LABOR-CAPITAL RELATIONS IN THE CONSTRUCTION SECTOR IN POLAND

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Abstract. The aim of this paper is to estimate the Cobb-Douglas production function and the CES (constant elasticity of substitution) function for the construction sector in Poland. The period since 2002 is analyzed. Moreover, the Solow decomposition of the economic growth is estimated. Most of the models are linearized in order to apply the ordinary least squares for linear regression models. The CES function is estimated both with a help of Kmenta approximation and the nonlinear least squares (NLS) using a variant of the Levenberg–Marquardt algorithm. In a short literature review some recent findings for Polish economy are briefly reminded in the context of the current research. Finally, it is concluded that the technological progress (both in the national economy and in the construction sector) is approximately 3%. The Cobb-Douglas function is preferred over the CES function, both in the national economy and in the construction sector. Elasticities of the labor are greater than elasticities of the capital.

Key words: capital, Cobb-Douglas function, employment, structural changes, total factor productivity.

1. Introduction

Poland is an example of the post-communist economy, which transited into a well-working capitalist system. Although, in 1990s – due to transition processes, privatization and closing of unprofitable factories – high unemployment emerged in certain regions of the country (see, for example, Newell, 2006), afterwords the economy developed in a very dynamic way.

Poland accessed the European Union in 2004. Except a high dynamic of the economic development, many (especially young and qualified) people emigrated to more developed countries of the so-called "old" EU countries.

However, Polish cities noticed many new investments. Highways were build linking various cities, roads were repaired and the mobility of the labor force increased very much. Not only the physical development played its significant role, but also social and cultural changes were important.

In 2000s many significant changes in the education system were made, resulting in a great demand for the university education amongst young people. Also, cities itself become sources of new workplaces and opportunities to make a career and find a well-paid job.

The average prices on the housing market increased between 2006 and 2013 by almost 26%. However, in the same period these prices increased by more than 65% in 10 biggest cities of Poland. In the most dynamically developing cities the prices increased even by 80% - just between 2005 and 2006. For a review see, for example, Augustyniak et al. (2012), Drachal (2014), Drachal (2013) and references therein.

Such changes must have had some impact on GDP (gross domestic product) and productivity (Bratsberg and Raaum, 2012; Zheng, Chau and Hui, 2012). However, it seems that the classical analysis with a help of Cobb-Douglas function has not been done yet. Actually, there is a work of Tomaszewicz and Świerczewska (2008) covering various sectors of economy, but it contains the sample from the period between 1993 and 2005 only. There is also the analysis by Tokarski (2007), in which it is stated that regions of Poland with a high ratio of value added in construction have also a lower level of TFP (total factor productivity). Tokarski's analysis is based on a sample between 1995 and 2007. Some partial analysis of the construction sector for Poland was also done by Kalinowski (2002).

The aim of this paper is to estimate the Cobb-Douglas and the CES (constant elasticity of substitution) functions for Poland, both in general (to have a comparison) and for the construction sector only. Moreover, the Solow decomposition is estimated and discussed. The period after 2002 is analyzed.

2. Literature review

The Cobb-Douglas production function is a well-known tool in the economic analysis. It is usually used to estimate the potential GDP and TFP. For some interesting modifications see, for example, the discussion by Jerzmanowski (2007). An interesting discussion is also presented, for example, by Growiec (2008), Welfe (2011) and Welfe (2013).

Unfortunately, in the case of Poland the Cobb-Douglas function approach is able to explain only 10-30% of the potential GDP increase between 1966 and 1998 (Welfe, 2002).

The review of TFP for various developing countries was presented by Saliola and Seker (2011). Denis, McMorrow and Roeger (2002) analyzed EU countries before 2002. The manufacturing sector of EU countries was analyzed by Fioramanti (2010). Some interesting discussion in the context of the East European transition economies was presented by Funke and Ruhwedel (2005). The recent overview of GDP structure of various EU countries was presented, for example, by Vinerean (2013).

However, for example, Hlousek (2007) argued that aspects such as preferences, technology and government policies should be viewed as fundamentals – especially in case of Visegrad states. Also, Hall and Jones (1999) discussed differences in capital accumulation, productivity and output per worker. They found that these factors are driven mainly by differences in institutions and government policies, i.e., the social infrastructure. Such an infrastructure is determined by the historical location and similar factors. As a result, they argued that the Cobb-Douglas approach can be biased.

