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IMPACT OF THE AGING OF THE ARMENIAN SCIENCE SECTOR ON THE NUMBER OF SCIENCE AND ENGINEERING PUBLICATIONS[1]

Armenia's science sector has undergone significant changes in recent years from the perspective of demographics and productivity, which directly affected the country's scientific potential and national innovation system. In the article, an attempt was made to present what kind of links and interrelationships there are between older scientists and scientific output. The share of scientific and technical workers aged 60 and over in Armenia and the number of scientific publications presented by the National Science Board from 1998-2021 were considered as indicators. The results of the econometric analysis showed that the relationships between the indicators are strong and inversely proportional. An increase in the share of older scientists leads to a decrease in the number of scientific publications in the long run. In such a case, it becomes especially urgent for the state to develop and implement policies in the field, on the one hand, to create conditions for young scientists, and on the other hand, to study the productivity

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factors of older scientists. At the same time, the results of the paper provide a basis for further research on age-scientific productivity links.

Keywords: *scientific potential, aging, scientific productivity, publications, econometric analysis, national innovation system*

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INTRODUCTION. In the late 1980s, there were more than 20,000 employees in the Armenian science sector. The country was a scientific and technological hub, and the main mission of the science sector was to serve the military-industrial complex of the Soviet Union. About 2.5% of the GDP was directed to the financing of scientific research (Yalanuzyan, 2022). Since independence, the wrong direction of sector policy has been followed by the outflow of young professionals from the sector (National Research Council, 2004, pp. 5-6), and currently one of the most prominent problems is the aging of the sector. However, the scientific potential is one of the most important assets of Armenia from the point of view of the development of the national innovation system and the knowledge-based economy (National Research Council, 2004, pp. 1-2). As Israyelyan (2022b) noted: "Science alone is not a magic bullet, but the key to scientific success resides in human resources" (para 17). "One of the important issues raised by the aging society is its impact on productivity, adaptation, and innovation". Besides, "… the literature on individual productivity measures shows great diversity across age, individuals, and measures" (National Research Council, 2012, pp. 106, 108). The number of scientific publications is a widely accepted and used indicator of scientific productivity, which describes the quantitative aspect of efficiency (Bonaccorsi and Daraio, 2003, p. 55). Thus, in the context of the dynamics of the development of science and demographic trends in Armenia, it becomes urgent to study the issues of productivity among older scientists.

LITERATURE REVIEW. The issue of the relationship between age and scientific productivity has been of interest to the scientific community since the middle of the last century. W. Dennis (1956, p. 724) focused on the number of publications in the 1800s at various life stages of scientists. In the following period and to this day, the question is in the field of interest of researchers (Kwiek and Roszka, 2022, p. 1). In general, there is a widespread view that scientific productivity declines with age (Cole, 1979, pp. 958-959, Bonaccorsi and Daraio, 2003, p. 49). Specialists have given various assessments in this regard. Aksnes et al. (2011) noted: "The average production of publication increases with age and reaches a peak at some point during the career and then declines" (p. 34). Or, "…science is a young person's game…" (Stroebe, 2014, p. 660). According to Simonton (1997, as cited in Stroebe, 2014, p. 662), the creative potential of a scientist is best manifested during the first two decades of

scientific activity. Different age categories of the maximum level of scientific productivity have been defined, such as 30-40 (National Research Council, 2012, p. 110) and 40-50 (Ricón, 2020). As a result of research conducted at the universities of Quebec, Gingras et al. (2008) found that there are two critical ages in professional activities of university employees: 40 and around 50. In the first case, productivity growth slows down, and in the second case, the scientific impact of university employees is at the lowest level. Nevertheless, "science is a collective endeavor and, as our data shows, researchers of all ages play a significant role in its dynamic" (Abstract section).

Stroebe (2014) noted:

"The majority of studies that analyzed the relationship between number of publications and age were conducted in the 1960s and 1970s at a time when, as noted earlier, there was much less pressure to publish in most university systems. This situation changed mostly after 1980 when clearer publication norms were established and financial rewards were more clearly tied to productivity". (p. 667)

At the beginning of the 21st century the view that "greying" of the academy results in lower research activity and a decline in scientific advancement" was widespread (Savage and Olejniczak, 2021, p. 4659). At the end of the previous century, there was a decline in interest in the topic in the scientific community, given the repeated picture obtained from research, although later the situation changed, as according to subsequent studies, productivity does not decrease among the elderly (Stroebe, 2014, pp. 660, 668-669).

