Cobb-Douglas Production Function: The Case of Poland's Economy

Chapter 31
Cobb-Douglas Production Function: The Case of Poland's Economy

Chaido Dritsaki and Pavlos Stamatiou

Abstract The aim of this paper is to analyze the relationship between international trade and economic and financial development for Poland for the period 1990–2016. For this long run relationship we apply the autoregressive distributed lag—ARDL technique as it was formed by Pesaran and Shin (Econometrics and economic theory in the 20th century. The Ragnar Frisch centennial symposium. Cambridge University Press, Cambridge, 1999) and Pesaran et al. (J Appl Econ 16:289–326, 2001) as well as the augmented Cobb-Douglas production function formed by Mankiw et al. (Quart J Econ 107:407–437, 1992). The results of ARDL test confirm the existence of long run relationship between examined variables. Capital seems to be an impetus of economic development both in the short and long run, while labor has a negative impact in Poland's economic growth. However, trade openness and financial development found to be insignificant on economic development both in the short and long run. Finally, causality results showed that there is a unilateral causal relationship between financial development and labor towards economic development and also a bilateral causal relationship between capital and trade openness with economic development.

Keywords Cobb-Douglas production function · ARDL bounds test
Vector error correction model · Granger causality analysis · Poland

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31.1 Introduction

Market openness and the financial sector are two important areas contributing to the economic growth of each country. A well-organized financial sector provides a variety of financial services in both the public and private sector. Of course, the impact of these financial services is more important in developed economies. Market openness contributes to the movement of resources from developed economies to developing countries with the help of technological progress. In addition, market openness allows foreign direct investment in the host country to help in supplementing the domestic capital and redefining the concept of economic efficiency by increasing productivity. Improvement of transport and, above all, communication helped to identify new markets for the exchange of goods and services globally. Grossman and Helpman (1990) argue that long-term market openness can contribute to economic growth with the help of technical knowledge by introducing high technology as a result of foreign direct investment. In conclusion, market openness will affect economic growth by taking advantage of the know-how of developed countries that boost productivity.

In the early 1990s, the countries of Central and Eastern Europe allowed the liberalization of capital flows to support their economic development. The most important event for these countries was the increase in foreign capital in the form of foreign direct investment. These investments were mainly focused on privatization, infrastructure development and structural reforms.

Poland has embarked on reforms since 1989 to tap foreign direct investment into its economic growth. However, in the 2000s there were strong short-term fluctuations, both upwards and downwards. Direct foreign investment inflows to Poland increased from \$3659 million in 1995 to \$9445 million in 2000. In the period 2001–2012, there was a strong change in the inflow of foreign direct investment, with upward trends during the years 2002–2004, 2006–2007 and 2010–2011. The highest foreign direct investment inflow was recorded in Poland in 2007 at \$23,561 million. It was evident that Poland was the main destination of the inflows of foreign direct investment from the Central European countries. The role of Poland as an exporter was negligible, but since the 2000s it has grown. In the years 2002–2011 there was an increase in Polish foreign investment. During that time, it raised from \$229 million to \$7211 million, to finally reach a record of \$8883 million in 2006. In 2012 foreign capital is withdrawn from abroad and Polish investor profits of \$894 million are repatriated. As in the other Central European countries, the recession of 2001–2002, which came into the E.U. with the outbreak of the global financial crisis, contributed to the volatility of foreign direct investment inflows and outflows in Poland (Kosztowniak 2013).

The purpose of this paper is to investigate the impact of market openness on economic growth over the long term using the Cobb-Douglas production function as formulated by Mankiw et al. (1992) for Poland. In Sect. 31.2, the literature review is mentioned. In Sect. 31.3, the methodology of the production function is analyzed. Section 31.4 describes the data and econometric methodology. Section 31.5 gives the empirical results of this paper, and Sect. 31.6 presents the conclusions of the paper.

31.2 Literature Review

The economic literature provides empirical results of productivity and the impact of market openness on domestic production and hence on economic growth, increasing capital and productivity factors.

Krueger (1978) in his work argues that liberalization of trade encourages the specialization of industries that have economies of scale leading in the long run to improve efficiency and productivity.

Tyler (1981) uses data from the OPEC countries and the middle income of the economy and concludes in his work that an increase in processing exports leads to technological progress resulting in economic growth.