Indeed, there is also another significant problem. Estimations based on samples containing periods before the transition in Poland suffer from comparability with capitalist economies. If various production functions are considered, then, usually the Cobb-Douglas estimations are found superior over the CES (see, for example, Epstein and Macchiarelli, 2009; Hacker, Johansson and Karlsson, 2004; Kemme, 1984; Roberts, 1994; Bairam, 1987).

In case of Poland, after the EU accession the transfer of technologies is found as a very important factor driving the productivity growth (Kolasa, 2005). Gawrycka, Sobiechowska-Ziegiert and Szymczak (2012) found that the increase in the production between 1991 and 2008 in Poland was mainly the result of the capital growth. However, for the period between 1998 and 2008 it was the technological progress. Similar results, emphasizing the role of the technological progress in Poland, were found by Benkovskis et al. (2013).

Caselli and Tenreyro (2005) discussed four types of a convergence. One of these types is a structural transformation being the result of a reallocation of production factors between different sectors of the economy. Such changes are usually dynamical in periods of accelerated technological and organizational progress. Therefore, it is interesting to analyze the period after EU accession for Poland.

Moreover, Kosztowniak (2013) stated that Foreign Direct Investments played a significant role in economic development in Poland after the transition. Its main influence was by the transfer of new technologies. Kosztowniak (2013) analyzed the period between 1995 and 2012. Some modification of the classical Cobb-Douglas function was used in this research. Gurgul and Lach (2012) analyzed the impact of a technological progress on the economic growth in Poland in 2000s (2012).

Roszkowska (2013) discussed various aspects of the relationship between the human capital and economic growth for Poland in a current perspective. Jabłoński (2005) analyzed the period between 1990 and 2001. It was found in their researches that the most significant factor of the economic growth is the human capital. Indeed, Welfe (2008) presented arguments why "new economies" are mostly based on knowledge and how it implies the significant role of human capital in the context of TFP analysis. General discussion on human capital in the context of growth models is given by, for example, Zhang (2014).

Finally, it should be mentioned that there are some arguments that relative (i.e., construction sector to total economy) TFP can drive house prices. A significant negative contribution of a relative TFP to construction prices was found in the U.K. and Spain. On the other hand, in the United States and Germany this contribution was found positive (Moro and Nuno, 2010). The analyzed sample consisted of the period between 1980 and 2007.

Applicability of various growth models was recently discussed, for example, by Durlauf, Kourtellos and Tan (2008), Leon-Ledesma, McAdam and Willman (2013) and Herrendorf and Valentinyi (2012). Of course, also papers by Mankiw, Romer and Weil (1992) and Fisher (1993) are very important. Definitely, such models are significant for the analysis of the construction sector (Herrendorf, Herrington and Valentinyi, 2013; Nasir et al., 2014; Dolage and Chan, 2013; Ruddock and Ruddock, 2011).

3. Methodology

The Cobb-Douglas production function (Cobb and Douglas, 1928) is a well-known tool in economic analysis (Felipe and Adams, 2005). It is also simple to estimate. However, one should be careful in economic interpretations, because Miller (2008) and Aiyar and Dalgaard (2009) presented a critique that this simplicity can lead to well-looking numerical outcomes, which do not provide interpretations satisfactory from the economic interpretation. Some doubts are also presented by Antras (2004) in case of the United States economy.

Further, the following notation of variables used in the econometric analysis is used. K denotes the gross value of fixed assets in thousands of PLN in 2002 prices. L denotes the number of employed persons in the national economy in thousands. GDP is given in millions of PLN in 2002 prices. The symbol "l_" before a variable means that it is the natural logarithm of the original variable. The symbol "sq_" before a variable means that this variable has been squared. The variables corresponding to the construction sector are marked with the letter "c", in order to differentiate from the data from the whole national economy. The yearly dynamic of K is denoted by gK and the yearly dynamic of Kc is denoted by gKc. Similar notation is used for variables L and Lc. The variable time has value 0 for 2002 year and it enumerates the following years, taking value 11 for 2013 year. The variable KL denotes the ratio K/L. The symbol "^" stands for the exponentiation.