Thus, research conducted over the years has generally shown that scientific productivity declines with age. At the same time, experts tried to find out other factors affecting this relationship. Stroebe (2014, p. 661) grouped the factors of age-related changes in scientific productivity into four groups: changes in cognitive abilities, changes in motivation, changes in the availability of resources, and changes in age restrictions.

Research on age-scientific productivity relationships in the fields of psychology, sociology, and economics has led to conflicting conclusions (Kwiek and Roszka, 2022, p. 5). It should be noted that economists considered the problem from the point of view of material incentives for scientists (Cole, 1979, p. 976; Levin and Stephan, 1989, as cited in Kwiek and Roszka, 2022; Diamond, 1984, as cited in Kwiek and Roszka, 2022; National Research Council, 2012, pp. 107, 112-113), although Turner and Mairesse (2005, as cited in Kwiek and Roszka, 2022, p. 5) pointed out that "incentives in research are largely non-monetary and reputation-based".

Along with age, the age and speed of professional and career advancement are also important, which cause a significant disparity between productivity indicators (Kwiek and Roszka, 2022, p. 3). Kwiek and Roszka noted that (2022) "In research productivity, inequality has been explained according to the

cumulative advantage theory and the "sacred spark" hypothesis" (p. 4). In another formulation, "productive scientists are likely to be even more productive in the future, while scientists who produce little original work are likely to decline further in their productivity" (Allison and Stewart 1974, as cited in Kwiek and Roszka, 2022, p. 4). The works according to which older scientists are more productive confirm Robert K. Merton's theory of cumulative advantage and the "Matthew" effect that "the scientific community is a gerontocracy, with age an important component in the stratification system of science" (Gingras et al., 2008; Merton R.K., 1968; 1968; 1973, as cited in Gingras et al., 2008). These professionals have access to more resources (also in terms of financial rewards) and they accumulate more scientific potential over the years. According to Stroebe (2014, pp. 668, 671-672), previous work performance was a more important factor than age. In addition, the quality of older scientists' publications has not suffered. The main reason for optimism is that aging is not the main problem: if a scientist was effective in his or her youth, he or she would be relatively more effective in his or her old age. A study of 11,500 Norwegian researchers also found age differences in the number of annual publications, with factors such as position, research field, and gender (Aksnes et al., 2011, p. 34).

Bonaccorsi and Daraio (2003, pp. 50, 75) linked problem-solving policies to the involvement of young professionals in the field of science (National Research Council, 2012, pp. 120-121).

Savage and Olejniczak (2021, p. 4659) expressed the scientific output of university employees in six different fields in scientific articles, conference proceedings, books, and book parts: important factors were "peer networks, institutional support, intrinsic and economic motivations". According to the results, apart from productivity, age affects the form of scientific activity: senior professionals focus mainly on books (Savage and Olejniczak, 2021, p. 4684).

The results of a study conducted by Kwiek and Roszka (2022, pp. 5, 25-27) in the Polish science sector showed that scientists who are promoted at a young age are much more productive. Thus, the primary factor is the path taken by scientists in terms of scientific output. The authors presented the number of scientific publications according to their weight.

Thus, from the analysis of the literature, it is noticeable that the relationship between age and scientific productivity has been in the field of researchers' interest for several decades. Findings from empirical studies are contradictory. At the same time, it should be noted that in many cases both positive and negative effects of age were caused by a number of factors.