Nishimizu and Robinson (1984) showed that the increase in exports raises productivity by increasing competitiveness and economies of scale, while imports are delaying the growth of overall productivity.

Romer (1990) investigates the relationship between market openness and economic growth. In his work he points out that opening the market helps innovation to increase domestic production and hence economic growth.

Greenaway et al. (2002) investigated long-term and short-term relationships with the effects of trade liberalization using panel data and the j-curve on the relationship between trade liberalization and economic growth.

Barro (2003) found that the terms of trade are included in the determinants of economic growth, but the statistical result of his work was weak.

Economidou and Murshid (2008) used data from 12 OECD countries to examine whether trade increases the productivity of manufacturing industries. The results of their study showed a positive effect of trade on the productivity growth of the manufacturing industry.

Jenkins and Katircioglu (2010) use data from Cyprus to look at the long-term impact of market openness on economic growth as well as on the causality between market openness, exchange rate and economic growth. The empirical results of their study confirm the long-term relationship. Moreover, their results show that imports do not cause economic growth.

Das and Paul (2011) used data from 12 Asian economies to control the impact of market openness on economic growth, implementing the GMM approach. The results of their study showed a positive impact of market openness on economic growth, with capital playing an important role in accelerating domestic production.

Pradhan et al. (2015) examine the relationship between market openness in the financial sector and economic growth for India, using monthly data for the period 1994–2001. The analysis of their work was carried out using the ARDL technique for the long-term equilibrium relationship and the error correction model and the relation of causality. The results of their study showed that there is a long-term equilibrium between the opening of the financial market and economic growth, and the causality effects showed a two-way causal link between market openness and economic growth.

For the Polish economy, there are only few works that have been published. Out of these the study conducted by Kosztowniak (2013) highlights the importance of production factors in Poland's economic growth for the years 1995–2012. Particular attention is paid to the impact of foreign direct investment on economic growth. The research analysis is made by the Cobb-Douglas production function using two models. The first contains four variables and the evaluation is done using the CLS method. The result of the model shows that there is a linear correlation between the inflow of foreign direct investment and the economic growth; however, FDI is not a significant factor determining GDP growth. The really significant factors were gross domestic expenditure on fixed capital and expenditure on R&D. The second model with six variables and the same method, constrained least squares (CLS) regression method, for the assessment, shows that the only factor contributing to economic growth is the government spending. The remaining variables are insignificant.

In another study, Kosztowniak (2014) defines theoretically the aspects of foreign direct investment that affect economic growth in Poland. Then, she sets out the conditions that are essential in order to have a positive impact from the foreign direct investment in the host country. In the empirical part of her work she uses the Cobb-Douglas production function for Poland in 1994–2012 and the VECM to identify the factors that are important for Poland's economic development. The results of this work showed that the effect of gross fixed capital formation, employment, FDI net inflows, exports and Gross Domestic Expenditure on research and development (R&D) on changes in the GDP value is decisive.

31.3 Theoretical Framework

31.3.1 The Production Function

In economic terms, the function of production is the relationship between the quantities of the factors of production (capital and labor) used and the quantity of output achieved by these factors. The form of this function can be formulated as follows:

$$Q = f(L, K) \tag{31.1}$$

where

- Q is the quantity of product produced.
- L is the quantity (labor hours) needed for the quantity of product Q.
- K is the quantity (labor hours of machinery) needed for the quantity of product Q.

The above function present the quantity produced from any combination of factors of production (labor and capital) getting the optimal production result. The basic goals of this production function are:

- Productivity measurement
- Determination of marginal product
- Determination of less costly combination of factors in the production for a specific quantity of product.

Cobb-Douglas production function is a specific form of production function. In 1928, Charles Cobb and Paul Douglas published a paper where they considered that production is determined from labor and capital. The function that was used is the following:

$$Q(L, K) = \mathrm{A}L^{\beta}K^{\alpha} \tag{31.2}$$

where

Q	total production (the real value of all goods produced in a year).
L	labor input (the total number of person-hours worked in a year).
K	capital input (the real value of all machinery, equipment, and buildings).
A	total factor productivity.
β and α	are the output elasticities of labor and capital, respectively.

31.3.2 Output Elasticity

The coefficient β measures the rate of increase in the variation of production for a percentage increase of labor, keeping capital stable. Respectively, coefficient α measures the rate of increase in the variation of production for a percentage increase of capital, keeping labor stable.

