STEM EFFECT ON GDP IN EU COUNTRIES: LABOR FORCE PERSPECTIVE

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ABSTRACT

This paper analyzes the impact of Science, Technology, Engineering, and Math (STEM) workforce on GDP in EU countries as a proxy for what could happen in Azerbaijan. We first estimate the effect of STEM labor force, which is measured by the number of workers in STEM occupations on GDP in 28 EU countries for 1992-2015. We use STEM labor force as the basis for innovation and productivity in a country as opposed to educational attainment used mostly for developed countries. Then, we use the estimated marginal effects to quantify the potential contribution of STEM labor force on GDP per capita in Azerbaijan. It was found that adding 44,000 STEM jobs (28% increase) in STEM labor force in Azerbaijan is predicted to cause $1944 increase in GDP per employee, which corresponds to $1102 in GDP per capita approximately.

Keywords: STEM, economic growth, productivity

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INTRODUCTION

Economic growth is the ultimate goal for any economy striving to achieve prosperity and higher living standards in the long run. Without reasonable perpetual growth policies, countries will relatively, even if not absolutely shrink and thus lose their competitiveness in the world economy. This is true, especially for emerging and developing economies, that should try harder to catch up with developed countries. Economists historically put forward two inputs: labor and physical capital. However, due to the fact that output grows at a higher pace than labor and capital, it was thought that some other factors had an effect. In one of the prominent studies of economic growth, Romer (1990) and Romer (1994) point to higher productivity through technological advancements, innovations, proper institutions and accumulation of human capital as main drivers of economic growth. There is no doubt that human capital is the key in determining the level of productivity. More and more studies that focus on the role of human capital in economic growth use educational attainment as a measure (OECD 1998). Sianesi and Reenen (2002) summarize research that focuses on returns to education and use years of schooling as a measure of human capital. Furthermore, Cohen and Soto (2007) ran across country regression and found that educational attainment is a significant determinant of GDP.

On the other hand, these studies ignore the fact that return to different types of education differently impacts GDP. Some studies suggest that STEM fields are a better measure of human capital. For example, Marginson et al. (2013)

argue that years of schooling is inadequate in proxying human capital, because it measures quantity, rather than quality. The authors compare STEM education across countries and claim that it is closely linked to R&D and industrial innovation. The importance and relevance of STEM education is not restricted to developed economies.

Azerbaijan, which experienced a transition from command economy to a market economy, has been on the path of setting and improving liberal institutions to foster economic growth since 1992. Analyzing how STEM education is relevant to Azerbaijan context is very important for policymakers.

This paper studies the effect of STEM workforce on GDP. By using the data of EU countries (28), we quantified the effect of STEM workforce on GDP after controlling for capital stock. Additionally, we used the constructed relationship between STEM workforce and GDP for EU countries to make prediction on how STEM workforce would affect GDP of Azerbaijan. To that extent, this article contributes to the literature by quantifying the potential contribution of the role of human capital, more specifically the labor force mix rather than educational attainments, in creating economic growth in Azerbaijan.

The remainder of this paper is structured as follows: Chapter 2 reviews the relevant literature, Chapter 3 set up the model, Chapter 4 set up the analysis and present results and the Chapter 5 presents summary and policy proposals.

LITERATURE REVIEW

Among many growth theories, undoubtedly the growth model put forward by Romer (1994) is still one of prominent ones. Romer (1994) showed that perpetual growth can be achieved through innovation in ideas. Therefore, many countries still believe in and make heavy investment in human capital, innovation and knowledge because of its significant contribution to economic growth.

Human capital can be accumulated either through better secondary and tertiary education, learning by doing, or on-the-job training. Young (1993), for example, integrates invention and learning by doing models by showing interdependence between research activity in the laboratory and production experience on the factory. There are also huge discussions regarding the importance of investment in education and building institutions to accumulate human capital. For instance, Hargot (2000) concludes that human capital is a very important concept to understand individual performance in relation to education and labor market. Capelli (2008) discusses the role of education on the economic wellbeing of individuals and argues that the more people are educated the more likely they will be rich and the less likely they will be unemployed. Kirby (2007) states that education can be viewed as an agency that is capable of fostering economic prosperity by promoting innovation and providing sufficient human capital. However, educational attainment is not the only channel for human capital formation. In fact, learning-by-doing and on-job-training can also play an important role in that regard. Zeev et al. (2017) explain how the apprenticeship concept led inventions in Britain, as this practice was the source of skilled mechanical labor. Besides the success of this institution, according to Zeev et al (2017), they did not require much science or even originality, but rather needed people who were good with hand skills and had been taught how to use them.

