
	[0.87977]	[9.25991]
C	0.526619	0.586718
	(4.27294)	(0.33826)
	[0.12324]	[1.73453]
R-squared	0.031646	0.779782
Adj. R-squared	-0.035137	0.764595
Sum sq. resids	315.7807	1.978914
S.E. equation	3.299847	0.261225
F-statistic	0.473867	51.34395
Log likelihood	-82.03503	-0.875027
Akaike AIC	5.314689	0.242189
Schwarz SC	5.452102	0.379602
Mean dependent	4.507904	3.389750
S.D. dependent	3.243358	0.538402
Determinant resid covariance (dof adj.)		0.634107
Determinant resid covariance		0.520785
Log likelihood		-80.37339
Akaike information criterion		5.398337
Schwarz criterion		5.673162
Number of coefficients		6

Table 3. VAR model for Philippines
Source: Authors' estimates, using data from World Bank

Vector Autoregression Estimates
Date: 01/03/25 Time: 11:09
Sample (adjusted): 1992 2023
Included observations: 32 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	GDP_WNM	U_WNM
GDP_WNM(-1)	0.429531	0.066605
	(0.16873)	(0.03970)
	[2.54574]	[1.67754]
U_WNM(-1)	0.490303	0.657683
	(0.57155)	(0.13449)
	[0.85785]	[4.89003]
C	2.864459	0.189497
	(1.60640)	(0.37801)
	[1.78316]	[0.50130]
R-squared	0.197846	0.477345
Adj. R-squared	0.142525	0.441299
Sum sq. resids	62.30278	3.449932
S.E. equation	1.465732	0.344910
F-statistic	3.576321	13.24295
Log likelihood	-56.06635	-9.767931
Akaike AIC	3.691647	0.797996
Schwarz SC	3.829060	0.935408
Mean dependent	6.685209	1.893500
S.D. dependent	1.582865	0.461442
Determinant resid covariance (dof adj.)		0.238209
Determinant resid covariance		0.195638
Log likelihood		-64.70827
Akaike information criterion		4.419267
Schwarz criterion		4.694092
Number of coefficients		6

Table 4 VAR model for Vietnam
Source: Authors' estimates, using data from World Bank

VAR Model for China
GDP_CHN = C(1,1)*GDP_CHN(-1) + C(1,2)*GDP_CHN(-2) + C(1,3)*U_CHN(-1) + C(1,4)*U_CHN(-2) + C(1,5)
U_CHN = C(2,1)*GDP_CHN(-1) + C(2,2)*GDP_CHN(-2) + C(2,3)*U_CHN(-1) + C(2,4)*U_CHN(-2) + C(2,5)
VAR Model for Indonesia
GDP_IDN = C(1,1)*GDP_IDN(-1) + C(1,2)*U_IDN(-1) + C(1,3)

U_IDN = C(2,1)*GDP_IDN(-1) + C(2,2)*U_IDN(-1) + C(2,3)
VAR Model for Philippines
GDP_PHI = C(1,1)*GDP_PHI(-1) + C(1,2)*U_PHI(-1) + C(1,3)
U_PHI = C(2,1)*GDP_PHI(-1) + C(2,2)*U_PHI(-1) + C(2,3)
VAR Model for Vietnam
GDP_WNM = C(1,1)*GDP_WNM(-1) + C(1,2)*U_WNM(-1) + C(1,3)
U_WNM = C(2,1)*GDP_WNM(-1) + C(2,2)*U_WNM(-1) + C(2,3)

VAR Model - Substituted Coefficients for China
GDP_CHN = 0.707872497851*GDP_CHN(-1) +
0.125958267256*GDP_CHN(-2) + 3.60161943499*U_CHN(-1) -
3.40656306371*U_CHN(-2) + 0.103846557245
U_CHN = 0.0498014536462*GDP_CHN(-1) -
0.053551657734*GDP_CHN(-2) + 1.06753951324*U_CHN(-1) -
0.168649663333*U_CHN(-2) + 0.518203034384
VAR Model - Substituted Coefficients for Indonesia
GDP_IDN = 0.272017906936*GDP_IDN(-1) + 0.16785784092*U_IDN(-1) +
2.45077161695
U_IDN = - 0.0324196258433*GDP_IDN(-1) + 0.895138130346*U_IDN(-1)
+ 0.711596455047
VAR Model - Substituted Coefficients for Philippines
GDP_PHI = 0.0870031479655*GDP_PHI(-1) + 1.04874275518*U_PHI(-1)
+ 0.526618733185
U_PHI = - 0.0465202458709*GDP_PHI(-1) + 0.873832229693*U_PHI(-1)
+ 0.586718015563
VAR Model - Substituted Coefficients for Vietnam
GDP_WNM = 0.429531309165*GDP_WNM(-1) +
0.490303292962*U_WNM(-1) + 2.86445876818
U_WNM = 0.0666046988192*GDP_WNM(-1) +
0.657683384817*U_WNM(-1) + 0.189497466494

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