ABSTRACT

Modern economy requires knowledge and skills, which are acquired by future employees mostly in the fields of education including science and engineering. The increase in the number of graduates in this type of studies can be achieved in different ways, one of which is to create conditions and increase the propensity of women to obtain this type of education. The aim of the research presented in the article is to analyse long-term trends in the number of students and graduates in Poland, with particular emphasis on engineering faculties and the participation of women. Authors using dispersion and structural similarity measures and dynamic models showed that the total number of students and graduates and the number of students in engineering studies are characterised by different patterns. At the same time, in both cases a different structure of total students and engineers by gender was observed, as well as a growing share of women.

Keywords: tertiary education, engineering programmes, gender equality

INTRODUCTION

One of the most important gender equality is related to access to education. We can recognize also other kinds of gender segregation like: horizontal occupational segregation, vertical/hierarchical segregation, pay segregation and segregation in values and preferences (Pološki Vokić, Sinčić Ćorić, Obadić, 2017). Many studies and research confirm that the gender disparity observed in the education sector has a direct link to poverty (Appleton, 1996), as well as to child survival, health and education (Schultz, 2002). According to The World Bank gender equality, whether in education or other areas is very important for increasing productivity and higher women’s integration in the labour market (World Bank, 2012). The study of Licumba et al. based on a panel data of five Southern African countries between 1970 and 2010, suggests that there is a positive and significant effect of gender equality in education on economic growth (Licumba, Dzator, Zhang, 2015). This relation was proved by Klasen (2002) who based on sample of 109 countries between 1960 and 1990 indicated a positive and significant coefficient of gender equality on economic growth. Some authors provided evidence that the effect of female education on economic growth depends on the country’s degree of industrialisation (Dollar, Gatti, 1999), while other shows that countries with high levels of female schooling will have higher levels of labour productivity and growth, regardless of the degree of industrialisation and/or level of human capital (Knowles, Lorgelly, Owen, 2002). Lagerlof (2003) explains how changes in gender equality in education are likely to affect the process of growth of human capital. In his model as equality in education goes up, women’s time becomes expensive and
couples tend to substitute quantity for quality of children. Fertility rates decline and investment in human capital and income per capita rises (see also: Kalaitzidakis et al., 2001). According to (OECD, 2017) OECD members should adopt practices that promote gender equality in education by: making the study equally inclusive and attractive for women and men, raising awareness among young men and women, parents, teachers and employers about the likely consequences of educational choices for employment opportunities, career progression and earnings as well as encouraging more women who have completed STEM (such as science, technology, engineering and mathematics) studies to pursue professional careers in these areas. Such practices are also implemented in other countries. Tahir and Yaqoob (2018), based on a sample of 600 alumni of universities in three districts of the Southern Punjab in Pakistan concluded that university education sensitizes women regarding gender equality and its role is visible in increased girl enrollment and women labor participation. Diversity education, focusing on different forms of difference implemented without providing clear definitions and policy goals to achieve gender equality, increases the risk for diminishing the transformative intent of broader social justice goals and overlooking gender equality completely (Forbes, Öhrn, Weiner 2011; Loots, Walker, 2015). That’s why many studies still report on the persistence of deeper seated inequalities between the genders in all spheres of higher education (e.g. Francis, Burke, and Read 2014). Women in both developed and developing countries continue to experience inequality in terms of education, employment status, hierarchical positions, compensations and career advancement (Burke, Singh, 2014; Kalayci, Hayirsever, 2014). Although in a modern world women are more represented in the workforce, caught up with men in the rates of higher-education graduation, increased their training and representation in formerly male-dominated professional fields in STEM, and they entered many previously male-dominated occupations (Costa et al., 2014), still even in more gender egalitarian national cultures, women and men continually occupy highly differentiated gender roles, resulting in the greater likelihood of women taking the primary responsibility for home and family in addition to paid work/career (Seierstad, Kirton, 2015). Tertiary education plays a crucial role in economic growth and social progress. Higher education drives research and innovation that fosters positive economic and social change at the local, regional, and national levels. In 2018 in the EU according to Eurostat 40.7% of people aged 30-34 hold a tertiary degree. The EU has thus effectively reached the 40% target set by the Europe 2020 strategy to promote economic growth and employment, while 45.8% of women, and only 35.7% of men, held a tertiary education qualification, although we can observe high variation in these attainment rates across countries mostly due to different labour migration or learning mobility patterns (Education and Training Monitor 2018, 2018). In the EU countries, more women complete their studies than men, while in the case of newcomers this proportion is the opposite (Silander, Haake, Lindberg, 2013). In 2016, women accounted for 54.1% of tertiary students in the EU, being a majority among tertiary students in all of the EU Member States except for Greece (48.5%) and Germany (48.2%). It is worth noting that these proportions are considerable different between academic disciplines. Across the EU-28, almost one third (32.0%) of all students in tertiary education were studying social sciences, journalism, information, business, administration or law in 2016. The second most common field of education was engineering, manufacturing and construction-related studies which accounted for 15.7% of all tertiary education students. In this field, almost three quarters (74.1%) of all students were male. Within natural sciences, mathematics, statistics, and information and communication technologies (ICT) the share of men in the total number of tertiary students was 61.1%. In 2016, an analysis of the number of graduates in the EU-28 by field of education shows that 14.8% of all students had graduated in engineering, manufacturing and construction-related studies and 11.0% in natural sciences, mathematics, statistics and ICT. Within the EU-28, close to three fifths (57.6 %) of all graduates in 2016 were women. An analysis by programme orientation reveals that this share was equal to 42.5% for natural sciences, mathematics, statistics, and information and communication technologies, and close to one quarter (27.7%) of the total for engineering, manufacturing and construction-related fields. In the same time we can observe diversified gap between the number of male and female graduates relative to the size of the population aged 20-29 across countries as well as field of studies (Tertiary education statistics, 2018). The main objective of the research is to present long-time tendencies for propensity of women to enrol engineering studies in comparison to men in Poland. In the paper a problem of regional
differences of STEM graduates was also undertaken. To achieve these goals authors have used different methodological approaches like dispersion and structural similarity measures and models. The data covers period 2005-2018 for students and period 2004 do 2018 for graduates. The authors have verified the research hypothesis that we can observe the growing participation of women in engineering higher education.