The partial derivatives of a Cobb Douglas production function are:

$$\frac{\partial Q}{\partial L} = \beta \mathrm{A}L^{\beta-1}K^{\alpha} \tag{31.3}$$

$$\frac{\partial Q}{\partial K} = \alpha \mathrm{A}L^{\beta}K^{\alpha-1} \tag{31.4}$$

The absolute value of the slope of an isoquant is the technical rate of substitution or TRS.

$$TRS = \frac{\frac{\partial Q}{\partial L}}{\frac{\partial Q}{\partial K}} = \frac{\beta \mathrm{A}L^{\beta-1}K^{\alpha}}{\alpha \mathrm{A}L^{\beta}K^{\alpha-1}} = \frac{\beta L}{\alpha K} \tag{31.5}$$

Equations (31.3) and (31.4) imply that the Cobb Douglas technology is monotonic, since both partial derivatives are positive. Equation (31.5) demonstrates the technology is convex, since the (absolute value) of the TRS falls as L increases and K decreases.

31.3.3 Returns to Scale

Suppose that all inputs are scaled up by some factor t. The new level of output is:

$$f(tL, tK) = \mathrm{A}(tL)^{\beta}(tK)^{\alpha} = t^{\beta+\alpha}\mathrm{A}L^{\beta}K^{\alpha} = t^{\beta+\alpha}f(L, K) \tag{31.6}$$

The sum of both coefficients $\beta + \alpha$ measures the return to scale and can be expressed as a typical response of output in a proportionate change in the two inputs.

If $\beta + \alpha = 1$ is an indication that return to scale is stable. In other words, we would say that if we double capital and labor, we will double the production.

If $\beta + \alpha > 1$ is an indication that return to scale increases, meaning that if we double capital and labor, we will more than double the production.

If $\beta + \alpha < 1$ is an indication that return to scale decreases. That means that if we double capital and labor, we will have less than double the production.

Following the studies of Mankiw et al. (1992) and Shahbaz (2012), we use Cobb-Douglas production function for period t as follows:

$$Q(t) = \mathrm{A}(t)K(t)^{\beta}L(t)^{1-\beta} \quad 0 < \beta < 1 \tag{31.7}$$

where

Q is domestic output,
A is technological progress,
K is capital stock and
L is labor.

On the above function, we assume that technology can be determined from financial development, international trade and skilled human capital. In other words, financial development and international trade jointly determine technology. Financial development causes economic growth via a channel which forms capital with direct investment whereas international trade determines technology and plays a vital role in economic growth. Thus, based on the aforementioned, the model of technology can be formulated as:

$$\mathrm{A}(t) = \mu TRA(t)^{\gamma}FD(t)^{\delta} \tag{31.8}$$

where

TRA is the indicator of trade openness.
FD is financial development.
μ is a constant.

Replacing Eq. (31.8) on Eq. (31.7) we get:

$$Q(t) = \mu TRA(t)^{\gamma} FD(t)^{\delta} K(t)^{\beta} L(t)^{1-\beta} u^{e} \tag{31.9}$$

Dividing both parts on Eq. (31.9) with population and taking the logarithms we have the following equation:

$$\ln Q_t = \mu + \gamma \ln TRA_t + \delta \ln FD_t + \beta \ln K_t + (1-\beta) \ln L_t + u_t \tag{31.10}$$

where

$\ln Q_t$ is log of real GDP per capita.
$\ln TRA$ is log of trade openness.
$\ln FD$ is real domestic credit to private sector per capita (used as a proxy to measure the financial development).
$\ln K$ is real capital stock per capita.
$\ln L$ is skilled labor proxies.
μ is constant.
u_t is error term that should be white noise

31.4 Data Collection and Econometric Methodology

Time series of the above model are annual covering the period 1990–2016. Data derive from OECD, UNCTAD Internet databases as well as world growth indices. The variable trade openness represents real exports per capita and real imports per capita. Real domestic credit to private sector per capita proxy for financial development.

