Efficiency of College Education in the Labor Market of the United States

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Abstract— **The paper discusses the worthiness of the resources allocated for college education from the point of view of their value in the labor market. We use Data Envelopment Analysis (DEA) to weigh the share of GDP spent on a college education and weighted time of labor force college study against productivity, employment rate, and labor force participation. We received that in the U.S. labor market the efficiency of a college education had no statistically significant tendency to increase or decrease over the period of 1980-2010 but was closely related to the business cycles with a lag of one year.**

Index Terms— **College education, Data Envelopment Analysis, Efficiency, Employment rate, Labor force participation, Labor force productivity.**

I. INTRODUCTION

THERE is growing evidence in American society that college education is, on average, no longer worth what it costs. The historical rate of return to a four-year college degree has seldom been estimated at less than 7 percent, and has throughout the last two decades of the last century remained at about 10 percent. However, these returns have fallen for most demographic groups according to recent work by Brown et al. [3] "… Indicates that the gains from college education were flat in the 1980s and actually decreased significantly in 1991-2007 period. On the other hand, the gains to a high school education have increased quite dramatically over time. We also show that both high school and college education help to decrease the gender gap in lifetime earnings, contrary again to the conclusion from wage premium calculations."

Further, it has been well established (and undisputed to this writing) that workers with more years of formal schooling have a lower risk of unemployment and shorter durations of unemployment than workers with more schooling, Mincer [17]. In addition, among the recent evidence, the monograph of Bennett and Wilezol [2] states that the cost of attending a college or university has risen four times the inflation rate since 1990, and by 2016, the cost of attending college will double compared with 2000. Also, the pay to college graduates has fallen by 5% since 2007-2008. One of the reasons, as the authors state, is the government policy of making college loans easily available: The total loan amount has exceeded a trillion dollars to date. Another reason is the increase in the overhead on college campuses. Colleges are overloaded with staff and services that are not directly related to the educational process. In 1976, the ratio staff/faculty was 0.5:1, now it is 1:1. In particular, the median pay for the public-college presidents exceeds $440 thousand, with some of them taking home above $1 million.

In line with these observations is an article [23] stating that from 1980 through 2011 the cost of a university education has risen from 20% to 44% (Table 1) of median household income, and only 57% of students complete the four-year program in six years. In inflation-adjusted terms, the college graduate made the same money in 2007 as in 1979. However, American education, as this article mentions, is not in very bad shape. More than 50% of the top 100 universities and 80% of top 10 are American. They produce most of the scientific papers and Nobel Prize laureates. And college graduates still make more than those without the degree. Source for information in the above paragraphs is [30].

TABLE 1
COST OF UNIVERSITY EDUCATION IN TERMS OF MEDIAN HOUSEHOLD INCOME

Year	Cost of 4- Year Institution	Median Household Income	College Cost, % of Income
(1)	(2)	(3)	(4)
2010–11	22,092	$50,054	44%
2009–10	21,093	$49,277	43%
2008–09	20,409	$49,777	41%
2007–08	19,363	$50,303	38%
2006–07	18,471	$50,233	37%
2005–06	17,451	$48,201	36%
2004–05	16,510	$46,326	36%
2003–04	15,505	$44,334	35%
2002–03	14,439	$43,318	33%
2001–02	13,639	$42,409	32%
2000–01	12,922	$42,228	31%
1990–91	7,602	$30,126	25%
1980–81	3,499	$17,606	20%

Keeping in mind the partially controversial evidence, we decided to test it using Data Envelopment Analysis (DEA). This allowed us to weigh the labor force productivity, employment rate, and labor force participation against percentage of GDP spent on a college education and time spent in college. We analyze the efficiency of the college

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education from 1980 through 2010. Literature using DEA for college efficiency estimations has been known for a while.See, for example, publications [1], [4]-[5], [11]-[21], [24]-[26]. However, the mainstream use of DEA applications was in ranking colleges or the evaluation of college programs. Contrary to that, this research concerns the labor market perception of college education, and thus adds an additional dimension to this area of study.

The paper is organized as follows. Section II introduces a DEA model used in this research, and Section III presents statistical data, obtained results, and their discussion.

