Wyzwania gospodarki globalnej
Prace i Materiały Instytutu Handlu Zagranicznego Uniwersytetu Gdańskiego 2012, nr 31

Challenges of the global economy
Working Papers Institute of International Business University of Gdańsk 2012, no. 31

Dorota Kuder
Justyna Wróblewska
Uniwersytet Ekonomiczny w Krakowie

An influence of changes in the traditional factors of production on economic growth of the United States in the years 1979–2007

The research purpose of the paper is measuring of the influence of the real capital input, the scale of employment and the technical-organizational progress on the dynamics of the United States economic growth in the years 1979–2007. The research hypothesis is the claim that, due to the relatively high population growth and waves of immigration, the scale of employment in the United States is potentially the biggest source of economic growth there. The applied research methods consist in the construction of an econometric model which comprises the impact of expenditure on real capital, the scale of employment and technical development (as defined by J.R. Hicks) on the GDP increase in the United States. The procedure proposed by Engle and Granger will be implemented. Additionally, a simple estimation of the degree of production capacities utilization in the American economy in the years 1997–2007 will be conducted with the application of the formula of the so-called Okun's law.

Wpływ tradycyjnych czynników produkcji na wzrost gospodarczy w Stanach Zjednoczonych w latach 1979–2007

Celem badawczym opracowania jest ocena wpływu nakładów kapitału brutto w cenach stałych, rozmiarów zatrudnienia oraz postępu techniczno-organizacyjnego na dynamikę wzrostu gospodarczego Stanów Zjednoczonych w latach 1979–2007. Hipotezą badawczą jest twierdzenie, że z uwagi na stosunkowo wysoki przyrost naturalny i fale napływu imigrantów, rozmiary zatrudnienia w Stanach Zjednoczonych są potencjalnie największym źródłem wzrostu gospodarczego w tym kraju. Zastosowane metody badawcze obejmują budowę modelu ekonometrycznego, który uwzględnia wpływ wydatków na kapitał rzeczowy i wpływ rozmiarów zatrudnienia oraz postępu technicznego (w ujęciu J.R. Hicksa) na wzrost poziomu PKB Stanów Zjednoczonych. W artykule zastosowano procedurę zaproponowaną przez Engle'a i Grangera. Dodatkowo autorki podejmą próbę oszacowania stopnia wykorzystania zdolności produkcyjnych w gospodarce amerykańskiej w latach 1997–2007, stosując w tym celu formułę zwaną prawem Okuna.

Keywords: economic growth, Cobb-Douglas production function, Okun's law, growth determinants

Introduction

The purpose of the paper is to examine the influence of real capital inputs, the scale of employment and the technical-organizational progress on the economic growth in the United States in the years 1979–2007. The simple Cobb-Douglas production function was implemented to carry out the intended analysis. Bearing in mind the exceptional characteristics of the labour market in this economy (typical employer's market with an increasing volume of labour force), the research hypothesis is the claim that the main source of the economic growth of the United States in the years 1979–2007 was the scale of employment. Such a thesis is justified by extended research of the authors on basic institutional areas of the American economy. For this reason, an additional research task will be to determine the degree of utilization of production capacities in the analyzed economy in the same analyzed period, with the application of a simple method, the so-called Arthur Okun's law. This research will be based on the level of the registered unemployment in the USA in the analyzed period of time. However, it should be pointed out that none of the analyses will take into account the aspect of human capital quality in the American economy.

Taking into account stochastic properties of the analyzed time series, we will apply the Engle-Granger two-step procedure to the estimation of the production function. The benefits of the abovementioned procedure lie in its simplicity and an intuitive character. It should, however, be emphasized that, at present, the most popular procedure is the one proposed by Johansen. The method comprises testing the number of long-term relationships (i.e. cointergrating relations), estimating cointegrating vectors and adjustment coefficients as well as testing hypotheses relating to them. Dynamically developing methods of Bayesian inference are also worth mentioning. The description of multivariate Bayesian models applied in the analysis of cointegrated processes together with their empirical application are presented among others by Koop et al. [2004], Wróblewska [2010].

1. Methodological assumptions and characteristics of a simple neoclassical production function

The neoclassical macroeconomic production function may be defined as a certain function F which describes dependencies taking place between the inputs of the factors of production, which traditionally include inputs of real capital K and labour L, and the amount of the product Y generated in an economy [Tokarski 2009, p. 13]. It may be written as the formula:

$$Y = F(K, L) \quad [1]$$

Although the neoclassical approach to the production function assumes decreasing effects of scale, the authors of this paper consider the possibility, that in the years 1979–2007, in the American economy, there may occur increasing effects of scale. The reasons are as follows. During the mentioned period the natural growth of American population was relatively high and additionally U.S. economy experienced quite high waves of immigration, which also supplied the labour force[1]. Moreover, American labour market can be defined as typical employer's market, what makes it very efficient and flexible.

The presented function satisfies the following assumptions [Barro and Sala-i-Martin 2004, pp. 26–29] and [Tokarski 2009, pp. 13–16]:

1. The domain of D_F production function F is a collection of such inputs K and L that $K \geq 0$ and $L \geq 0$
2. The production function F is at least twice differentiable in D_F^2.
3. For each $(K,L) \in D_F$ the dependency forms:

$$F(K,0) = F(0,L) = 0 \quad [2]$$

This means that to generate any positive magnitude Y both the real capital inputs K and the labour inputs L are necessary. Lack of one of the above mentioned factors of production renders the production process impossible.

4. The production function F satisfies the relation:

$$\forall K, L > 0 \lim_{K \to +\infty} F(K, L) = \lim_{K \to +\infty} F(K, L) = +\infty \quad [3]$$

This assumption may be understood as the following dependency: very large, tending to $+\infty$ the capital inputs K (labour L), given non-zero labour (capital) inputs, correspond to very large, tending to $+\infty$ stream of the manufactured product Y.