31.4.1 Unit Root Tests

The primary step is to test the integration order of the variables. Thus, we use the Dickey-Fuller (1979, 1981) and Phillips-Peron (1988) test. The general form of augmented Dickey-Fuller (ADF) can be formed as follows:

$$\Delta Y_t = \delta_0 + \delta_1 t + \delta_2 Y_{t-1} + \sum_{i=1}^{\rho} \beta_i \Delta Y_{t-i} + u_t \tag{31.11}$$

where:

u_t is error term that should be white noise.
i 1, 2, …, ρ number of time lags

$$\Delta Y_t = Y_t - Y_{t-1}$$

The number of time lags on first differences on Eq. (31.11) denotes that there is no serial correlation on error term.

Phillips-Perron test differs from the augmented Dickey-Fuller test as far as autocorrelation and heteroscedasticity are concerned.

31.4.2 Auto Regressive Distributed Lag (ARDL) Cointegration

In applied econometrics, cointegration techniques have been applied to determine the long-run relationship between time series that are non-stationary. Also, time series create an error correction model for short-run dynamics and long-run relationship of the variables. Avoiding traditional cointegration techniques (different integration techniques, small samples), we apply the autoregressive distributed lag (ARDL) as it was formed by Pesaran and Shin (1999) and Pesaran et al. (2001). Thus, the advantages of this test refer to the flexibility of ARDL technique as far as the integrating order of the variables is concerned, whereas Monte Carlo technique provides consistent results of small samples. (see Pesaran and Shin 1999).

The ADRL (p, q) model specification is given as follows:

$$\mathrm{A}(L)y_t = \mu + \mathrm{B}(L)x_t + u_t \tag{31.12}$$

where

$$\mathrm{A}(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \cdots - \alpha_p L^p$$
$$\mathrm{B}(L) = 1 - \beta_1 L - \beta_2 L^2 - \cdots - \beta_q L^q$$

L is a lag operator such that $L^0 y_t = y_t$, $L^1 y_t = y_{t-1}, \ldots$
y_t and x_t are stationary variables.
u_t is a white noise.
μ is intercept term.

The ADRL (p, q_1, q_2, …, q_k) model specification is given as follows:

$$A(L)y_t = \mu + B_1(L)x_{1t} + B_2(L)x_{2t} + \cdots + B_k(L)x_{kt} + u_t \tag{31.13}$$

31.4.2.1 The Steps of the ARDL Cointegration Approach

Step 1: Determination of the Existence of the Long Run Relationship of the Variables

In the first stage, the existence of long run relationship among variables is examined using as endogenous each variable of the model and exogenous the same variables. Test is employed with F statistic and is compared with critical bounds quoted by Pesaran et al. (2001) to ascertain the existence of cointegrating relationship or not. The empirical formulation of ARDL technique for cointegration is given below:

$$\begin{aligned}\Delta \ln Q_t = {} & \beta_0 + \gamma_T T + \delta_Q \ln Q_{t-1} + \delta_{TRA} \ln TRA_{t-1} + \delta_{FD} \ln FD_{t-1} + \delta_K \ln K_{t-1} \\ & + \delta_L \ln L_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln Q_{t-i} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln TRA_{t-i} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln FD_{t-i} \\ & + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln K_{t-i} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln L_{t-i} + \varepsilon_{1t}\end{aligned} \tag{31.14}$$

$$\begin{aligned}\Delta \ln TRA_t = {} & \beta_0 + \gamma_T T + \delta_{TRA} \ln TRA_{t-1} + \delta_Q \ln Q_{t-1} + \delta_{FD} \ln FD_{t-1} + \delta_K \ln K_{t-1} \\ & + \delta_L \ln L_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln TRA_{t-i} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln Q_{t-i} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln FD_{t-i} \\ & + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln K_{t-i} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln L_{t-i} + \varepsilon_{2t}\end{aligned} \tag{31.15}$$

$$\begin{aligned}\Delta \ln FD_t = {} & \beta_0 + \gamma_T T + \delta_{FD} \ln FD_{t-1} + \delta_{TRA} \ln TRA_{t-1} + \delta_Q \ln Q_{t-1} + \delta_K \ln K_{t-1} \\ & + \delta_L \ln L_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln FD_{t-i} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln TRA_{t-i} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln Q_{t-i} \\ & + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln K_{t-i} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln L_{t-i} + \varepsilon_{3t}\end{aligned} \tag{31.16}$$