II. Data Envelopment Analysis

In our research, we investigate how college preparation helps to improve the labor market. More specifically, we evaluate how money and time spent on college improve employed labor force productivity, employment rate, and participation. In other words, we indirectly evaluate the opportunity cost of time and money spent on college by computing the efficiency of college education in dynamics. While the positive impact of better education and training in general is beyond doubt for the vast majority of students and demonstrated by numerous studies in the literature, our goal is to find a quantitative measure of their effects. To achieve this goal, we compare the employed labor force productivity and participation, and employment rate to the college-related share of GDP and weighted average time spent in college. To do that, we weigh the first two indicators against the last two using the Data Envelopment Analysis (DEA) as a research tool.

DEA was invented in Charnes et. al. [6] by combining an efficiency ratio of Farrell [10] with a technique of transformation of a linear-fractional programming problem to the linear programming problem suggested in Charnes & Cooper [5]. DEA estimates the relative efficiency of a group of objects referred to as Decision-Making Units (DMUs) that use inputs to produce outputs. DEA combines all the indicators of each object into an efficiency index E scaled to an interval [0,1]. An object is considered efficient if it receives a score equal to 1, and inefficient if it receives a score of less than 1. The DEA efficiency measure is based on the efficiency ratio, [10]:

$$E = \frac{\sum_{i=1}^{s} u_i Y_i}{\sum_{j=1}^{r} v_j X_j} \qquad (1)$$

where $\boldsymbol{u} = (u_1,..., u_s) \geq 0$ and $\boldsymbol{v} = (v_1,..., v_r) \geq 0$ are the weights assigned to outputs and inputs, respectively.

To estimate the weights, the DEA sets up the following series of optimization problems: For each DMU$_k$, $k = 1,..., N$, find vectors $\boldsymbol{u}_k = (u_{k1},..., u_{ks}) \geq 0$ and $\boldsymbol{v}_k = (v_{k1},...,v_{kr}) \geq 0$ that

Maximize

$$E_k = \frac{\sum_{i=1}^{s} u_{ki} Y_{ki}}{\sum_{j=1}^{r} v_{kj} X_{kj}} \qquad (2)$$

subject to

$$\sum_{j=1}^{r} v_{kj} X_{kj} = 1$$

For all DMU$_m$, $m = 1,\ldots,N$ in the group taken with the same weight coefficients $\boldsymbol{u}_k = (u_{k1},..., u_{ks})$ and $\boldsymbol{v}_k = (v_{k1},...,v_{kr})$, $E_m \leq 1$.

Conceptually, DEA ratio model (2) allows each DMU to assign the weight coefficients to each input and output favorably. However, the potential of a given DMU to achieve the maximum efficiency score is bound by the requirement that with the weight coefficients assigned to it, no other DMU in the group receives an efficiency score greater than 1. This indicates that a poorly performing DMU cannot achieve a high efficiency score for itself through a manipulation of the weight coefficients. If this was the case, an object that performs excetionally well would have received an efficiency score greater than 1.

Publication Charnes et al. [6] showed that maximization of the efficiency ratio (2) is equivalent to solving a series of linear programming (LP) problems, one for each DMU in a group:

For each DMU$_k$, $k = 1,..., N$,

Minimize θ

subject to

$$\begin{aligned} &\sum_{m=0}^{N} \lambda_{km} X_{mj} \leq \theta_k X_{kj},\ j = 1,...,r; \\ &\sum_{m=1}^{N} \lambda_{km} Y_{mi} \geq Y_{ki},\ i = 1,...,s; \\ &\lambda_{km} \geq 0,\ m = 1,..., N. \end{aligned} \qquad (3)$$

The LP-algorithm given by the formulas (3) forms a linear combination of DMUs that outperforms the currently selected DMU$_k$ by both inputs and outputs.

Formulas (2) and (3) define ratio and envelope DEA models, respectively. The output minimization (OM) ratio DEA model (2) is dual to the envelope input minimization (IM) DEA model (3) with the weight coefficients u_{kj} and v_{kj} being the multipliers. The efficiency scores provided by both OM and IM models are equal to each other. Both models are of the "constant returns to scale" (CRS) type: the efficiency scores remain the same if one or several indicators change proportionally, or the units of measurement of inputs or outputs change, see publications [6] and [27] for detail.