5. Assuming that $MPK = \frac{\partial Y}{\partial K} = \frac{\partial F}{\partial K}$ and $MPL = \frac{\partial Y}{\partial L} = \frac{\partial F}{\partial L}$ signify respectively marginal product of capital (MPK) and marginal product of labour (MPL), for each K>0 and L>0 the relations form:

$$MPK > 0 \quad [4a]$$

and

$$MPL > 0 \quad [4b]$$

These dependencies mean that for each positive combination of capital and labour inputs there are corresponding positive marginal products of these factors of pro-

[1] The U.S. GDP underestimates the gray market, resulting from the illegal work of immigrants.

duction. This means that if capital K (labour L) inputs increase, given constant labour (capital) inputs, the production scale Y also increases.

6. K.-I. Inada conditions are satisfied. They are described by the formulas:

$$\forall L>0 \lim_{K\to 0^+} MPK = +\infty \tag{5a}$$

$$\forall L>0 \lim_{K\to +\infty} MPK = 0 \tag{5b}$$

$$\forall K>0 \lim_{L\to 0^+} MPL = +\infty \tag{5c}$$

$$\forall K>0 \lim_{L\to +\infty} MPL = 0 \tag{5d}$$

The above conditions lead to the conclusion that very small (very large) capital inputs K, given positive labour inputs L, correspond to very large (very small) marginal product of capital (MPK). Moreover, for the reason that $MPK = \frac{\partial Y}{\partial K} = \frac{\partial F}{\partial K}$, given very small (very large) capital inputs and constant labour inputs, the slope of the curve product-capital input tends to infinity (to zero).

In turn, very small (very large) labour inputs L, given positive capital inputs K, correspond to very large (very small) marginal product of labour (MPL). What is more, for the reason that $MPL = \frac{\partial Y}{\partial L} = \frac{\partial F}{\partial L}$, given very small (very large) labour inputs and constant capital inputs, the slope of the curve product-labour input tends to infinity (to zero).

7. The following dependencies occur:

$$\forall K, L>0 \frac{\partial MPK}{\partial K} = \frac{\partial^2 Y}{\partial K^2} < 0 \tag{6a}$$

and

$$\forall K, L>0 \frac{\partial MPL}{\partial L} = \frac{\partial^2 Y}{\partial L^2} < 0 \tag{6b}$$

These relations lead to the conclusion that an increase in capital (labour) inputs, given constant inputs of the other factor of production, is accompanied by a decrease in marginal product of capital (labour). Additionally, the curve product-capital inputs (product-labour inputs), given constant labour (capital) inputs, is concave.

The production function is consistent with the law of diminishing marginal productivity, both with respect to real capital inputs K and labour inputs L. This means that if capital (labour) inputs increase, given constant labour (capital) inputs, the scale of production increases slower and slower, and the marginal product of capital (marginal product of labour) decreases.

8. For each K ≥ 0 and L ≥ 0 the production function:
   may be homogeneous of arbitrary degree Ω>0. As a result, for each ξ ≥ 0 the relation occurs:

$$F(\xi K, \xi L) = \xi^{\Omega} F(K, L) \qquad [7]$$

In the case when the degree of homogeneouity Ω is larger (smaller) than a unit, the production function is characterized by increasing (decreasing) efffects of scale. This means that with the degree of homogeneouity Ω >1 (Ω< 1) an ξ-tuple increase in factors of production inputs, given ξ > 1, leads to more (less) than ξ-tuple increase in the stream of product generated in an economy. This results from the fact that when Ω > 1 and ξ > 1, the relation occurs:

$$F(\xi K, \xi L) = \xi^{\Omega} F(K, L) = \xi^{\Omega} Y > \xi Y$$

whereas when Ω < 1 and ξ > 1, the relation occurs:

$$F(\xi K, \xi L) = \xi^{\Omega} F(K, L) = \xi^{\Omega} Y > \xi Y$$

The Cobb-Douglas[2] production function may constitute a particular example of macroeconomic neoclassical production function. It may be described by the formula (Tokarski 2009, pp. 17–20):

$$\forall K, L \geq 0 \; Y = F(K, L) = AK^{\beta_1} L^{\beta_2} \qquad [8]$$

where:
A – total factor productivity,
β_1 and β_2 – elasticity of product Y with respect to real capital K and labour L inputs, which means that the function [8] is homogeneous (with respect to K and L) of degree $\Omega = \beta_1 + \beta_2$, that is with Ω<1 (Ω >1) the function will be characterized by decreasing (increasing) effects of scale, whereas with Ω = 1, that is when $\beta_2 = 1 - \beta_1$ permanent effects of scale of the production process[3] will appear.

Apart from the concept of total factor productivity, which measures the level of economy technological development, one should also define the concept of technical progress. T. Tokarski treats this category as a dynamic process as a result of which the same input of factors of production (capital K and labour L) may lead to

[2] Paul H. Douglas and Charles W. Cobb together consulted the production function in 1927 as a mathematical equation which was to correspond to empirical relations between production, employment and real capital in the American economy [Douglas 1948]. It is an extremely important fact that P.H. Douglas in 1972 admitted that the function form of the equation had first been discovered by Philip Wicksteed, who never lived to receive any recognition on this account [Barro and Sala-i-Martin, 2004, p. 29].

[3] For more detail see also: [Tokarski, 2005, pp. 41–60), and the area of models in conditions of increasing effects of scale in [Tokarski, 2005, pp. 137–154; Tokarski 2009, pp. 269–299]. [Tokarski 2008] is a work totally devoted to this problem.

the production of a larger and larger stream Y, or the same product stream may be generated with smaller and smaller inputs of capital and labour [2009, p. 27]. Taking into consideration the technical progress, the production function takes the following form:

$$\forall t \in [0,+\infty) Y(t) = F(\Lambda(t), K(t), L(t)] \qquad [9]$$

where:

K and L are defined as before,

$\Lambda > 0$ – resource of scientific-technical knowledge available in an economy; the resource does not have to be understood as total factor productivity A in the Cobb-Douglas function. Function [9] satisfies all requirements (with respect to K and L) imposed on the production function [1] and $\frac{\partial \Phi}{\partial \Lambda} > 0$, which means that if the resource of available knowledge Λ increases, given the *ceteris paribus* assumption, also the amount of the generated product Y increases.