$$\Delta \ln K_t = \beta_0 + \gamma_T T + \delta_Q \ln Q_{t-1} + \delta_{TRA} \ln TRA_{t-1} + \delta_{FD} \ln FD_{t-1} + \delta_Q \ln Q_{t-1} + \delta_L \ln L_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln K_{t-i} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln TRA_{t-i} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln FD_{t-i} + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln Q_{t-i} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln L_{t-i} + \varepsilon_{4t} \tag{31.17}$$

$$\Delta \ln L_t = \beta_0 + \gamma_T T + \delta_Q \ln Q_{t-1} + \delta_{TRA} \ln TRA_{t-1} + \delta_{FD} \ln FD_{t-1} + \delta_K \ln K_{t-1} + \delta_Q \ln Q_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln L_{t-i} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln TRA_{t-i} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln FD_{t-i} + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln K_{t-i} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln Q_{t-i} + \varepsilon_{5t} \tag{31.18}$$

where Δ are the first differences, β_0 is the drift, γ_T is the trend, δ_Q, δ_{TRA}, δ_{FD}, δ_K, and δ_L are the long run coefficients and ε_{1t}, ε_{2t}, ε_{3t}, ε_{4t} and ε_{5t} are the error terms of white noise.

The null hypothesis of non cointegration among variables on Eqs. (31.14), (31.15), (31.16), (31.17) and (31.18) are:

$$H_0 : \delta_Q = \delta_{TRA} = \delta_{FD} = \delta_K = \delta_L = 0$$

(there is no cointegration-long run relationship)

Against the alternative of cointegration

$$H_1 : \delta_Q \neq \delta_{TRA} \neq \delta_{FD} \neq \delta_K \neq \delta_L \neq 0$$

Step 2: Choosing the Appropriate Lag Length for the ARDL Model/ Estimation of the Long Run Estimates of the Selected ARDL Model

The lag length for each variable of ARDL model is very important in order to avoid non-normality, autocorrelation and heteroskedasticity. To determine the optimal lag in each variable for long run relationship, we use the Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC) or Hannan-Quinn Criterion (HQC). ARDL model is estimated with variables in their levels. Lags on variables interchange until we find the model with the smallest values of Akaike, Schwarz, and Hannan-Quinn criteria or the smallest standard errors or the highest value on R^2 with statistical significant coefficients.

The selected ARDL (k) model long run equation is:

$$\ln Q_t = \beta_0 + \gamma_T T + \sum_{i=1}^{k} \alpha_{1i} \ln Q_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \ln TRA_{t-i} + \sum_{i=1}^{k} \alpha_{3i} \ln FD_{t-i} + \sum_{i=1}^{k} \alpha_{4i} \ln K_{t-i} + \sum_{i=1}^{k} \alpha_{5i} \ln L_{t-i} + \varepsilon_{1t} \quad (31.19)$$

where k is the number of optimum lag order.

The best performed model provides the estimates of the associated Error Correction Model (ECM).

Step 3: Reparameterization of ARDL Model into Error Correction Model
In order to avoid spurious regression, we transform model's variables in first differences to become stationary. The spurious regression may be solved but the first order equation provides only the short run relationship among variables. As the long run relationship is more important for researchers, cointegration and the error correction model were examined connecting the short and long run relationship of the variables of the model. The error correction model can be formed as follows:

$$\Delta \ln Q_t = \beta_0 + \gamma_T T + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln Q_{t-1} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln TRA_{t-1} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln FD_{t-1} + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln K_{t-1} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln L_{t-1} + \lambda_1 ECM_{t-1} + e_{1t} \quad (31.20)$$

$$\Delta \ln TRA_t = \beta_0 + \gamma_T T + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln TRA_{t-1} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln Q_{t-1} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln FD_{t-1} + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln K_{t-1} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln L_{t-1} + \lambda_2 ECM_{t-1} + e_{2t} \quad (31.21)$$

$$\Delta \ln FD_t = \beta_0 + \gamma_T T + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln FD_{t-1} + \sum_{i=0}^{q_1} \alpha_{2i} \Delta \ln TRA_{t-1} + \sum_{i=0}^{q_2} \alpha_{3i} \Delta \ln Q_{t-1} + \sum_{i=0}^{q_3} \alpha_{4i} \Delta \ln K_{t-1} + \sum_{i=0}^{q_4} \alpha_{5i} \Delta \ln L_{t-1} + \lambda_3 ECM_{t-1} + e_{3t} \quad (31.22)$$