In the envelope model (3), at the point of minimum, only those λ_{km} are non- zero that correspond to the efficient DMUm, $m = 1, \ldots,N$; not necessarily all of them. Some of the weight coefficients u_{kj} and v_{kj} in the ratio DEA model (2) may be zero at the point of maximum. This means that some outputs or inputs are not crucial and may be decreased or increased, respectively, without change in the efficiency scores. Publications [8] and [27] provide details and review of the contemporary DEA.

III. College Education Efficiency Modeling and Analysis

To construct a model of the college education efficiency, we used the employed labor force productivity, employment rate, and labor force participation as outputs, and percentage of GDP spent on a college education and time spent on college preparation, as inputs. Statistical data on the nominal and real GDP were collected from the website of the Bureau of Economic Analysis [28], on the labor force and labor force participation – from the website of the Bureau of Labor Statistics [29]. The employed labor force productivity indicator was calculated as a ratio of the real GDP expressed in chain 2005 dollars to the employed labor force, and the employment rate as a ratio of the employed labor force to the total civilian labor force. Statistical data regarding the share of GDP spent on college education were obtained as a ratio of the expenditures by all postsecondary degree-granting institutions to the nominal GDP. The expenditure component (the numerator) of this ratio was obtained from the website [31] of the National Center for Educational Statistics (NCES). To estimate the duration of college preparation, we used statistics available on the website [31]. It provides two indicators: percentage of the civilian labor force age 25 to 64 having 1 to 3 years of college, and that of workers having 4 years or more. Some additional data were collected from the websites [33] and [34]. We used this information to calculate the weighted average duration of college by taking the mid-value of two years for the first category and five years for the second. Although this approach gives only a rough approximation, a possible error does not affect the efficiency score dramatically because the DEA model used in this research is indifferent to the proportional change in the indicators. By doing so, we received DEA inputs and outputs shown in columns 2- 6 of Table 2 and Figure 1.

Efficiency scores were calculated by using DEA model (3). They are shown in column 7 of Table 2 and in Figure 2. They reveal that the years 1980, 1981, 1998, 1999, 2005, 2006, and 2010 were fully efficient. Some of them served as peer DMUs with non-zero λ-values. By weighing the inputs corresponding to the fully efficient years by the λ-values, we received that 2.52% of GDP spent on a college education and 1.84 years of college study may be considered as optimal for this period.

The efficiencies of other years were in the range of 93.5 %-97.7%. It should be stressed that DEA evaluates relative efficiency only, so that these efficiency scores should be used for comparison purposes only. Since DEA assigns zero weights to some inputs and outputs, the efficiency scores will not change if the values of these indicators change. By counting the non- zero weight coefficients for the college-related inputs, we obtained 29 cases for the percentage ofGDP spent for college education, and 22 cases for the time spent in college. The difference in the numbers of cases is not statistically significant (p-value is 6.9%). However, if confirmed in a broader study, it may be interpreted as a greater value of college spending with regard to the time of college study. In other words, college education would be more efficient if made cheaper than made more intense and less time-consuming.

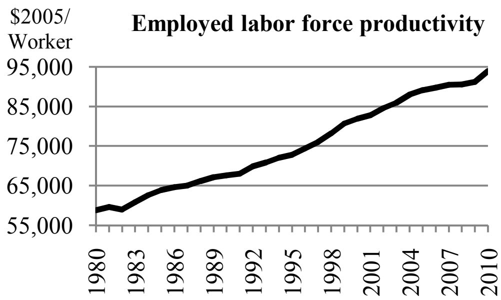
Statistical analysis of the efficiency scores dynamics did not reveal statistically significant trends. The regression coefficient of the efficiency versus time is b = 0.1077, p-value = 67.16%, which is much greater than the standard value of 5%. Based on this observation, we could claim that on average the efficiency of college education remained unchanged