Since in the literature on the subject, there are a number of kinds of technical progress, for example technical progress as defined by J.R. Hicks, R.M. Solow and R.F. Harrod, the first definition was assumed for the purpose of this work. The technical progress as defined by Hicks as technical progress in which real capital and labour productivity are enhanced in the same degree. This means that an increase in knowledge resource Λ is such that it does not change the marginal rate of substitution $mrs \equiv -\frac{MPK}{MPL}$ between inputs of factors of production. Therefore, the production function with the technical progress as defined by Hicks may be written according to the formula:

$$\forall t \in [0,+\infty)\ Y(t) = \Phi(\Lambda(t), \mathrm{K}(t), L(t)) = \Lambda(t) \cdot F(\mathrm{K}(t), L(t)] \qquad [10]$$

where the function F (K, L) is described by the equation (1).

Moving again to the Cobb-Douglas function, with the presence of production effects of scale and with technical progress as defined by Hicks, the function may be described by the following formula:

$$Y = \Phi(\Lambda. K. L) = \Lambda F(K, L) = \Lambda K^{\beta_1} K^{\beta_2} \qquad [11]$$

The above definition of the Cobb-Douglas function [11] will be analyzed in a further part of the article.

2. An empirical analysis of the factors of economic growth in the United States

Econometricians agree that data characterized by a trend frequently present a serious problem for a researcher[4]. An inappropriate analysis of trends, both deterministic and stochastic, may lead to spurious regressions, not interpreted values of t-Student statistics or other statistics, measures of goodness of fit assuming 'too high' values, and generally, make it more difficult to assess the obtained regression results [Charemza, Deadman, 1997, p. 122].

It is noteworthy that a considerable part of economic time series is a realization of covariance non-stationary processes [Maddala, 2006, p. 299], which is manifested by e.g. changeability of average level of the observed path of an analyzed time series. In the analyses of macroeconomic data, particular importance is attributed to processes integrated of order 1, I(1), i.e. the ones whose first differences are stationary processes since most of the observed macroeconomic time series may be considered their realization. Searching for an appropriate method of modelling such time series led to the origin of the cointegration idea. Processes are cointegrated if there exists their non-zero linear combination, which is a stationary process.

Bearing in mind the above mentioned properties of macroeconomic series, an analysis of the production function for the US economy (1979–2007) will be preceded by an analysis of stochastic properties of the applied series, and afterwards, if they appear to be a realization of I(1) processes, the procedure proposed by Engle and Granger will be implemented, which will allow their adequate analysis. It consists in an estimation of a long-term relation, and then a presentation of a deviation from the long-term path, accordingly delayed, as a mechanism of error correction in a short-term equation [Charemza, Deadman, 1997, pp. 133]. More precisely, at first, the parameters of the cointegrating vector are estimated by the ordinary least squares method (OLS) and a test of OLS residuals stationarity should be performed. Next, if the results of the performed test permit to consider the residuals a realization of a covariance stationary process, the error-correction model should be estimated, replacing the cointegrating vector by its estimate obtained in the first step.

The Dickey-Fuller test (DF) and the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS) will be applied to investigate stochastic properties of the analyzed series. In the Dickey-Fuller test (DF), the set of hypotheses is checked

$$H_0: \rho = 0, H_1: \rho < 0$$

[4] See also: [Greene, 2000; Maddala 2006; Charemza, Deadman, 1997].

in the model:

$$\Delta x_1 = \rho x_{t-1} + \varepsilon_t, \varepsilon_t \sim iid(0, \sigma^2),\ t = 1,2,\ldots T \qquad [12]$$

where:

x_t – an analyzed one-dimensional stochastic process.

Therefore, the null hypothesis corresponds to the presence of a unit root, and an alternative – to covariance stationarity of the process x_t. In order to verify the null hypothesis, one will apply the quotient of the estimated value of ρ obtained by the ordinary least squares method (OLS) and its OLS standard error, i.e.:

$$DF = \frac{\hat{\rho}}{D(\hat{\rho})} \qquad [13]$$

where:

$$\hat{\rho} = \frac{\sum_{t=1}^{T} \Delta x_t x_{t-1}}{\sum_{t=1}^{T} x_{t-1}^{\ 2}} \text{ and}$$

$$D(\hat{\rho}) = \sqrt{\frac{\frac{1}{T-1}\sum_{t=1}^{T}(\Delta x_t - \hat{\rho} x_{t-1})^2}{\sum_{t=1}^{T} x_{t-1}^{\ 2}}}.$$

Testing the above mentioned set of hypotheses one cannot rely on critical values for the *t* test performed in the classical linear regression model because, given the null hypothesis is true, the test statistic does not have the Student distribution. The tables of critical values for the DF test were given by Dickey and Fuller[5]. If the test statistics is lower than DF_α, where DF_α stands for α-quantile of the Dickey and Fuller distribution, we reject the null hypothesis, and so the process x_t is covariance stationary. Otherwise, the rejection of the null hypothesis is ungrounded, the process x_t is more of the random walk type (is I(1)). Extending the equation [7] by deterministic components (such as a constant or a linear trend) the DF test may be applied to test stationarity of deviations from the mean or the deterministic trend.

In the DF test, the null hypothesis corresponds to the presence of a unit root, so the data must speak strongly against the stochastic trend in order to reject the hypothesis. The DF test has little power, and as a result the hypothesis of stationarity may be rejected too rarely. Therefore, it is recommended to perform the non-stationarity test in a parallel manner to the test in which the null hypothesis will correspond to (trend) stationarity, e.g. the KPSS test, which is performed on the basis of the following representation:

[5] See also statistical tables in: [Greene, 2000].

$$
\begin{aligned}
x_t &= \mu + \beta t + r_t + u_t \\
r_t &= r_{t-1} + v_t \\
r_0 &= 0
\end{aligned}
\qquad [14]
$$

where:
$v_t \sim iid(0, \sigma_v^2)$.