$$\Delta \ln K_t = \beta_0 + \gamma_T T + \sum_{i=1}^{p} \alpha_{1i}\Delta \ln K_{t-1} + \sum_{i=0}^{q_1} \alpha_{2i}\Delta \ln TRA_{t-1} + \sum_{i=0}^{q_2} \alpha_{3i}\Delta \ln FD_{t-1} + \sum_{i=0}^{q_3} \alpha_{4i}\Delta \ln Q_{t-1} + \sum_{i=0}^{q_4} \alpha_{5i}\Delta \ln L_{t-1} + \lambda_4 ECM_{t-1} + e_{4t} \tag{31.23}$$

$$\Delta \ln L_t = \beta_0 + \gamma_T T + \sum_{i=1}^{p} \alpha_{1i}\Delta \ln L_{t-1} + \sum_{i=0}^{q_1} \alpha_{2i}\Delta \ln TRA_{t-1} + \sum_{i=0}^{q_2} \alpha_{3i}\Delta \ln FD_{t-1} + \sum_{i=0}^{q_3} \alpha_{4i}\Delta \ln Q_{t-1} + \sum_{i=0}^{q_4} \alpha_{5i}\Delta \ln Q_{t-1} + \lambda_5 ECM_{t-1} + e_{5t} \tag{31.24}$$

The ECM term derives from cointegration models and is referred to estimated equilibrium errors. The coefficient λ of ECM is the short run adjustment coefficient and presents the adjustment velocity from equilibrium or the correction of inequilibrium for each period. The sign of λ coefficient should be negative and statistical significant and it varies from 0 to 1. Finally, it should be mentioned that ARDL and ECM models are estimated with least squares methodology (LS).

31.4.3 *Granger Causality Tests Under the Framework of VECM*

After establishing for long run relationship, we determine causality direction among variables. Granger (1969) claims that if the estimated variables are cointegrated then there is a causal relationship among them in at least one direction. Granger test for causal relationship among variables is employed using error correction models [see Eqs. (31.20)–(31.24)].

31.5 Empirical Results and Discussions

In our paper, the Cobb-Douglas production function is used to analyze the long run causal relationship between trade openness of economic growth and financial development as well as between capital and labor. At first, we test for series stationarity.

Table 31.1 Unit root tests

Variable	ADF		P-P	
	Levels			
	C	C, T	C	C, T
LQ	0.258(0)	−1.869(1)	0.180[1]	−3.659[3]**
LTRA	−1.870(0)	−1.325(0)	−1.997[2]	−1.325[0]
LFD	−0.303(0)	−3.121(1)	−0.278[3]	−2.430[2]
LK	−0.680(5)	−5.459(4)*	−0.526[0]	−2.644[2]
LL	−0.109(0)	−2.490(0)	−0.589[3]	−2.490[0]
	First differences			
	C	C, T	C	C, T
ΔLQ	−6.989(0)*	−3.788(5)**	−6.989[0]*	−7.892[5]*
ΔLTRA	−4.763(0)*	−5.210(0)*	−4.763[1]*	−5.212[1]*
ΔLFD	−4.369(1)*	−4.273(1)**	−4.023[7]*	−3.941[7]**
ΔLK	−4.604(4)*	−4.319(4)*	−3.806[5]*	−4.598[8]*
ΔLL	−3.549(0)**	−4.166(0)**	−3.490[1]**	−4.161[1]**

Notes
1. *, ** and *** show significant at 1, 5 and 10% levels respectively
2. The numbers within parentheses followed by ADF statistics represent the lag length of the dependent variable used to obtain white noise residuals
3. The lag lengths for ADF equation were selected using Schwarz Information Criterion (SIC)
4. Mackinnon (1996) critical value for rejection of hypothesis of unit root applied
5. The numbers within brackets followed by PP statistics represent the bandwidth selected based on Newey West (1994) method using Bartlett Kernel
6. C = Constant, T = Trend, L = Δ = First Differences

In Table 31.1, the results of unit root test, Dickey-Fuller and Phillips-Peron test are provided.