TABLE 2
DEA INPUTS AND OUTPUTS, EFFICIENCY, AND BUSINESS CYCLES

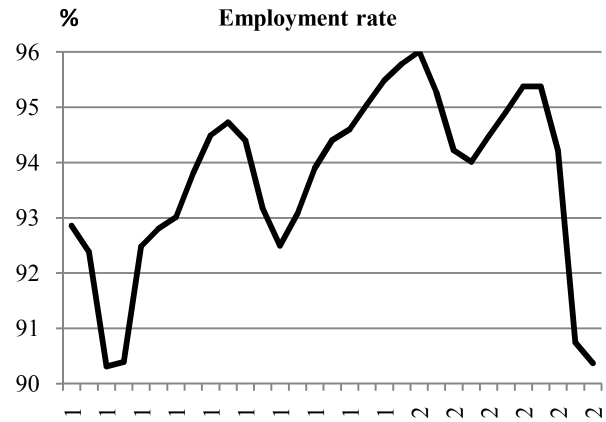
Year	Employe d labor force producti vity, $2005	Emp loy ment rate, %	Labor force particip ation, %	Spen ding on colle ge, % GDP	Year s of colle ge	Effici ency, %	Busine ss **c**ycle[a]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1980	58749	92.9	63.8	2.30	1.45	100.0	*93.0*
1981	59584	92.4	63.9	2.25	1.45	100.0	*100.0*
1982	58938	90.3	64.0	2.33	1.50	96.8	*93.0*
1983	60802	90.4	64.0	2.32	1.57	97.5	93.9
1984	62583	92.5	64.4	2.29	1.60	99.9	94.8
1985	63867	92.8	64.8	2.31	1.63	100.0	95.6
1986	64605	93.0	65.3	2.37	1.63	98.3	96.5
1987	64986	93.8	65.6	2.40	1.66	97.5	97.4
1988	66170	94.5	65.9	2.43	1.68	97.3	98.3
1989	67147	94.7	66.5	2.46	1.72	96.9	99.1
1990	67572	94.4	66.5	2.52	1.73	95.8	*100.0*
1991	68030	93.2	66.2	2.61	1.75	94.6	*93.0*
1992	69878	92.5	66.4	2.61	1.82	94.1	93.7
1993	70815	93.1	66.3	2.60	1.88	93.5	94.4
1994	72023	93.9	66.6	2.58	1.92	94.2	95.1
1995	72746	94.4	66.6	2.57	1.97	94.6	95.8
1996	74390	94.6	66.8	2.55	1.98	96.1	96.5
1997	75996	95.1	67.1	2.51	1.98	98.5	97.2
1998	78157	95.5	67.1	2.49	2.00	100.0	97.9
1999	80687	95.8	67.1	2.53	2.05	100.0	98.6
2000	81937	96.0	67.1	2.61	2.08	99.1	99.3
2001	82796	95.3	66.8	2.73	2.10	97.4	*100.0*
2002	84574	94.2	66.6	2.85	2.13	96.7	*93.0*
2003	85935	94.0	66.2	2.84	2.15	97.4	94.4
2004	87948	94.5	66.0	2.83	2.18	98.3	95.8
2005	89064	94.9	66.0	2.80	2.17	100.0	97.2
2006	89724	95.4	66.2	2.81	2.19	100.0	98.6
2007	90426	95.4	66.0	2.91	2.23	98.8	*100.0*
2008	90546	94.2	66.0	3.01	2.28	96.7	96.5
2009	91208	90.7	65.4	3.20	2.27	97.5	*93.0*
2010	93935	90.4	64.7	3.17	2.28	100.0	-
Min	58749	90.3	63.8	2.25	1.45	93.5	
Max	93935	96.0	67.1	3.20	2.28	100.0	
Avrg	75026	93.7	65.9	2.61	1.90	97.7	

[a]The peaks and troughs years are obtained from http://nber.org. Their values are taken as 100% and 93%, respectively, for the correlation calculations and are italicized. Other values are interpolated.

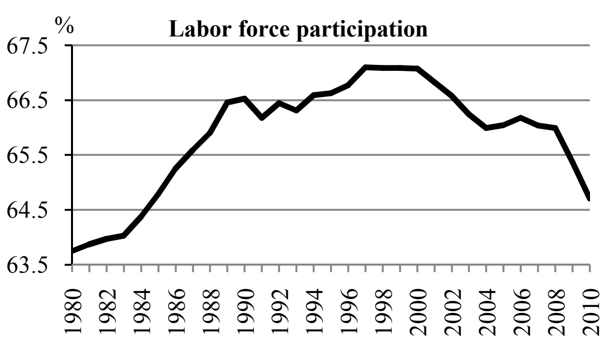
during the period of study. At the same time, there are clearly visible cycles in Figure 2. We assumed that business cycles may be the reason of the cyclicity. To test this hypothesis, we used information of the National Bureau of Economic Research (NBER) available on the website [32]. This website provides data on the peaks and troughs of the business cycles. Since the objective of this research was to investigate the correlation between the business cycles and the cycles of college efficiency scores, the exact numerical values of the peaks or troughs were not of importance. For the