According to the above notation the Cobb-Douglas function can be expressed in the following way

(1) GDP = const * K^a * L^b ,

which can be transformed into the linear equation

(2) l_GDP = l_const + a * l_K + b * l_L.

The last equation is linear and parameters const, a and b can be estimated by the ordinary least squares method.

The linear regression analysis is not always applicable. It is assumed that there is no heteroskedasticity (i.e., the variance is constant), residuals are normally distributed and not autocorrelated. These assumptions can be tested, for example, by White's test, Jarque-Bera test and LM test, respectively. Moreover, the specification of the model can be tested by RESET test (Montgomery, Peck and Geoffrey Vining, 2012; Hill, Griffiths and Lim, 2011).

The Cobb-Douglas function is a special case of the CES function (Solow, 1956). For a review of various growth models see, for example, the book by Barro and Sala-i-Martin (2004). The CES function is given by the following equation

(3) GDP = gamma * [delta * K^(-rho) + (1 – delta) * L^(-rho)]^(-mu / rho) ,

which can be linearized in the following way

(4) l_GDP = l_gamma – (mu / rho) * l_[delta * K^(-rho) + (1 – delta) * L^(-rho)] .

Unfortunately, the last equation is still nonlinear and the ordinary least squares method cannot be applied. One of the possible solutions is to use the Kmenta approximation (Kmenta, 1967; Greene, 2003), i.e., to estimate the following linear equation

(5) l_GDP = l_gamma + mu * delta * l_K + mu * (1 – delta) * l_L – 0.5 * rho * mu * delta * (1 – delta) * sq_l_KL .

If rho is close to 0, then the error in Kmenta approximation is small.

However, parameters of nonlinear equations can also be estimated directly. One of the possible methods is to use the nonlinear least squares (NLS) and the Levenberg-Marquardt algorithm (see, for example, Henningsen and Henningsen, 2011). The estimation of the CES function is non trivial. Various discussions on this topic and the economic interpretation can be found, for example, in papers by Thursby (1980), Hodges (1969), Nelson (1965), Zarembka (1970), Klum, McAdam and Willman (2012), Koesler and Schymura (2012), Temple (2012) and Henningsen and Henningsen (2012).

In the Cobb-Douglas function, i.e.,

GDP = const * K^a * L^b ,

the parameter const is not time dependent. It should be time dependent, if technological progress is assumed. Then, by differentiating (see, for example, Barro and Sala-i-Martin, 2004) the above equation with respect to time, the following equation is obtained

(6) gGDP = gc + a * gK + b * gL ,

where gc can be interpreted as the dynamic of the technological progress, gK – the dynamic of the capital growth, gL – the dynamic of the labor force growth and gGDP as GDP dynamics. Of course, this equation can be estimated by the ordinary least squares method. It is called the Solow decomposition (Arrow et al., 1961).

The discussion of the original Solow growth model can be found, for example, in papers by McQuinn and Whelan (2007), Gundlach (2005), Burda and Severgnini (2014), Carter (2011) and Neuhaus (2006).

Sometimes, the Cobb-Douglas function is also discussed in the following form

(7) GDP = const * e^(g * time) * K^a * L^b .

Then, the parameter g is interpreted as the technological progress in a sense of Hicks (i.e., the one not changing the marginal rate of substitution between capital and labor) and e denotes the base of the natural logarithm. This equation can be linearized in the following way

(8) l_GDP = l_const + g * time + a * l_K + b * l_L

and estimated by the ordinary least squares method.

The yearly data from the period between 2002 and 2013 were obtained from Central Statistical Office of Poland (GUS, 2015). ESA 2010 (European Union, 2013) and PKD 2007 (Dz. U. z 2007 r. Nr 251, poz. 1885) methodologies are applied. The calculations were done in GRETL (2015).

4. Results and their interpretation

If it is not stated otherwise, the 5% p-value is assumed.

Table 1 presents the estimation and the diagnostic of Eq. (2), which corresponds to the Cobb-Douglas function of the national economy given by Eq. (1). All estimated parameters are statistically significant. The R-squared is very high. Assumptions of a regression model are not violated. However, the null hypothesis of an adequacy of the specification of the model can be rejected. The sum of coefficients is greater than 1, which can be interpreted as increasing returns to scale. The elasticity of labor is greater than 1, whereas the elasticity of capital is smaller than 1.