From the above results we can see that all variables are stationary in first differences. In other words, all variables are integrated order one I(1). So, we can use the Johansen (1988) procedure for the long run equilibrium relationship. This procedure is subject to asymptotic properties meaning that is suitable only for large samples. In small samples, Johansen test is found to be upward biased, rejecting null hypothesis more often than what asymptotic theory suggests. Thus, if the size sample is small, the results will be unreliable and the Auto Regressive Distributed Lags (ARDL) test of Pesaran et al. (2001) should be used. Furthermore, ARDL approach is sensitive on the measurement of lags in the model. The mistaken number of time lags gives biased results (see Shahbaz 2010, 2012). For the number of time lags in the model, we use the Akaike criterion. In Table 31.2, the results of ARDL bounds tests are given. The critical bounds derive from Narayan's paper (2005), which are appropriate for small samples.

The results of the above table show that we get five cointegrating vectors. So, we can see that there is a long run relationship among the examined variables for Poland for the period 1990–2016.

Table 31.2 The ARDL bounds testing cointegration approach analysis

Bounds testing to cointegration			Diagnostic tests			
Estimated models	Optimal lag length	F-statistics	Jarque-Bera	ARCH (1)	RESET	LM(1)
F_Q(Q/TRA, FD, K, L)	(1, 3, 3, 3, 3)	8.211*	11.48*	0.236	0.062	4.023
F_{TRA}(TRA/Q, FD, K, L)	(2, 2, 3, 1, 3)	7.515*	0.986	0.025	0.015	12.83*
F_{FD}(FD/TRA, Q, K, L)	(2, 2, 3, 2, 2)	11.36*	1.273	0.323	1.893	10.80*
F_K(K/TRA, FD, Q, L)	(1, 2, 2, 0, 0)	9.675*	1.119	0.172	0.798	0.170
F_L(L/TRA, FD, K, Q)	(3, 3, 3, 3, 2)	9.019*	0.825	3.445**	0.688	10.79*

Notes

*, **, *** represent significance at 1, 5, 10% levels respectively. Appropriate lag length of the variables is selected following AIC

According to Narayan (2005), the existing critical values reported in Pesaran et al. (2001) cannot be used for small sample sizes because they are based on large sample sizes. Narayan (2005) provides a set of critical values for sample sizes ranging from 27 observations. They are 2.68–3.53 at 90%, 3.05–3.97 at 95%, and 3.81–4.92 at 99%

After the confirmation of long run relationship among the variables the next step is to determine the short and long run elasticity. The results on these dynamics are presented on Table 31.3.

The results of Table 31.3 show that market openness and capital have positive effect in the economic growth of Poland whereas financial development and labor seems to be correlated negative. Because capital variables and labor are statistical significant in 1 and 10% level of significance, we can say that 1% capital increase will cause increase in development by 0.20% approximately while a labor increase by 1% will affect development negatively by 0.13% approximately. This result is in accordance with Kosztowniak (2013) paper which claims that the real important factor for economic growth is gross domestic expenditures of fixed capital.

The short run results on Table 31.3 show that the short run coefficient on error correction term is −0.806 and statistical significant in 1% level of significance. That implies that there is a long run relationship among variables for Poland. Moreover, this result shows that the short-run change from the long-run equilibrium is corrected by 80.6% each year. The results from short run analysis are similar to those coming from long run. Market openness and capital have positive effect in economic growth whereas financial growth and labor are negative. Also, labor and capital are statistical significant in 1% level of significance. Finally, diagnostic tests, both in the short and long run satisfy all the assumptions of the linear regression model where autocorrelation and heteroscedasticity are absent and residuals are normally distributed.

Table 31.3 ARDL long-run and short-run results

Dependent variable: LQ			
Long-run results			
	Coefficients	S.Error	t-statistic
Constant	8.884	0.909	9.771*
Trend	0.024	0.005	4.703*
LTRA	0.065	0.072	0.896
LFD	−0.024	0.023	−1.071
LK	0.198	0.045	4.386*
LL	−0.128	0.074	−1.735***
Adjusted R^2	0.997		
F-statistic	1820.5*		
X^2N	1.285		
X^2SC	3.178		
X^2ARCH	0.685		
Dependent variable: ΔLQ			
Short-run results			
	Coefficients	S.Error	t-statistic
Constant	0.032	0.004	7.758*
ΔLTRA	0.032	0.046	0.694
ΔLFD	−0.035	0.014	−2.448**
ΔLK	0.197	0.028	6.822*
ΔLL	−0.194	0.071	−2.707*
ECM_{t-1}	−0.806	0.177	−4.542*
Adjusted R^2	0.818		
F-statistic	23.591*		
X^2N	1.085		
X^2SC	1.223		
X^2ARCH	0.166		