Murphy et al. (1991) is one of the early studies analyzing human capital formation through occupational channels, specifically engineering. Examining the relationship between economic growth and occupational proportion of lawyers versus engineers in the labor force, they found that the countries with more engineering majors accumulated more human and physical capital. The authors argued that the policies focused on improving the attractiveness of engineering as an occupation are possibly indirect sources of economic growth.

Augustine (2005) emphasizes the links between prosperity, knowledge-intensive jobs dependent on science and technology, and continuous innovation to address societal problems. That is, even though the STEM workforce is relatively small, they are significant contributors to competitiveness, economic growth and overall standard of living of a country (Langdon, 2011). The STEM term is not only widely used for addressing educational policy, but also has implications for workforce, national security and immigration policies (Gonzalez & Kuenzi, 2012, August).

Most of the STEM studies use number of people with specific educational specialties as a proxy to measure human capital stock in that area, considering the high correlation between number of specific occupation graduates and the labor force of the same occupation. However, this correlation may not be positive in many developing countries, due to the quality of the tertiary education, limited availability of education of specific occupations, and pre-mature labor markets of transitional economies. Therefore, we propose to use number of workers in STEM occupations as a proxy for human capital and quantify its effect on economic growth. This is the first study that attempts to quantify the relationship between STEM and economic growth in Azerbaijan and planned to help policymakers.

MODEL

The basic aggregate production function underlying the neoclassical growth model is as follows:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} \qquad (1)$$

Here, Y represents output or real income which is measured as GDP. A represents total factor productivity, and L represents total labor force. Following Cohen and Soto (2007), we can modify this production function to incorporate STEM education in the production function. For simplicity we ignore the total factor productivity and focus only on capital and labor aspect of production function.

$$Y_{it} = K_{it}^{\alpha} H_{it}^{\beta} \qquad (2)$$

Total labor force is replaced with human capital (H) enhanced with STEM education. We go a step further and use only stem labor force for human capital to see its effect on GDP. This equation could be expressed in per-employee format after dividing each term by total labor force. So, it becomes:

Where y is GDP per employee, k is gross fixed capital formation per employee, and *h* is stem labor force per worker. The above equation can be written in the following format in levels for econometric estimation.

$$y_{it} = \delta_{it} + \alpha k_{it} + \beta h_{it} + u_{it} \qquad (3)$$

Finally, the regression equation that will be estimated is as follows:

$$GDPperWork_{it} = \delta_{it} + \alpha CAPperWork_{it} + \beta StemLF_{it} + u_{it}$$

Where, *GDPperWork* is GDP per worker, *CAPperWork* is capital per worker, and *StemLF* is STEM labor force per 1,000 employee.

DATA AND EMPIRICAL ANALYSIS

Analysing the relationship between input (human capital) and output (GDP) works in developed countries where quality of education is highly competitive. However, in countries where pipeline input and output differ for specific occupations, this approach will not yield relevant results due to the following reasons:

1. Inadequate level of STEM education quality in order to get hired.
2. Employment in other areas, due to the lack of availability of STEM jobs.
3. Attractiveness of job opportunities in other areas after graduation.

These are the reasons why it is not recommended, and it is not consistent to weigh STEM capacity by STEM education, especially in post-Soviet countries and the countries in which STEM graduates do not fully meet STEM employment requirements. Therefore, it is more reasonable to measure economic growth-human capital correlation using employment data rather than schooling information. Thus, we will try to analyse and explain STEM employment's impact on selected countries' economic growth.