The series y_t is therefore presented as a sum of the deterministic trend ($\mu + \beta t$), random walk (r_t) and stationary random disturbances (u_t, $E(u_t) = 0$). Testing trend-stationarity is equal to testing the hypothesis H_0:$\sigma_v^2 = 0$. Assuming that $\beta = 0$ the hypothesis of level stationarity may be tested.

The above presented methods will be applied to the analysis of the following processes:

Y – value of gross domestic product,
K – real capital inputs,
L – scale of employment.

Table 1. Results of performed Dickey-Fuller (DF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests

Variable	DF with linear trend		KPSS with linear trend	
	value of test statistic	conclusion	value of test statistic	conclusion
y = ln(Y)	-2.866	I(1)	0.060	Trendstationary process
k = ln(K)	-0.722	I(1)	0.343	I(1)
l = ln(L)	-1.613	I(1)	0.186	I(1)

Source: Own calculations using programmes: "gretl" and "Excel".

The assumed significance level is $\alpha = 0.05$, the critical set for the test DF is the range: (-∞; -3.55), and the critical set for the KPSS test is the range: (0.146; +∞). The results of the performed tests indicate that the analyzed series (logarithms of original data) should be considered a realization of non-stationary processes. Indeed the result is not straightforward in the case of the GDP series. However, taking into account the fact that in a further part of the work this will be a dependent variable and other processes are I(1), one should continue to expect cointegration between the examined processes.

In the next step, applying OLS, we estimate the following regression (the dynamized Cobb-Douglas production function based on the formula [11]:

$$Y_t = K_t^{\beta_1} L_t^{\beta_2} \exp(\beta_3 + \beta_4 t + \varepsilon_t) \qquad [15]$$

that is:

$$y_t = \beta_1 k_t + \beta_2 l_t + \beta_3 + \beta_4 t + \varepsilon_t \qquad [16]$$

Obtained:

$$\hat{y}_t = 0{,}212 k_t + 1{,}156 l_t + 1{,}223 + 0{,}008t$$

The augmented Dickey-Fuller test (ADF test) was applied to the residuals from the estimated regression.

The empirical value of the test statistic amounts to -3.473, which yields *p*-value equal to approximately 0.2. Taking into consideration little power of the applied test (particularly in the case of estimating relations with a trend) it may be assumed that the residuals process is stationary, and so the obtained relation is a cointegrating relation[6]. The analyzed series are cointegrated. This means that deviations from the long-term path are stationary, and the estimated regression equation is not an spurious regression so its parameters may be interpreted.

Given the *ceteris paribus* assumption:

- if real capital inputs in the US economy in a given year increase by 1%, GDP will increase by around 0.2% as a result;
- if the scale of employment in the US economy in a given year increases by 1%, GDP will increase by around 1.2% as a result;
- from year to year, the technical-organizational progress leads to an increase in the US economy production output of 0.8%.

Interpreting the point estimate leads us to the conclusion that in the case of this analysis it appeared that increasing effects of scale of the production process are present in the United States economy. An increase of 1% in inputs of both factors of production, capital and labour, increases the product stream generated in the economy by more than 1% (more specifically, by approximately 1.4%). This means that the magnitude of the production output increases in time faster than the inputs of factors of production necessary to generate it.

The last stage is estimating the error correction model which displays information about short-term and long-term relationships:

$$\Delta y_t = \alpha_1 ECM_{t-1} + \alpha_2 \Delta k_t + \alpha_3 \Delta l_t + \alpha_4 + v_t \qquad [17]$$

where:

ECM$_{t-1}$ – error correction term, that is a deviation from cointegrating relation delayed by 1 period, in this case by 1 year.

Obtained:

$$\Delta \hat{y}_t = \underset{(0,224)}{-0{,}598}\ E\hat{C}M_{t-1} + \underset{(0,137)}{0{,}289}\ \Delta k_t + \underset{(0,169)}{1{,}304}\ \Delta l_t + \underset{(0,004)}{0{,}003}$$

where $E\hat{C}M_{t-1} = y_{t-1} - \hat{y}_{t-1}$

[6] The conclusion was confirmed in an independent analysis in which Johansen procedure was applied (test results are available upon request).

The OLS standard errors are given in parantheses.

The speed of adjustment towards the long-run equilibrium level is specified by α_1. In this case, at the 0.005 significance level, one may accept the hypothesis stating that it is negative, and so there appears a correction of deviations resulting from shocks originating from outside the analyzed system of variables. Data reach the long-run equilibrium after approximately $\frac{1}{|-0,598|}$ of a year, that is after around 20 months.

3. An analysis of the degree of production capacities utilization in the American economy as related to the dynamics of economic growth

Having analyzed the influence of supply factors of the United States economic growth, one should take into consideration the problem of the production capacity utilization level in the analyzed period of time. This task will be carried out after certain simplifying assumptions[7] have been introduced. Even if the obtained results are only estimated, they will constitute a certain cognitive value.

By applying a simple formula one can determine the relation between the forced unemployment and the real GDP [Okun 1960]. The very popular Okun's law, named after Arthur Okun who first proposed it, states that the percentage ratio of product decreasing to unemployment rate increasing expressed in percentage points is approximately 1:3 [Barro 1997, p. 305]. This law can also be expressed in the following way: for each percentage point of the unemployment rate above the natural unemployment rate, the real GDP is 3% lower than the potential GDP [Hall and Taylor 2004, pp. 146–147].

While calculating the natural rate of unemployment, R. Barro suggests taking into consideration the process of resigning from work as well as the process of taking up work during the year. Therefore, a change in employment may be understood as the number of people who took up work minus the number of people who resigned from work. The natural rate of unemployment (u) is therefore determined by the formula [Barro 1997, pp. 282–285]:

$$u = \frac{\sigma}{\sigma + \varphi} \qquad [18]$$

where:
σ – rate of resigning from work,
φ – rate of taking up work.