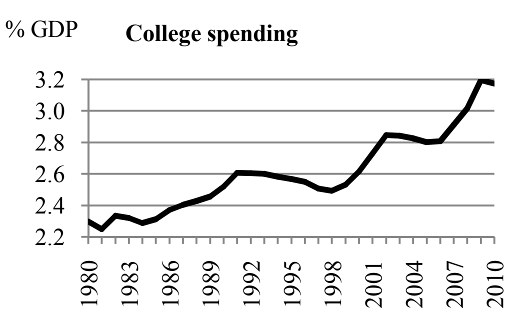
a) Employed labor force productivity, Output – 1



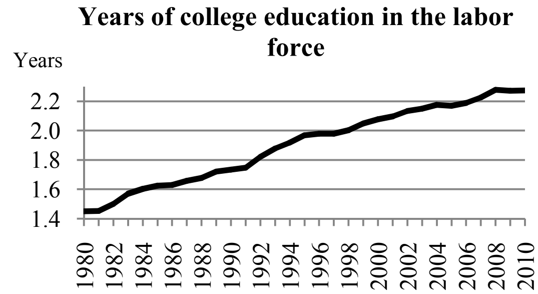
b) Employment rate, Output - 2



c) Labor force participation, Output - 3



d) Spending on college, Input - 1



e) Years of college education, Input – 2

Fig. 1. DEA inputs and outputs in dynamics

convenience of graphical presentation, we assigned 100% to the peaks, and 93% – just below the minimal DEA efficiency score – to the troughs, and connected them by line segments. (Use of any other peak- trough range would not affect the correlation coefficient between the dynamics of efficiency score and peak-trough cycles.) The business cycle's piecewise curve is shown in column 8 of Table 2 and in Figure 2. Statistical analysis revealed that the correlation coefficient (r = 0.4718) is statistically significant at the 1% level (F = 0.0098) and is greatest when the efficiency scores are taken with a lag of one year. This observation suggests that the college- trained part of the labor force is more volatile.

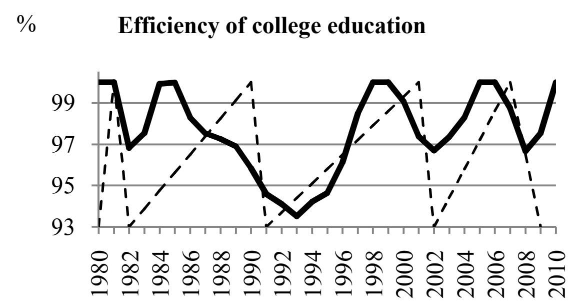


Fig. 2. Efficiency of college education and business cycles
Efficiency scores ——— Business cycles - - - - -

Our results suggest that firms may carry highly skilled workers "in inventory" and use layoffs of highly skilled workers as a less costly measure with regard to the change in the goods inventory. At the same time, the college-educated part of the labor force enjoys the benefits of economic growth even before it actually begins. As Topel [22] argues, "There are important structural differences among industries in short-run employment, hours, and inventory decisions." Using the Topel's ideas, our work suggests that recently firms have found it less expensive to inventory high skilled labor as opposed to goods. This may have been the result of "just in time" goods production with virtually no inventories of goods. Publication [9] partially supports our findings and shows that a similar situation takes place in contemporary China.

IV. Conclusion

The paper investigates to what extent financial resources and time spent on college education are justified by an increase in the productivity, employment, and labor force participation in the United States labor market. We used the DEA efficiency index that weighed the employed labor force productivity, employment rates, and labor force participation against a college- related share of GDP and weighted time spent by the labor force on college study for the period of 1980- 2010. The obtained results revealed that the efficiency index had no statistically significant trend, but correlated with the business cycles with a lag of one year. The latter observation underlines an assumption that the college- trained part of the labor force is more volatile with regard to business cycles. It loses jobs faster at the very beginning of the downward sloping stage of the business cycle and gains quicker when the upward phase of the cycle begins. Parameters of the fully efficient years allowed for the estimates of the optimal values of the share of GDP and the duration of college preparation. Our research paves the way to further discipline-wise analysis with the stress on the STEM-related disciplines.

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