Table 2 presents the estimation and the diagnostic of Eq. (2), which corresponds to the Cobb-Douglas function of the construction sector given by Eq. (1). In the first estimation the const coefficient was statistically not significant. Therefore, it was rejected from the model. The R-squared of the obtained model is very high. All assumptions of a regression model are not violated. Also, the adequacy of the specification of the model cannot be rejected. The sum of coefficients is slightly greater than 1, which can be interpreted as increasing returns to scale. However, these returns are smaller than the average for the national economy. Elasticities are smaller than 1. Both of them in the construction sector are smaller than the ones in the national economy.

Table 3 presents the estimation and the diagnostic of Eq. (8), which corresponds to the Cobb-Douglas function of the national economy given by Eq. (7). In the first estimation not all estimated parameters were statistically significant. As a result, only time and labor remained in the final model. The R-squared is very high. Assumptions of a regression model are not violated. However, the null hypothesis of an adequacy of the specification of the model can be rejected. The sum of coefficients is greater than 1, which can be interpreted as increasing returns to scale. The elasticity of labor is greater than 1. The technical progress is estimated to be approximately 2%. Unfortunately, the lack of variable corresponding to the capital makes the obtained model questionable from the interpretation point of view.

Table 4 presents the estimation and the diagnostic of Eq. (8), which corresponds to the Cobb-Douglas function of the construction sector given by Eq. (7). In the first estimation the capital parameter was statistically not significant. The R-squared of the final model is very high. Assumptions of a regression model are not violated. Also, the hypothesis of an adequacy of the specification of the model cannot be rejected. The sum of coefficients is greater than 1, which can be interpreted as increasing returns to scale. The elasticity of labor is smaller than 1. It is also smaller than in the corresponding model of the national economy. The technical progress is estimated to be approximately 3%. Unfortunately, the lack of variable corresponding to the capital makes the obtained model questionable from the interpretation point of view, as in the previous case.

Table 5 presents the estimation and the diagnostic of the Solow decomposition, given by Eq. (6), for the national economy. In the first estimation the capital parameter was statistically not significant. The R-squared of the final model is small. Assumptions of a regression model are not violated. Also, the hypothesis of an adequacy of the specification of the model cannot be rejected. The sum of coefficients is smaller than 1, which can be interpreted as decreasing returns to scale. The elasticity of labor is smaller than 1. The technical progress is estimated to be approximately 3%. Unfortunately, the lack of variable corresponding to the capital makes the obtained model questionable from the interpretation point of view.

Table 6 presents the estimation and the diagnostic of the Solow decomposition, given by Eq. (6), for the construction sector. In the first estimation the capital parameter and the constant were statistically not significant. The R-squared of the final model is moderately high. Assumptions of a regression model are not violated. Also, the hypothesis of an adequacy of the specification of the model cannot be rejected. The sum of coefficients is smaller than 1, which can be interpreted as decreasing returns to scale. The elasticity of labor is smaller than 1. It is smaller than in the corresponding model of the national economy. The technical progress is estimated to be approximately 3%. Unfortunately, the lack of variable corresponding to the capital makes the obtained model questionable from the interpretation point of view.

Table 7 presents the estimation and the diagnostic of the Kmenta approximation of the CES function of the national economy, given by Eq. (5). The estimated productivity is very small. Parameter rho is approximately -0.0015. The elasticity of substitution is approximately 1.0015. The parameter mu is approximately 1.76, which indicates increasing returns to scale. Therefore, the Cobb-Douglas function should be a good approximation of the CES function in this case. Unfortunately, the estimated parameter delta is greatly over 1, which means that the obtained model is not good for the economic interpretation. For the explicit formulas, see, for example, Henningsen and Henningsen (2011). The R-squared of the estimated model is high. Assumptions of a regression model are not violated. Also, the hypothesis of an adequacy of the specification of the model cannot be rejected.

Table 8 presents the estimation and the diagnostic of the Kmenta approximation of the CES function of the construction sector, given by Eq. (5). Unfortunately, all parameters were statistically not significant in the first estimation. Rejection of the parameter with the highest p-value (i.e., l_Kc) resulted in a model with parameters statistically significant (10% p-value). The estimated productivity is very high, i.e., approximately 3.85. Parameter delta is assumed to be 0, which makes the parameter rho goes to infinity. As a result, the CES function turns to the Leontief function. In other words, there is no substitutability between labor and capital in the construction sector, according to the Kmenta approximation.