[7] Method of estimating the degree of production capacities utilization was taken from the work [Nasiłowski 2004, pp. 26–31].

Taking into account the assumptions made by R. Barro [1997, p. 285] – σ at the level 0.01, whereas φ at the level 0.15, the natural rate of unemployment will amount to 6.2%.

In the year 2000, the official rate of unemployment in the US economy reached the lowest level since the year 1970, namely the value of 4.0%. Numerous economists had expected a long time before that such a low rate would lead to the appearance of uncontrolled inflation, and for this very reason they had recommended to maintain the natural rate of unemployment at the level of around 6%, which would ensure stability in the American economy. Despite the fact that the rate of unemployment reached such a low level, the inflation rate in the year before 1999) reached the level of 2.1%, and in the following years: 2000 – 3.3%, 2001 – 2.7% and 2002 – 1.4% [*Economic Report…*, 2010, table B-43 and B-63].

Determining the level of the natural unemployment rate for a given economy usually leads to many controversies, and is not easy. In September 2006, the US Bureau of Labour Statistics informed that the official rate of unemployment in the United States was at 4.6%. However, Joel Prakken, the chief economic advisor for the US government, estimated the natural unemployment rate for this period at around 5.25% (±0.5 of a percentage point), while Nariman Behravesh, the chief economist and vice president of *Global Insight*, established the natural unemployment rate at a slightly lower level – between 4.5 and 5% [Mandel, 2006].

Assuming that the natural unemployment rate in an economy is accompanied by full employment, the production output for that period of time is described as potential production, and full utilization of factors of production takes place. Each percentage point of real unemployment above the natural unemployment rate multiplied by 3.0 determined the size of the recessionary gap, that is the percentage level of not utilized production capacities. Studying data on levels of the unemployment rate in the US economy in the years 1979-2008 presented in table 2 one may draw the conclusion that, if one was to assume the calculations by R. Barro concerning the natural rate of unemployment at the level of 6.2%, only in the years 1980–1987 and 1991–1993 the forced unemployment was present in the US economy, and in the other analyzed periods the rate of official unemployment was below or at the level of the natural unemployment rate. This could lead to the conclusion that in the majority of years the US economy functioned at full production capacity (even if following Joel Prakken or Nariman Behravesh one assumed the thesis of the natural unemployment rate at the level of approximately 5%). Therefore, the estimates by the US Bureau of Labour Statistics seem most probable. One should remember, however, that the estimated rate changes in time, which limits the usefulness of the Okun's law in the case of long-term analyses. Its usefulness is then practically reduced to speculation.

Table 2. Unemployment rate in the United States in 1979–2008 in percentage terms

Year	Unemploy-ment rate	Year	Unemploy-ment rate	Year	Unemploy-ment rate
1979	5.80	1989	5.30	1999	4.20
1980	7.10	1990	5.60	2000	4.00
1981	7.60	1991	6.80	2001	4.70
1982	9.70	1992	7.50	2002	5.80
1983	9.60	1993	6.90	2003	6.00
1984	7.50	1994	6.10	2004	5.50
1985	7.20	1995	5.60	2005	5.10
1986	7.00	1996	5.40	2006	4.60
1987	6.20	1997	4.90	2007	4.60
1988	5.50	1998	4.50	2008	5.80
1979–1988	7.32	1989–1998	5.86	1999–2008	5.03

Source: Own calculations based on: [*Economic Report…*, 2010, table B-42].

The degree of production capacities utilization in the US economy may also be estimated by comparing income generated in reality with potential income generated at full employment. To simplify, one should assume that full employment means work involvement of all employees in the productive age, where the efficiency of the potentially employed is the same as the efficiency of the employed in reality. If the unemployment rate is calculated in relation to the whole labour resource, the workforce resource is described by the formula:

$$\text{workforce resource} = \frac{\beta}{\gamma} \qquad [19]$$

where:
β – number of the registered unemployed,
γ – official rate of the registered unemployment.

On the basis of the formula [13], it may be established that income generated at full employment will be therefore described by:

$$Y_p = \frac{\beta}{\gamma} \cdot W$$

where:
W – average work efficiency in the whole national economy.

Average work efficiency is described by the formula:

$$W = \frac{Y_f}{Z_f} \quad [20]$$

where:
Y_f – income generated in reality,
Z_f – number of the employed in reality.

The degree of existing production capacities utilization can be determined by the quotient of income generated in reality and income generated at full employment (expressed as an index, that is x100), and all the calculations are presented in table 3.

$$\text{Degree of production capacities utilization } \frac{Y_f}{Y_p} \cdot 100 \quad [21]$$

Table 3. Evaluation of degree of production capacities utilization in the US economy in 1979–2007

Year	GDP in prices from 2005 (in billions USD)	Employment (in thousands of people)	Average work efficiency (in USD)	Registered unemployment (in thousands of people)	Participation of unemployment in workforce resources	Income at full employment	Degree of production capacities utilization (in percentage terms)
1979	5,855.0	98,824	59.2467	6,137	0.0585	6,215.3	94.2
1980	5,839.0	99,303	58.7998	7,637	0.0714	6,289.3	92.8
1981	5,987.2	100,397	59.6352	8,273	0.0761	6,483.1	92.4
1982	5,870.9	99,526	58.9886	10,678	0.0969	6,500.3	90.3
1983	6,136.2	100,834	60.8545	10,717	0.0961	6,786.4	90.4
1984	6,577.1	105,005	62.6361	8,539	0.0752	7,112.4	92.5
1985	6,849.3	107,150	63.9225	8,312	0.0720	7,379.5	92.8
1986	7,086.5	109,597	64.6596	8,237	0.0699	7,619.5	93.0
1987	7,313.3	112,440	65.0418	7,425	0.0619	7,801.9	93.7
1988	7,613.9	114,968	66.2263	6,701	0.0551	8,054.1	94.5
1989	7,885.9	117,342	67.2044	6,528	0.0527	8,324.7	94.7
1990	8,033.9	118,793	67.6294	7,047	0.0560	8,510.4	94.4
1991	8,015.1	117,718	68.0873	8,628	0.0683	82,601.1	93.2
1992	8,287.1	118,492	69.9381	9,613	0.0750	8,964.2	92.4
1993	8,523.4	120,259	70.8754	8,940	0.0069	9,183.0	92.8
1994	8,870.7	123,060	72.0843	7,996	0.0610	9,449.0	93.9
1995	9,093.7	124,900	72.8078	7,404	0.0560	9,626.2	94.5
1996	9,433.9	126,708	74.4539	7,236	0.0540	9,976.8	94.6
1997	9,854.3	129,558	76.0609	6,739	0.0494	10,376.0	95.0