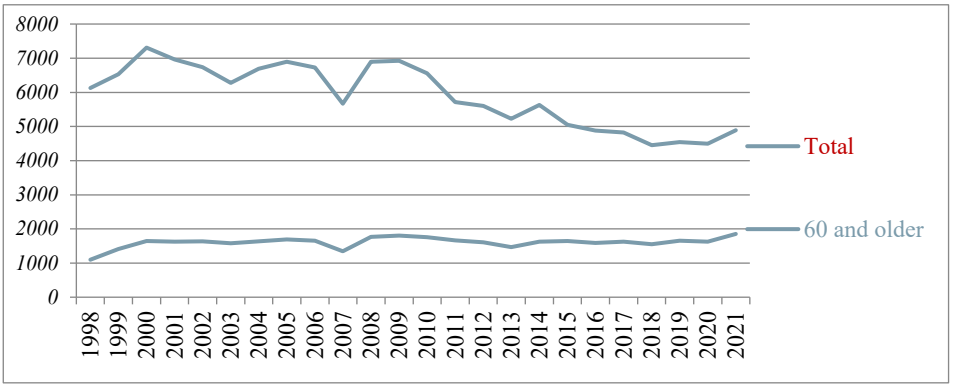
RESEARCH METHODOLOGY. Foreign literature, various research, reports, and articles in the science sector of Armenia, as well as statistical databases, in particular, the RA Statistical Committee (2001-2022), World Bank (2022), and National Science Board (2021) served as an informative basis for the research.

The dynamics of the number of scientific and technical workers in Armenia, the number and the share of scientific workers aged 60 and over, as well as the number of scientific publications in the years 1998-2020 were observed and presented. To make a comparison, the number of publications was also presented per million people. Next, a correlation and econometric analyses were carried out: the method of least squares was applied. The study considered the relationship between the share of scientific and technical workers aged 60 and over in the total number of scientists and the number of publications (whole count). We presented the number of publications in whole counting: ″Especially in analyses based on small data sets, it seems unlikely that results obtained using full and fractional counting will be very different″ (Perianes-Rodriguez et al., 2016, p. 30). The number of publications includes the sum of S&E (science and engineering) articles and conference papers in Scopus. Moreover, each co-authorship of a scientist of a given country is considered as one separate publication. First of all, we carried out a correlation analysis. Next, with the help of an econometric model, we calculated how the share of scientists aged 60 and over affects the number of S&E articles and conference papers. Before estimating the econometric model, the stationarity of the series was checked in terms of model variables.

Various reasons had an impact on the demographic situation and dynamics of the science sector:

1. *Weak infrastructure base* (Sahakyan, 2022; Israyekyan, 2022a; Israyelyan, 2022b, para 5)
2. *A more biased attitude towards retaining older scientists by state-run scientific organizations* (National Research Council, 2004, p. 7; Sahakyan, 2022, para 1). In that sense, science is considered in many cases as a sphere of solving social problems (Israelyan, 2022a, para 3). As a result, ″the sciences in Armenia are becoming the realm of the aged″. (Sahakyan, 2022, para 1),
3. *Low levels of sector funding and wages* (National Research Council, 2004; Israyelyan, 2022a). In recent years, an active policy has been carried out in the direction of raising the salaries of scientists (the RA Science Committee) and financing the sector (The Gituzh Initiative). According to the goal set by The Gituzh Initiative, funding for the sector should be 4% of the budget (Sahakyan, 2022; Israyelyan, 2022a, para 5, 10).

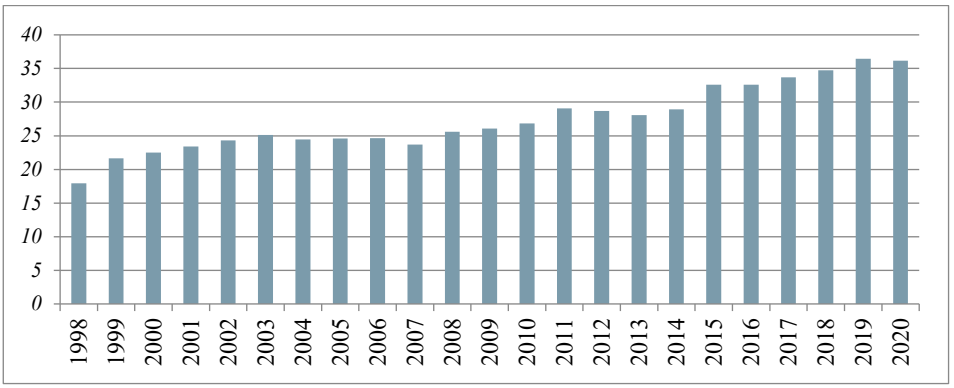
Among the global trends affecting the aging of the science sector is the decline in the birth rate, the aging of the population, particularly those born before the 1960s, as well as "the increase in required knowledge to make a contribution to science" (Ricón, 2020, Conclusion section). Chart 1 shows the dynamics and trends of the scientific potential of Armenia graphically.