Table 9 presents the estimation of the CES function for the national economy by the nonlinear least squares (NLS) method. The CES function is given by Eq. (3). Table 9 presents the estimation of the modified equation, i.e. Eq. (4). The variable K1 is K divided by 1000. Similarly, the variable L1 denotes L divided by 1000. Such divisions were done due to certain numerical problems. The parameter mu is approximately 2.22, which indicates increasing returns to scale. The parameter rho is statistically not significant. In other words it can be assumed to be equal to 0. It means that the CES function reduces to the Cobb-Douglas function.

Table 10 presents the estimation of the CES function for the construction sector by the nonlinear least squares (NLS) method. The CES function is given by Eq. (3). Table 10 presents the estimation of the modified equation, i.e. Eq. (4). The parameter mu is approximately 1.15, which indicates increasing returns to scale. The parameter rho is statistically not significant. In other words it can be assumed to be equal to 0. It means that the CES function reduces to the Cobb-Douglas function.

5. Conclusions

Most of estimated models indicate increasing returns to scale, both for the national economy and the construction sector. However, returns in the construction sector are lower than in the national economy. On the other hand, the estimated technological progress has similar value in the national economy and in the construction sector, i.e., approximately 3%. The detailed values differ between 2.4% and 3.2% depending on the model used. Therefore, it can be concluded that the real value is some value from the between. In comparison to previous researches (cited in the first part of this paper) such values seem probable and reasonable. Elasticities of the labor are greater than elasticities of the capital. As a result, it can be argued that most of the growth is due to the labor, not due to the capital. In one case, even the Leontief function was found. Finally, it seems that the Cobb-Douglas function is the preferred specification over the CES function both in the construction sector and in the national economy.

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Table 1. Estimation and diagnostic of the OLS model. Dependent variable: l_GDP

	Coefficient	Std. Error	t-ratio	p-value	
const	-15.1786	1.63779	-9.2677	<0.00001	***
l_K	0.66869	0.212248	3.1505	0.01173	**
l_L	1.55067	0.532088	2.9143	0.01719	**

Mean dependent var	13.85807	S.D. dependent var	0.155176
Sum squared resid	0.006618	S.E. of regression	0.027117
R-squared	0.975014	Adjusted R-squared	0.969462
F(2, 9)	175.6025	P-value(F)	6.16e-08
Log-likelihood	27.98983	Akaike criterion	-49.97965
Schwarz criterion	-48.52493	Hannan-Quinn	-50.51824
rho	0.280857	Durbin-Watson	0.979910

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 10.5425
with p-value = P(Chi-square(5) > 10.5425) = 0.0612439

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 1.63745
with p-value = 0.440994

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 0.932914
with p-value = P(F(1,8) > 0.932914) = 0.362393

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 7) = 10.6811
with p-value = P(F(2, 7) > 10.6811) = 0.00746883

Table 2. Estimation and diagnostic of the OLS model. Dependent variable: l_GDPc

	Coefficient	Std. Error	t-ratio	p-value	
l_Kc	0.323928	0.0664947	4.8715	0.00065	***
l_Lc	0.831137	0.173851	4.7808	0.00074	***

Mean dependent var	11.14063	S.D. dependent var	0.223449
Sum squared resid	0.021566	S.E. of regression	0.046439
R-squared	0.999986	Adjusted R-squared	0.999984
F(2, 10)	345428.9	P-value(F)	6.35e-25
Log-likelihood	20.90205	Akaike criterion	-37.80410
Schwarz criterion	-36.83428	Hannan-Quinn	-38.16316
rho	0.503041	Durbin-Watson	0.985198

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 3.30193
with p-value = P(Chi-square(5) > 3.30193) = 0.653546

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 0.521285
with p-value = 0.770556

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 2.74639
with p-value = P(F(1,9) > 2.74639) = 0.131853

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 8) = 0.416865
with p-value = P(F(2, 8) > 0.416865) = 0.672641

Table 3. Estimation and diagnostic of the OLS model. Dependent variable: l_GDP

	Coefficient	Std. Error	t-ratio	p-value	
time	0.0240464	0.00178949	13.4376	<0.00001	***
l_L	1.44282	0.00122147	1181.2151	<0.00001	***