1998	10,283.5	131,463	78.2235	6,210	0.0045	10,794.8	95.3
1999	10,779.8	133,488	80.7548	5,880	0.0042	11,305.7	95.3
2000	11,226.0	136,891	82.0069	5,692	0.0399	11,698.8	96.0
2001	11,347.2	136,933	82.8668	6,801	0.0473	11,914.9	95.2
2002	11,553.0	136,485	84.6467	8,378	0.0578	12,269.4	94.2
2003	11,840.7	137,736	85.9666	8,774	0.0599	12,592.2	94.0
2004	12,263.8	139,252	88.0691	8,149	0.0553	12,977.9	94.5
2005	12,638.4	141,730	89.1724	7,591	0.0508	13,325.0	94.8
2006	12,976.2	144,427	89.8461	7,001	0.0462	13,615.0	95.3
2007	13,254.1	146,047	90.7523	7,078	0.0462	13,903.6	95.3

Source: Own calculations.

The results indicate that the US economy did not reach 100% of its potential production capacities in any of these years. In the years 1982–1983, the unemployment rate reached the level of around 9.6%, which resulted in a reduced degree of the production capacities utilization in the United States – in this period the economy was losing almost 10% of the potential production annually. On the contrary, the most optimistic period from the viewpoint of the actually generated production output in relation to the potential was the turn of the 20th and 21st centuries. From 1998 to 2001, the US economy utilized over 95% of its production capacities (as much as 96% in the year 2000), which was related to a very low level of unemployment and a low rate of the registered unemployment.

Conclusions

Human resources play an important role in the dynamics of the economic growth in the Unites States. Although the analysis did not take into account their quality[8], nevertheless we can see a more than proportionate impact of employment on the GDP level in the US economy. Real capital inputs, understood as gross fixed assets in fixed prices, do not exert such a strong influence on the GDP growth. On the contrary, technical progress in this analysis considered in accordance with the Hicks definition, influences both labour inputs and capital inputs, resulting in an annual GDP increase of approximately 0.8%. Another important conclusion may be drawn – the research established that in the US economy the obtained elasticities confirm increasing effects of scale of the production process.

A simple analysis of the level of the US economy production capacities utilization in the years 1979–2007 demonstrated that in none of the years the American

[8] See also [Growiec, Marć 2009], [Florczak 2008].

economy reached 100% of its potential production capacities, and on average 93.86% of the capacities were utilized in the analyzed period. On the other hand, the level was never lower than 90.3 (in the year 1982). These results are of course closely tied to the registered unemployment rate, which results from the applied methodology.

References

Barro R.J., 1997, *Makroekonomia*, Wydawnictwo Naukowe PWN, Warszawa.
Barro R.J., Sala-i-Martin, 2004, X., *Economic Growth*, Massachusetts Institute of Technology Press, Cambridge, Massachusetts – London, England.
Charemza W.W., Deadman D.F., 1997, *Nowa ekonometria*, Polskie Wydawnictwo Ekonomiczne, Warszawa.
Douglas P.H., 1948, *Are There Laws of Production?*, American Economic Review 1948, March, vol. XXXVIII, pp. 1–41.
Economic Report of the President, Council of Advisers, United States Government Printing Office, Washington D.C. 2010, http://www.gpoaccess.gov/eop/ [dostęp: 20.11.2010].
Florczak W., 2008, *Kapitał ludzki w empirycznych modelach wzrostu*, Ekonomista, no. 2, pp. 169–200.
Greene W.H., 2000, *Econometric Analysis*, Pentice-Hall, Inc., Upper Saddle River, New Jersey.
Growiec J., Marć Ł., 2009, *Produktywność czynników w krajach OECD*, Gospodarka Narodowa, no. 9, pp. 23–47.
Hall R. E., Taylor J. B., 2004, *Makroekonomia*, Wydawnictwo Naukowe PWN, Warszawa.
Johansen S., 1996, *Likelihood-based inference in cointegrated vector auto-regressive models*, Oxford University Press, New York.
Juselius K., 2007, *The Cointegrated VAR Model. Methodology and Applications,* Oxford University Press, New York.
Koop G., Strachan R., van Dijk H., Villiani M., 2004, *Bayesian approaches to cointegration*, [in:] T.C. Mills, K. Patterson (ed.), *Palgrave Handbook of Econometrics*, vol. 1, Econometric Theory (pp. 871–898), Palgrave Macmillan, London UK.
Maddala G., 2006, *Ekonometria*, Wydawnictwo Naukowe PWN, Warszawa.
Mandel M., 2006, http://www.businessweek.com/bwdaily/dnflash/content/oct2006 [dostęp: 1.10.2010].
Nasiłowski J., 2004, *Wzrost gospodarczy i wahania koniunkturalne w gospodarce amerykańskiej w latach 1940–2002*, doctoral dissertation written under scientific supervision of prof. dr hab. Wojciech Pacho, Warszawa.
Okun A. M., 1960, *The Value of Anticipations Data in Forecasting National Product*, [in:] *Bureau of Economic Research*, The Quality and Economic Significance of Anticipations Data 1960, vol. 10, Princeton University Press, pp. 406–460.
Tokarski T., 2005, *Wybrane modele podażowych czynników wzrostu gospodarczego*, Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków.
Tokarski T., 2008, *Efekty skali a wzrost gospodarczy*, Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków.
Tokarski T., 2009, *Matematyczne modele wzrostu gospodarczego. Ujęcie neoklasyczne*, Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków.
Wróblewska J., 2010, *Modele i metody bayesowskiej analizy kointegracji*, Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie, Kraków.