Notes
*, **, *** represent significance at 1, 5, 10% levels respectively
X^2N, X^2SC, and X^2ARCH are normality (Jarque-Bera), Lagrange multiplier values for serial correlation), and ARCH tests for heteroscedasticity

Granger causality test is accomplished according to error correction model. At first, the variables on levels were estimated in an unrestricted VAR model. For lag length, the Akaike information criterion (AIC), Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ) were selected. The unrestricted VAR was estimated with one time lag and an absence of serial correlation was found. After, we apply three types of Granger causality. The short run causality tests for independent variables with Wald F statistic, the long run causality tests the error correction coefficient with t-student and the joint short and long run causality with the lagged independent variables and the corresponding error correction term

Table 31.4 Results of Granger causality tests

	Short run					Long run	Joint long-and-short run causality				
	ΔLQ	ΔLTRA	ΔLFD	ΔLK	ΔLL	ECM_{t-1}	ΔLQ, ECM_{t-1}	ΔLTRA, ECM_{t-1}	ΔLFD, ECM_{t-1}	ΔLK, ECM_{t-1}	ΔLL, ECM_{t-1}
ΔLQ		0.251***	−0.026*	0.114**	−0.308*	−0.411*		3.661*	3.364*	4.947*	6.888*
ΔLTRA	1.850*		0.117	0.032	0.593**	−0.034*	2.576*		1.049	0.994	2.649**
ΔLFD	1.042	0.081		0.483	−1.301	−0.848	1.852	0.098		1.294	1.018
ΔLK	1.464**	0.116	0.183		0.276	−0.405*	3.428*	0.265	3.108		1.595
ΔLL	−0.396	0.227	−0.160	0.059		−0.572	2.089	0.461	0.342	0.901	

Note
*, ** and *** show significance at 1, 5 and 10% levels respectively

using Wald F test. On Table 31.4, the results of Granger causality with the three types are given.

The results on Table 31.4 show a short run causal relationship among market openness, financial development, capital and labor with economic growth. Also, there is a short run causal relationship between economic growth, labor and market openness as well as between economic growth and capital. Based on the results of error correction coefficient, there is a long run relationship between market openness, financial development, capital and labor with economic growth as well as between economic growth, labor and market openness. Finally, for the joint causality there are causal relationships between market openness, financial development, capital and labor with economic growth as well as between economic growth and capital, and labor with market openness.

31.6 Conclusions

Market openness promotes economic growth through various channels such as attracting foreign direct investment, accessing advanced technology to boost domestic production, and enhancing productivity. In theoretical literature and empirical research there are many different explanations for the role and implications of market openness in host countries. Other works show a positive impact on economic growth, while others have come to different results. However, in all of them there is a broad consensus regarding the assertion that the increase in productivity is necessary for creating wealth and improving the competitiveness of a country.

This paper examines whether market openness promotes or hampers economic growth in Poland in the long run. For this purpose, we used the Cobb-Douglas production function as formulated by Mankiw et al. (1992). The paper was carried out for the period 1990–2016 and the recently developed econometric ARDL cointegration technique was used for the long-term equilibrium relationship of the time series of the model, while the causality direction was investigated using the Granger error correction model (VECM Granger causality approach).

The results of the paper have shown that long-term market openness and capital have a positive impact on Poland's economic growth, while financial development and labor appear to be negatively related. This result is partly in line with the study conducted by Kosztowniak (2013) which argues that the really important factor for increasing economic growth is the gross domestic expenditure on fixed capital. Also, the results of the short-term analysis are similar to those of the long-term. Market openness and capital have a positive effect on economic growth, while the effect of financial growth and labor is negative.

Finally, the results achieved with the use of the error correction model for causality showed that there is a long-run and short-run one-way causal relationship between financial growth and labor towards the economic growth and a bilateral causal relationship between capital and market openness to economic growth.

In conclusion, we may say that in the period under review the opening of the market and mainly capital are the main factors for the economic growth in Poland both in the short and long term.

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