Mean dependent var	13.85807	S.D. dependent var	0.155176
Sum squared resid	0.004513	S.E. of regression	0.021244
R-squared	0.999998	Adjusted R-squared	0.999998
F(2, 10)	2553474	P-value(F)	2.88e-29
Log-likelihood	30.28681	Akaike criterion	-56.57362
Schwarz criterion	-55.60380	Hannan-Quinn	-56.93268
rho	0.339576	Durbin-Watson	0.919227

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 9.67768
with p-value = P(Chi-square(5) > 9.67768) = 0.0849004

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 0.85072
with p-value = 0.653535

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 1.05082
with p-value = P(F(1,9) > 1.05082) = 0.332081

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 8) = 25.1876
with p-value = P(F(2, 8) > 25.1876) = 0.000352732

Table 4. Estimation and diagnostic of the OLS model. Dependent variable: l_GDPc

	Coefficient	Std. Error	t-ratio	p-value	
const	5.20913	0.654879	7.9543	0.00002	***
l_Lc	0.872295	0.101666	8.5800	0.00001	***
time	0.0255877	0.00452404	5.6559	0.00031	***

Mean dependent var	11.14063	S.D. dependent var	0.223449
Sum squared resid	0.008883	S.E. of regression	0.031417
R-squared	0.983826	Adjusted R-squared	0.980231
F(2, 9)	273.7195	P-value(F)	8.70e-09
Log-likelihood	26.22367	Akaike criterion	-46.44734
Schwarz criterion	-44.99262	Hannan-Quinn	-46.98593
rho	0.191649	Durbin-Watson	1.581690

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 5.95649
with p-value = P(Chi-square(5) > 5.95649) = 0.310476

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 0.609357
with p-value = 0.73736

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 0.304651
with p-value = P(F(1,8) > 0.304651) = 0.596059

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 7) = 0.204028
with p-value = P(F(2, 7) > 0.204028) = 0.820122

Table 5. Estimation and diagnostic of the OLS model. Dependent variable: gGDP

	Coefficient	Std. Error	t-ratio	p-value	
const	0.0316081	0.00666837	4.7400	0.00106	***
gL	0.875713	0.343222	2.5515	0.03112	**

Mean dependent var	0.040261	S.D. dependent var	0.023715
Sum squared resid	0.003264	S.E. of regression	0.019042
R-squared	0.419726	Adjusted R-squared	0.355251
F(1, 9)	6.509903	P-value(F)	0.031121
Log-likelihood	29.06734	Akaike criterion	-54.13469
Schwarz criterion	-53.33890	Hannan-Quinn	-54.63632
rho	0.077425	Durbin-Watson	1.705988

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 0.14083
with p-value = P(Chi-square(2) > 0.14083) = 0.932007

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 4.08096
with p-value = 0.129966

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 0.0594553
with p-value = P(F(1,8) > 0.0594553) = 0.813496

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 7) = 1.18041
with p-value = P(F(2, 7) > 1.18041) = 0.361614

Table 6. Estimation and diagnostic of the OLS model. Dependent variable: gGDPc

	Coefficient	Std. Error	t-ratio	p-value	
const	0.0282374	0.0122829	2.2989	0.04708	**
gLc	0.744785	0.150376	4.9528	0.00079	***

Mean dependent var	0.042815	S.D. dependent var	0.072423
Sum squared resid	0.014079	S.E. of regression	0.039551
R-squared	0.731588	Adjusted R-squared	0.701764
F(1, 9)	24.53054	P-value(F)	0.000788
Log-likelihood	21.02717	Akaike criterion	-38.05434
Schwarz criterion	-37.25855	Hannan-Quinn	-38.55597
rho	-0.186312	Durbin-Watson	2.341102

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 0.0388568
with p-value = P(Chi-square(2) > 0.0388568) = 0.980759

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 1.42324
with p-value = 0.490848

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 0.30038
with p-value = P(F(1,8) > 0.30038) = 0.5986

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 7) = 0.652857
with p-value = P(F(2, 7) > 0.652857) = 0.549571