Note: Adapted from the RA Statistical Committee (2001-2022)

Chart 1. ***The dynamics of the number of people performing scientific and technical works in the RA***

In the period 1998-2020, the number of people employed in the sector decreased by about 15% and amounted to 4,499 people. In the same period, however, the number of older personnel performing scientific and technical work increased by more than 70% and amounted to 1,626 people. Naturally, the share of employees of the mentioned group in the sector has increased. Instead of 18 % in 1998, in 2020, professionals from this group made up more than a third of the total number of professionals in the sector (about 36%).

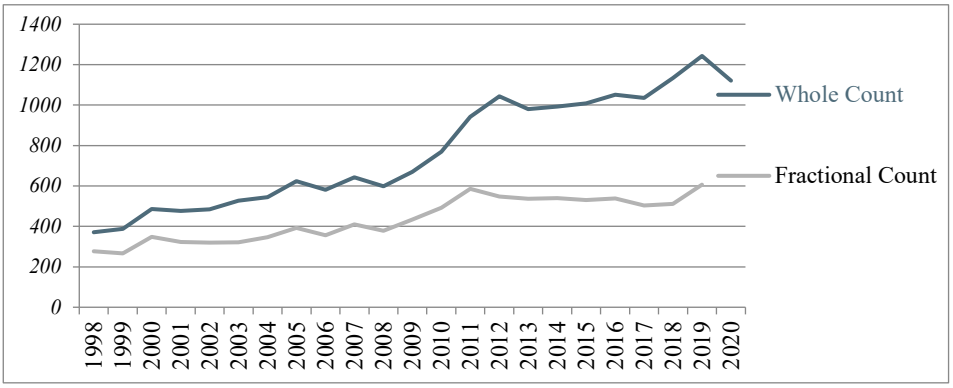


Note: Adapted from the RA Statistical Committee (2001-2022)

Chart 2. ***The share of scientific and technical workers aged 60 and over in the RA***

It should be noted that in 2020, professionals aged 50 and older made up more than half of the number of researchers (51.2%). Thus, the phenomenon of aging of the science sector is also present in Armenia.

Armenia's integration into the national scientific family is proceeding at a slow pace, and there have been various concerns about it. Ultimately, as a result of the mentioned process, the works of Armenian scientists will become more recognizable. Chart 3 illustrates the dynamics of the number of S&E publications in the Scopus database.



Note: Adapted from National Science Board (2021)

Chart 3. ***Dynamics of S&E jorunal articles and conference papers in the RA***

From the presented data, it is noticeable that the number of S&E articles and conference papers has increased since 1998, both in whole and fractional counting. Moreover, in the first case, the number of publications tripled, and in the second case (in 2019) it increased more than twice. Thus, there is a positive trend in the representation of Armenian scientists in the international scientific community. However, it is not a growth that can be considered satisfactory. In particular, the number of publications in the neighboring countries of Georgia and Azerbaijan per 1 million inhabitants increased by 4.6 and 5.9 times, respectively, from 1998-2020, and by 3.5 times in the case of Armenia.

ANALYSIS. The correlation coefficient calculated with the help of the available statistical data of 23 years (1998-2020) regarding the two variables was significant (0.94). This result indicates that there is a fairly strong correlation between the two indicators. It was found that the series are not stationary and their stationary series should be considered in the model. In addition, preliminary calculations have shown that the share of scientists aged 60 and over is affected by a certain lag. It should be noted that lags 2.5 and 8 were significant. As a result, the following econometric model was proposed to be evaluated.

$$D\big(D(WC_t)\big) = \alpha + \beta_2 * D(OLD_{t-2}) + \beta_5 * D(OLD_{t-5}) + \beta_8 * D(OLD_{t-8}) + \varepsilon_t,$$

where,

$D\big(D(WC_t)\big)$ – is the index of the number of S&E articles and conference papers in whole counting taken in year t with the double difference,

$D(OLD_{t-2}), D(OLD_{t-5}), D(OLD_{t-5})$ – are the indicators of the share of the scientists aged 60 and over in the 2nd, 5th and 8th lags, respectively, taken with first-order differences,

α, β_2, β_5 *and* β_8 – are the unknown parameters of the model,

ε_t – is the random error of the econometric model in year t.

t – is an index describing the year ($t = \overline{1998,2020}$).