**RESEARCH METHODS**

The analyses of changes in the number of students and graduates, as well as in the gender structure were based on chosen statistical measures and econometric models of dynamics. The authors used for this purpose: relative changes, the coefficient of variation, trend models:

\[ y_t = \beta_0 + \beta_1 t + u_t \]  

where:
- \( y_t \) – dependent variable,
- \( t \) – time variable, \( t = 1, 2, \ldots, n \),
- \( \beta_0, \beta_1 \) – coefficients,
- \( u_t \) – error term,

and the distance measure of structures (city metric), calculated according to the following formula:

\[ v_t = \sum_{i=1}^{k} |\alpha_{it} - \alpha_{i(t-1)}| \]  

where:
- \( k \) – the number of components in the analysed structure,
- \( \alpha_{it} \) – share of \( i \)-th component in the analysed structure in period \( t \),
- \( \alpha_{i(t-1)} \) – share of \( i \)-th component in the analysed structure in period \( t-1 \).

**EMPIRICAL ANALYSIS**

The data comes from Statistics Poland (2019) and concern students of Polish higher education institutions as of 30 XI in the given academic year between 2005 and 2018 and graduates of Polish higher education institutions in the given academic year (2003/2004 – 2017/2018). The structure of the obtained data made it possible to perform analyses by gender and taking into account engineering studies. Figure 1 presents the total number of students of Polish higher education institutions in Poland 2005–2018.

**Figure 1: Students of Polish higher education institutions as of 30 XI in the given year (2005–2018) – grand total**

During the whole analyzed period there is visible strong decreasing tendency in the number of students of higher education institutions. In 2005-2008 the changes in the number of students (both females and males) were very small whereas in 2009-2018 the changes were greater (faster fall for males than for females). The number of female students is greater than number of male students in all years.

Figure 2 presents the number of students of first-cycle programmes with the title of Engineer in 2005–2018 in Poland.
The number of students of first–cycle programmes with the title of Engineer increased in the first part of examined period (2005-2012) and decreased in the second part (2012-2018). The fall in the first period was slower than growth in the second period. The share of female students in students of first–cycle programmes with the title of Engineer is about three times smaller than share of male students. Table 1 presents parameters of linear trend models and relative changes for 6 examined variables in the research period.

Table 1: Parameters of linear trend models and relative changes for students (2005-2018) and engineering students (2012-2018) of Polish higher education institutions

| Variable                        | $\beta_0$  | $\beta_1$  | $R^2$  | Relative change (2018/2005) |
|---------------------------------|------------|------------|--------|-----------------------------|
| Students grand total            | 2131648.93 | -62905.22  | 0.95   | -37.03%                     |
| 2 students grand total females  | 1214900.46 | -34311.98  | 0.91   | -35.37%                     |
| 3 students grand total males    | 916748.47  | -28593.24  | 0.98   | -39.20%                     |
| 4 students engineers total      | 415169.29  | -17545.61  | 0.99   | 24.14%                      |
| 5 students engineers total females | 139858.86 | -6560.71   | 0.97   | 60.72%                      |
| 6 students engineers total males | 275310.43 | -10984.89  | 0.99   | 12.29%                      |