Table 7. Estimation and diagnostic of the OLS model. Dependent variable: l_GDP

	Coefficient	Std. Error	t-ratio	p-value	
const	-596.904	122.311	-4.8802	0.00122	***
l_K	99.2252	20.7219	4.7884	0.00138	***
l_L	-97.4567	20.8184	-4.6813	0.00158	***
sq_l_KL	-4.14363	0.871202	-4.7562	0.00143	***

Mean dependent var	13.85807	S.D. dependent var	0.155176
Sum squared resid	0.001729	S.E. of regression	0.014701
R-squared	0.993472	Adjusted R-squared	0.991025
F(3, 8)	405.8541	P-value(F)	4.46e-09
Log-likelihood	36.04342	Akaike criterion	-64.08683
Schwarz criterion	-62.14721	Hannan-Quinn	-64.80495
rho	-0.289578	Durbin-Watson	2.557439

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 9.35511
with p-value = P(Chi-square(8) > 9.35511) = 0.31323

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 2.92143
with p-value = 0.23207

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 0.746575
with p-value = P(F(1,7) > 0.746575) = 0.416185

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 6) = 0.937102
with p-value = P(F(2, 6) > 0.937102) = 0.442419

Table 8. Estimation and diagnostic of the OLS model. Dependent variable: l_GDPc

	Coefficient	Std. Error	t-ratio	p-value	
const	1.34905	0.667262	2.0218	0.07391	*
l_Lc	1.14609	0.111077	10.3179	<0.00001	***
sq_l_KLc	0.0189924	0.00641013	2.9629	0.01589	**

Mean dependent var	11.14063	S.D. dependent var	0.223449
Sum squared resid	0.020481	S.E. of regression	0.047704
R-squared	0.962709	Adjusted R-squared	0.954422
F(2, 9)	116.1731	P-value(F)	3.73e-07
Log-likelihood	21.21172	Akaike criterion	-36.42344
Schwarz criterion	-34.96872	Hannan-Quinn	-36.96203
rho	0.453088	Durbin-Watson	1.084647

White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 3.00996
with p-value = P(Chi-square(5) > 3.00996) = 0.69845

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 1.69812
with p-value = 0.427817

LM test for autocorrelation up to order 1 -
Null hypothesis: no autocorrelation
Test statistic: LMF = 2.02611
with p-value = P(F(1,8) > 2.02611) = 0.192423

RESET test for specification -
Null hypothesis: specification is adequate
Test statistic: F(2, 7) = 0.184855
with p-value = P(F(2, 7) > 0.184855) = 0.835154

Table 9. Estimation the NLS model. l_GDP = ln(gamma) - (mu/rho)*ln(delta*K1^(-rho)+(1-delta)*L1^(-rho))

	Estimate	Std. Error	t-ratio	p-value	
gamma	2.2245	0.337129	6.5983	0.00010	***
mu	2.2245	0.337129	6.5983	0.00010	***
rho	-0.0191591	0.0524633	-0.3652	0.72340	
delta	0.253279	0.0581017	4.3592	0.00183	***

Mean dependent var	13.85807	S.D. dependent var	0.155176
Sum squared resid	0.006629	S.E. of regression	0.027140
R-squared	0.974973	Adjusted R-squared	0.969412
Log-likelihood	27.98000	Akaike criterion	-49.96000
Schwarz criterion	-48.50528	Hannan-Quinn	-50.49859
rho	0.276942	Durbin-Watson	0.984424

Table 10. Estimation the NLS model. l_GDPc = ln(gamma) - (mu/rho)*ln(delta*Kc^(-rho)+(1-delta)*Lc^(-rho))

	Estimate	Std. Error	t-ratio	p-value	
gamma	1.14683	0.110959	10.3356	<0.00001	***
mu	1.14683	0.110959	10.3356	<0.00001	***
rho	-0.0697593	0.0844433	-0.8261	0.43010	
delta	0.205863	0.112897	1.8235	0.10154	

Mean dependent var	11.14063	S.D. dependent var	0.223449
Sum squared resid	0.020508	S.E. of regression	0.047735
R-squared	0.962661	Adjusted R-squared	0.954363
Log-likelihood	21.20395	Akaike criterion	-36.40789
Schwarz criterion	-34.95317	Hannan-Quinn	-36.94648
rho	0.452835	Durbin-Watson	1.084488

Received: 11 February 2015 • **Accepted**: 19 February 2015