Given this rationale, in the regression analysis conducted below, STEM capacity is measured by the number of people working in STEM field (STEM labor force). Unfortunately, due to the reason that this data does not exist in the Republic of Azerbaijan, we are unable to conduct a direct comparison. Instead, we conducted panel regression analysis with fixed effect for 28 European Union countries. STEM labor force statistics is obtained from Eurostat statistical database. In this database, STEM workforce classification was made according to the International Labor Organization's International Standard Classification of Occupations-08 (ISCO-08). All other information such as population, gross domestic product, gross fixed capital formation and other statistics were taken from World Bank statistics database.

Data for all STEM occupations, except economists, statistical mathematical and related associate professionals, and financial analysts, exist for 24 years (1992-2015 years). Due to the limited time period (2011-2015 years), these occupations were not added to the main analysis. Summary of variables used in the analysis is provided in Table 1.

Table 1. Summary of the data used for regression analysis

Variable	Min.	Max,	Mean	Standard deviation
GDP per employee	$3,199.89	$1,217,546.48	$94,338.90	$16,9219.48
STEM labor force per 1,000 employees	0.00063	7.79497	0.12	0.86
Gross Fixed Capital Formation per employee	$0.03	$119.84	$5.80	$15.84
OBSERVATION INFORMATION				
Observation number	570			
Country number	28			
Years	1992-2015			

Regression analysis on Table 2 reveals positive and statistically significant estimates both for STEM labor force and capital variables. R-squared for the test is 98% which means STEM labor force variable together with gross fixed capital formation explains 98% of the variation in GDP per worker in the data.

Table 2. Summary of the regression analysis of the provided data

Real GDP per worker	Coef.	Std. Err	t	P> |t|
Real Gross Fixed Capital Formation per worker	1.503473	.0570696	26.34	0.000
STEM worker	249277.5	10380.77	24.01	0.000
Intercept	55588.89	1154.348	48.16	0.000
R^2=0.98				

Results do not change if we add STEM occupations (2631, 3314 and 2413) which were removed due to the lack of long-time horizon data. However, considering that there are only 5 years of these occupations' statistics, it is preferred to use the first analysis as main reference.

Based on the analysis provided above, we can perform the following calculations: GDP per capita will increase by $1.5 if capital per employee increases by $1. Besides, 1 percentage point increase in STEM labor force (stem w represents the percentage of labor force employed in STEM sectors), causes $2349 increase in GDP per employee. Considering that average labor force is 57.62% in the world (Authors own calculation based on World Bank statistics for 26 years of world population), then 1%-point increase in STEM labor force, will cause $1353 of increase in GDP per capita.

As stated above, although we do not have statistical information regarding the classification of STEM employment in Azerbaijan, using these results as a proxy, we can come up with useful policy proposals for Azerbaijan. Since the population of the Republic of Azerbaijan is 9,649,341 (World Bank statistics, 2016), total labor force and STEM-related labor force should be around 5,559,950 and 156,234, respectively (Author's own calculation based on Eurostat labor force survey statistics for 27 years is STEM labor force consists 2.81% of population of EU-28 countries).

It could be concluded that 28% increase from 156,234 to 200,000 in STEM labor force in Azerbaijan, is predicted to cause $1944 increase in GDP per employee which corresponds to $1102 in GDP per capita approximately.

$$\text{stem } w_1 = \frac{156234}{5559950} = 0{,}0281$$

$$\text{stem } w_2 = \frac{200000}{5559950} = 0{,}0359$$

$$\Delta stem\ w = 0.0359 - 0.0281 = 0.0078$$

$$\Delta rgdp\ w = 0.0078 * 249278 = \$1944$$

CONCLUSION AND POLICY PROPOSALS

This paper analyzes the potential contribution of STEM labor force on economic activity in Azerbaijan by using the estimated marginal effect of STEM labor force on 28 EU countries during 1992-2015. We found that 28% increase in STEM labor force in Azerbaijan, is predicted to cause $1102 in GDP per capita approximately.

Based on the regression analysis and basic calculation provided above, it will be reasonable to propose that the improvement in the share of STEM employees in the overall labor force of Azerbaijan is beneficial to the increase of GDP per capita. Though the question of how to achieve an increase in STEM labor force should be the topic of a separate study, three main directions could be considered as starting points in short, mid and long-term periods:

1. The first action is to increase the number of STEM graduates by increasing STEM faculties and universities.
2. The second action is to develop consistent investment programs for qualified STEM graduates in order to get STEM jobs and enrich their productive abilities that will create an economic value in mid-term time period.
3. Besides the actions above, STEM specialties should be promoted in order to create a short-term increase in the STEM labor force number.