* – parameters statistically significant on the level 0.01

All estimated parameters in all trend models were statistically significant and goodness of fit was very high. All estimated slopes were negative what means that values of examined variables decreased systematically during analyzed periods. Comparing values in the first year (2005) and in the last year (2018) one can observe that for 3 variables (grand total) level in the last year was lower than in the first year of study whereas the situation for students engineers was different. Although there was a drop in the second part of analyzed period the level in 2018 was still higher than in 2005. Figure 3 presents the total number of graduates of Polish higher education institutions in 2003/2004 – 2017/2018 in Poland.
The number of graduates of Polish higher education institutions increased in the first part of examined period (2003/2004-2010/2011), decreased in the second part (2010/2011-2017/2018) apart from one academic year – 2016/2017. The decrease in the second part of analyzed period was so fast that the number of graduates (both females and males) was much lower in 2017/2018 than in 2003/2004. Figure 4 presents the number of graduates of first-cycle programmes with the title of Engineer in 2003/2004 – 2017/2018 in Poland.

The number of graduates of Polish higher education institutions (both females and males) in the first part of analyzed period was about twice lower than in the second part. It is a positive phenomenon but in the last academic year the value of analyzed variable again dropped although not in the high degree. Table 2 and 3 present distances between gender structures of students and graduates in the selected years of the research.

**Table 2: Distance between gender structures of Polish students of higher education institutions in 2005 and in 2018**

|                         | 2005 | 2018 |
|-------------------------|------|------|
| Grand total             |      | 0.0299 |
| First-cycle programmes with the title of Engineer |      | 0.1442 |

The shares of females and males in students of higher education institutions were almost the same at the beginning and at the end of analyzed period – distance between structures in 2005 and 2018 was very close to zero. Such distance was greater in case of students of first-cycle programmes with the title of Engineer – the share of females increased from 24.5% in 2005 to 31.7% in 2018 what is a positive phenomenon.
Table 3: Distance between gender structures of graduates of Polish higher education institutions

| Academic years          | Grand total | First–cycle programmes with the title of Engineer |
|-------------------------|-------------|---------------------------------------------------|
| 2003/2004 – 2017/2018   | 0.0278      | 0.1232                                            |
| 2003/2004 – 2010/2011   | 0.0137      | 0.1165                                            |
| 2010/2011 – 2017/2018   | 0.0415      | 0.0067                                            |

Because of different tendencies for graduates in the first and second parts of the analyzed period, the distances were calculated for three pairs of academic years. The smallest distance characterized structures in the second part of the analyzed period so the changes in shares of females and males in the first academic years were responsible for the value of the distance of structures in the whole period. The share of females increased from 31.95% in 2003/2004 to 38.1% in 2017/2018, which is again a positive phenomenon. Figure 5 presents the number of graduates of first–cycle programmes with the title of Engineer by gender and voivodships in the academic year 2017/2018.

Figure 6: Graduates of Polish higher education institutions in the academic year 2017/2018 by voivodships– first–cycle programmes with the title of Engineer

In comparison to academic year 2003/2004, the number of graduates of first–cycle programmes with the title of Engineer grew substantially in all regions, although the number of technical universities in all voivodships did not change. The greatest increase was in Mazowieckie (capital voivodship) – from 6,000 until almost 9,000 graduates and also in voivodships: Śląskie, Dolnośląskie, Wielkopolskie and Małopolskie. We have noticed also the growing share of women among graduates in all regions. Figure 7 presents coefficients of variation (CV) of the share of females in graduates of first–cycle programmes with the title of Engineer in voivodships in 2003/2004 – 2017/2018.
Figure 7: Coefficients of variation of share of females in graduates of higher education institutions in voivodships in 2003/2004 – 2017/2018 – first–cycle programmes with the title of Engineer

We can observe diminishing values of CV beginning from 2010/2011 academic year, which is evidence of higher homogeneity of analysed regions according to gender structure of graduates in engineering fields of study.

CONCLUSIONS

In Poland there has been a decrease in the number of students in recent years. This applies mainly to master's and part-time studies. A significant decrease in the number of students started in 2010 and could be caused, among other things, by a better situation on the labour market, as graduates of Bachelor's studies could find employment relatively easily and their wages are similar to graduates of Master’s studies. Among engineers, this trend was different and was characterised by an increase in the number of students until 2012 and a subsequent decrease. Different patterns over time and different gender structures were also characteristic of total and engineering graduates. In the analysed period, an increase in the share of women both among students and graduates was also observed, mainly in engineering studies. This phenomenon is connected with the change of cultural and social patterns – women gain more independency and prefer career over motherhood. At the same time, the results obtained indicate that regional differences in the share of women in engineering studies are levelling out. Unfortunately, other studies being conducted indicate that the participation rate of women in the Polish labour market is still characterized by strong differentiation at the regional and sectoral levels, and there still exists significant gender wage gap (Batóg, Batóg, 2018). Removing these differences requires more effective implementation of state policies in these areas.

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