STATISTICAL ANNEX

Calculations for econometric model – calculations were conducted with the application of programme "gretl" and "Excel"

Year	GDP	CAPITAL	EMPLO-YMENT	Y/L	K/L	ln(Y/L)	ln(K/L)	d(ln(Y/L))	d(ln(K/L))	TFP
1979	5,855.00	21,694.43	98.824	59.24674	219.5259	4.081711	5.39147			
1980	5,839.00	22,590.73	99.303	58.79983	227.4929	4.074139	5.427119	-0.00757	0.035649	
1981	5,987.20	22,731.83	100.397	59.63525	226.4194	4.088247	5.422389	0.014108	-0.00473	
1982	5,870.90	22,597.99	99.526	58.98861	227.0562	4.077344	5.425197	-0.0109	0.002808	
1983	6,136.20	22,511.50	100.834	60.85447	223.2531	4.108485	5.408306	0.031141	-0.01689	
1984	6,577.10	22,927.25	105.005	62.63606	218.3444	4.137341	5.386073	0.028856	-0.02223	0.038342
1985	6,849.30	23,512.73	107.150	63.92254	219.4375	4.157672	5.391068	0.020331	0.004994	0.0182
1986	7,086.50	24,557.41	109.597	64.65962	224.0701	4.169137	5.411959	0.011465	0.020891	0.002551
1987	7,313.30	25,326.57	112.440	65.0418	225.2452	4.17503	5.41719	0.005893	0.00523	0.003662
1988	7,613.90	26,054.22	114.968	66.22625	226.6215	4.193077	5.423281	0.018047	0.006092	0.015448
1989	7,885.90	26,583.47	117.342	67.20441	226.547	4.207739	5.422952	0.014662	-0.00033	0.014802
1990	8,033.90	26,850.04	118.793	67.62941	226.0238	4.214043	5.42064	0.006304	-0.00231	0.00729
1991	8,015.10	26,626.40	117.718	68.08729	226.188	4.220791	5.421367	0.006748	0.000726	0.006438
1992	8,287.10	27,084.13	118.492	69.93805	228.5735	4.24761	5.431858	0.026819	0.010491	0.022343
1993	8,523.40	27,856.03	120.259	70.87536	231.6336	4.260923	5.445157	0.013313	0.013299	0.007639
1994	8,870.70	28,902.24	123.060	72.08435	234.863	4.277837	5.459002	0.016914	0.013846	0.011007
1995	9,093.70	29,686.76	124.900	72.80785	237.6843	4.287824	5.470943	0.009987	0.011941	0.004892
1996	9,433.90	30,519.69	126.708	74.45386	240.8663	4.31018	5.484242	0.022356	0.013299	0.016682

Year	GDP	CAPITAL	EMPLO-YMENT	Y/L	K/L	ln(Y/L)	ln(K/L)	d(ln(Y/L))	d(ln(K/L))	TFP
1997	9,854.30	31,528.35	129.558	76.06091	243.3532	4.331535	5.494514	0.021355	0.010272	0.016972
1998	10,283.50	32,896.00	131.463	78.22353	250.2301	4.359571	5.522381	0.028036	0.027867	0.016146
1999	10,779.80	34,495.21	133.488	80.75482	258.4143	4.391418	5.554564	0.031847	0.032183	0.018116
2000	11,226.00	36,040.48	136.891	82.00685	263.2786	4.406803	5.573213	0.015385	0.018649	0.007428
2001	11,347.20	37,311.75	136.933	82.8668	272.4818	4.417235	5.607572	0.010432	0.034359	-0.00423
2002	11,553.00	38,542.63	136.485	84.64666	282.3946	4.438486	5.643305	0.021251	0.035734	0.006005
2003	11,840.70	39,773.01	137.736	85.96663	288.7626	4.453959	5.665605	0.015474	0.022299	0.005959
2004	12,263.80	42,437.84	139.252	88.06911	304.7557	4.478122	5.719511	0.024163	0.053906	0.001163
2005	12,638.40	44,933.00	141.730	89.17237	317.0324	4.490571	5.759004	0.012449	0.039493	-0.0044
2006	12,976.20	46,861.71	144.427	89.84608	324.4664	4.498098	5.782182	0.007527	0.023178	-0.00236
2007	13,254.10	47,564.35	146.047	90.75229	325.6784	4.508134	5.78591	0.010036	0.003728	0.008445

Calculations applied while estimating model with error correction mechanism ECM

Period	Increments ln(GDP)	Delayed deviations	ln(K) increments	ln(L) increments
1979–1980	-0.002736	0.02019	0.040484	0.004835
1980–1981	0.025064	-0.005121	0.006227	0.010957
1981–1982	-0.019616	-0.002452	-0.00591	-0.008713
1982–1983	0.044198	-0.01916	-0.00383	0.013057
1983–1984	0.069388	0.002345	0.0183	0.040532
1984–1985	0.040553	0.0126	0.025216	0.020222
1985–1986	0.034045	0.01602	0.043472	0.02258
1986–1987	0.031503	0.00635	0.03084	0.02561
1987–1988	0.040281	-0.006692	0.028326	0.022234
1988–1989	0.035101	-0.006521	0.02011	0.020439
1989–1990	0.018594	-0.007716	0.009978	0.01229
1990–1991	-0.002343	-0.01385	-0.00836	-0.009091
1991–1992	0.033373	-0.01233	0.017045	0.006554
1992–1993	0.028115	0.001442	0.028101	0.014802
1993–1994	0.039938	-0.001916	0.03687	0.023024
1994–1995	0.024828	-0.004811	0.026782	0.014841
1995–1996	0.036728	-0.01122	0.027671	0.014372
1996–1997	0.043598	-0.00538	0.032515	0.022243
1997–1998	0.042633	-0.00279	0.042464	0.014597
1998–1999	0.047133	0.005565	0.047469	0.015286
1999–2000	0.040559	0.01656	0.043822	0.025173
2000–2001	0.010739	0.01033	0.034666	0.000307
2001–2002	0.017974	0.00496	0.032457	-0.003277
2002–2003	0.024598	0.01143	0.031424	0.009124
2003–2004	0.035109	0.01042	0.064852	0.010946
2004–2005	0.030088	0.01073	0.057132	0.017639
2005–2006	0.026377	-8.70E-05	0.042029	0.01885
2006–2007	0.02119	-0.01281	0.014883	0.011154