In context of these points, it is obvious that the first action is the most crucial for the Republic of Azerbaijan. According to State Examination Centre of the Republic of Azerbaijan (The State Students Admission Commission, 2015), the approximate number of STEM graduates is not a small portion of overall graduates. Therefore, immediate action needed to take is to improve quality of STEM education, since the start point of leaks in the STEM pipeline comes from this reason. After assuring the start point is robust by improving STEM education quality, Azerbaijan Republic should develop a strategy granting STEM incentives and tax exemptions to companies, employees and single entrepreneurs in order to fill the leak in the STEM pipeline between graduation and labor force.

The novelty of this research is that it attempts to quantify the effect of STEM workforce on GDP in Azerbaijan, even though the historical data for STEM workforce is not available. A major drawback of this research is the quantified relationship between STEM workforce and GDP calculated for EU countries and its application directly to the case of Azerbaijan (the dynamics of economies and workforce of this countries are different). Future research can rely on micro-level data that includes STEM field information and earnings in Azerbaijan.

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Appendix 1.

List of STEM occupations, according to OECD methodology

ISCO 08 Codes	TITLE	ISCO 08 Codes	TITLE
21	Science and engineering professionals	2522	Systems administrators
211	Physical and earth science professionals	2523	Computer network professionals
2111	Physicists and astronomers	2529	Database and network professionals not elsewhere classified
2112	Meteorologists	31	Science and engineering associate professionals
2113	Chemists	311	Physical and engineering science technicians
2114	Geologists and geophysicists	3111	Chemical and physical science technicians
212	Mathematicians	3112	Civil engineering technicians
2120	Mathematicians, actuaries and statisticians	3113	Electrical engineering technicians
213	Life science professionals	3114	Electronics engineering technicians
2131	Biologists, botanists, zoologists and related professionals	3115	Mechanical engineering technicians
2132	Farming, forestry and fisheries advisers	3116	Chemical engineering technicians
2133	Environmental protection professionals,	3117	Mining and metallurgical technicians
214	Engineering professionals (excluding electrotechnology)	3118	Draughtspersons
2141	Industrial and production engineers	3119	Physical and engineering science technicians not elsewhere classified
2142	Civil engineers	312	Mining, manufacturing and construction supervisors
2143	Environmental engineers		
2144	Mechanical engineers	3121	Mining supervisors
2145	Chemical engineers	3122	Manufacturing supervisors
2146	Mining engineers, metallurgists and related professionals	3123	Construction supervisors
2149	Engineering professionals not elsewhere classified	313	Process control technicians
215	Electrotechnology engineers	3131	Power production plant operators
2151	Electrical engineers	3132	Incinerator and water treatment plant operators
2152	Electronics engineers	3133	Chemical processing plant controllers
2153	Telecommunications engineers	3134	Petroleum and natural gas refining plant operators
216	Architects, planners, surveyors and designers	3135	Metal production process controllers
2161	Building architects	3139	Process control technicians not elsewhere classified
2162	Landscape architects	314	Life science technicians and related associate professionals
2163	Product and garment designers	3141	Life science technicians (excluding medical)
2164	Town and traffic planners	3142	Agricultural technicians
2165	Cartographers and surveyors	3143	Forestry technicians

Continue: Appendix 1.

2166	Graphic and multimedia designers	315	Ship and aircraft controllers and technicians,
251	Software and applications developers and analysts	3151	Ships' engineers
2511	Systems analysts	3152	Ships' deck officers and pilots
2512	Software developers	3153	Aircraft pilots and related associate professionals
2513	Web and multimedia developers	3154	Air traffic controllers
2514	Applications programmers	3155	Air traffic safety electronics technicians
2519	Software and applications developers and analysts not elsewhere classified	2631	Economists
252	Database and network professionals	3314	Statistical, mathematical and related associate professionals
2521	Database designers and administrators	2413	Financial analysts

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