After estimating the model by the method of least squares, we obtained the following estimated model:

$$D\left(\widehat{D(WC_t)}\right) = \underbrace{19.5}_{(0.4614)} - \underbrace{36.1}_{(0.0024)} * D(OLD_{t-2}) - \underbrace{47.1}_{(0.0016)} * D(OLD_{t-5}) + \underbrace{41.8}_{(0.0030)} * D(OLD_{t-8}), R^2_{adj} \approx 0.68, DW \approx 1.5$$

The obtained results show that the model is of high quality. The model quality is high, the model is overall significant, the coefficients are also significant except for the free member.

Based on the estimated model, the following conclusions can be drawn:

- If the share of scientific and technical workers aged 60 and over increases by 1 percentage point in a given year, the number of publications will decrease by 36.1 on average after 2 years.
- If the share of scientific and technical workers aged 60 and over increases by 1 percentage point in a given year, the number of publications will decrease by 83.2 on average after 5 years.
- If the share of scientific and technical workers aged 60 and over increases by 1 percentage point in a given year, the number of publications will decrease by 41.4 on average after 8 years.

The Armenian science sector is also not exempt from demographic trends. Baby boomers made up a third of science workers in 2021, the largest age group. Demographic trends and a decline in the number of young people entering the science sector make it even more difficult to attract and retain talent, for which it is necessary to provide appropriate working conditions and create additional incentives (Sweet et al., 2010, p. 33). Prettner and Trimborn aptly described (2012): "Lower population growth inevitably slows down technological progress in the long run, which in turn leads to a lower economic growth rate along the balanced growth path" (p. 10).

Over time, historical and institutional factors other than age, such as article publication norms, may also influence the productivity of scientists in particular age groups, which can create a contradictory picture (Stroebe, 2014, pp. 665-666). In countries such as the United States, one of the ways to promote innovation and scientific activity is to encourage immigration policies, as well as to provide funding for the activity of young scientists (National Research Council, 2012, pp. 120-121). In Armenia, on the contrary, the vicious phenomenon of "brain drain" accompanied almost the entire period of independence.

There are some limitations in the study. First, scientific or scientific-technical activity can be characterized by a number of other indicators as well (in particular, related to patent activity and technology transfer). The research was carried out at the level of the science sector, while each scientist contributed separately. In various foreign studies, the authors emphasized the

weight of scientific articles. Furthermore, both effective and ineffective scientists continue to work in old age, which has its positive and negative aspects (Stroebe, 2014, pp. 671-672). The number of scientific publications represents only the quantitative aspect of scientific activity. However, "there is a great deal of evidence that the number of publications and number of citations are highly correlated" (Stroebe, 2014, p. 665). The results of scientific activity and the role of women are also of particular interest. However, it should be noted that in 2021 only one-third of professionals aged 60 and over were women. Meanwhile, in 2021, women made up 53 % of the industry. In this context, it is of great interest to observe the involvement of women in scientific activity in other age categories and to carry out comparisons of the scientific output of male and female scientists.

CONCLUSIONS. Based on the analysis, we made several conclusions. The aging of science is a common phenomenon. Half of those employed in the Armenian science sector are 50 and older, and more than a third are 60 and older. Brain drain also greatly hinders the deepening or intensification of aging processes. At the same time, the number of S&E publications increased between 1998 and 2021.

The results of the econometric analysis carried out to reveal the relationship between the aging of the science sector and scientific productivity showed that the increase in the share of older scientists has long-term negative consequences on scientific productivity. In particular, if the share of scientific and technical workers aged 60 and over increases by one percentage point, the number of S&E publications decreases on average by 36.1 after 2 years, by 83.2 after 5 years, and by 41.4 after 8 years.

The example of Armenia complements the prevailing point of view in the research area of age and productivity relationship, that is, scientific productivity decreases along with age. However, it should be noted that the research was conducted at the sector level. Further areas of study could be related to the individual productivity of older scientists, as well as the qualitative aspect of scientific publications. Thus, in addition to creating attractive conditions for young scientists, it is essential to more effectively exploit the scientific potential, particularly the potential of older scientists.

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