SUMMARY – EXIT

Regression statistics	
Multiple R	0.882162
R squared	0.77821
Matching R squared	0.750486
Standard error	0.008772
Observations	28

Regression statistics	
Multiple R	0.882162
R squared	0.77821
Matching R squared	0.750486
Standard error	0.008772
Observations	28

ANALYSIS OF VARIANCES

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	0.0064799	0.00216	28.07013	5.09E-08
Residual	24	0.001846774	7.69E-05		
Total	27	0.008326674			

	Coefficients	*Standard error*	*t Stat*	*Value-p*	*Low 95%*	*High 95%*
Intersection	0.003221	0.004056621	0.794016	0.434967	-0.00515	0.011593
Delayed deviations	-0.59802	0.223642604	-2.67398	0.013274	-1.05959	-0.13644
ln(K) increments	0.289298	0.136977472	2.112011	0.045283	0.00659	0.572006
ln(L) increments	1.304021	0.169017694	7.715294	5.96E-08	0.955186	1.652857

RESIDUAL COMPONENTS – EXIT

Obser-vation	*Expected increments ln(GDP)*	*Residual components*
1	0.009164	-0.011900827
2	0.022372	0.00269194
3	-0.00838	-0.01123244
4	0.030596	0.013601914
5	0.059968	0.009420424

6	0.029351	0.011201999
7	0.035662	-0.001617159
8	0.041741	-0.010238244
9	0.044411	-0.004130291
10	0.039591	-0.004490437
11	0.026748	-0.00815417
12	-0.00277	0.000427614
13	0.024071	0.009301353
14	0.029791	-0.001675625
15	0.045057	-0.005118953
16	0.0332	-0.008371385
17	0.036677	5.07273E-05
18	0.044851	-0.001252516
19	0.036209	0.006424055
20	0.033559	0.013574074
21	0.038822	0.001736275
22	0.007472	0.003266251
23	0.005371	0.012602942
24	0.017374	0.007223117
25	0.030026	0.005083455
26	0.036334	-0.006245633
27	0.040013	-0.013635957
28	0.029733	-0.008542503

ENGLE – GRANGER PROCEDURE
Step 1: unit root testing for variable l_GDP
Dickey-Fuller Test for process l_ GDP
sample size 28
Null hypothesis: presence of a unit root a = 1; process I(1)
with absolute term and linear trend
model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
Autocorrelation of first-degree residues: 0.328
estimated value (a-1) amounts to: -0.41934
Test statistic: tau_ct(1) = -2.866
value p 0.1877
Step 2: unit root testing for variable l_CAPITA
Dickey-Fuller Test for process l_CAPITA
sample size 28
Null hypothesis: presence of a unit root a = 1; process I(1)
with absolute term and linear trend

model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
Autocorrelation of first-degree residues: 0.396
estimated value (a-1) amounts to: -0.0445817
Test statistic: tau_ct(1) = -0.722075
value p 0.9613
Step 3: unit root testing for variable l_EMPLOY
Dickey-Fuller Test for process l_ EMPLOY
sample size 28
Null hypothesis: presence of a unit root a = 1; process I(1)
with absolute term and linear trend
model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
Autocorrelation of first-degree residues: 0.369
estimated value (a-1) amounts to: -0.203186
Test statistic: tau_ct(1) = -1.61285
value p 0.7619
Step 4: cointegrating equation
Cointegrating equation -
Estimation KMNK with application of 29 observations 1979–2007
Dependent variable: l_GDP

	coefficient	standard error	of t-Student	value p	
const	1.22289	0.920476	1.329	0.1960	
l_CAPITA	0.211792	0.0461912	4.585	0.0001	***
l_EMPLOY	1.15577	0.141737	8.154	1.66e-08	***
time	0.00841392	0.00282285	2.981	0.0063	***

arithmetic mean of dependent variable	9.072106	Standard deviation of dependent variable	0.266372
residual sum of squares	0.003164	Standard error of residues	0.011251
Coefficient of determination R-squared	0.998407	Corrected R-squared	0.998216
Logarithm of credibility	91.13547	Akaike information criterion	-174.271
Schwarz Bayesian Criterion	-168.8018	Hannan-Quinn criterion	-172.558
Autocorrelation of residues – rho1	0,510816	Durbin-Watson statistic	0.851286

Step 5: unit root testing for variable uhat
Augmented Dickey-Fuller Test for process uhat
for 2-degree delay of process (1-L)uhat
sample size 26
Null hypothesis: presence of a unit root a = 1; process I(1)
model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
Autocorrelation of first-degree residues: 0.151
delayed differences: F(2, 23) = 3.325 [0.0539]
estimated value (a-1) amounts to: -0.69773
Test statistic: tau_ct(3) = -3.47256
Asymptotic value p = 0.2092
Cointegration takes place if every applied process is I(1), i.e. the null hypothesis of a unit root is not rejected and residual process (uhat) from cointegrating equation is not integrated I(0), i.e. the null hypothesis of a unit root is rejected.