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# DYNAMICS OF ECONOMIC GROWTH IN IRELAND IN 1980–2014

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This paper is aimed at modelling a GDP growth rate in Ireland in order to separate the periods of particularly intense growth which are particularly important from the perspective of economic miracle definition. We applied a threshold error correction approach to cover several perspectives of the growth dynamics using different thresholds. A threshold cointegration approach allows to identify a long-run equilibrium within the context of different regimes, which provides a way of identification of asymmetric adjustment in both: short and long horizons. We extended the procedure of threshold identification by using individual economic variables as threshold variables and we further used a model with statistically significant parameters as a basis of testing. Enders and Siklos (2001) introduced the methodology to measure the long-run equilibrium in different ways, i.e., as SETAR and Momentum TAR. In general, GDP growth rate observed in 1980–2014 is the subject of analysis but we validate the results using a longer sample starting from 1973. We find that structural changes are most often identified in the period of recession of 2008–2009. Best models are obtained with the following thresholds: net income from the EU and GDP growth rate. This stresses the important role of investment and the source of its funds.

**Keywords:** intense economic growth; Ireland; threshold cointegration; validation

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# ДИНАМИКА ЭКОНОМИЧЕСКОГО РОСТА В ИРЛАНДИИ В 1980–2014 гг.

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Статья посвящена моделированию темпов роста ВВП в Ирландии, чтобы отделить периоды особенно интенсивного роста, которые особенно важны с точки зрения определения экономического чуда. Мы применили пороговый подход коррекции ошибок, чтобы охватить несколько аспектов динамики роста с использованием различных пороговых значений, расширили процедуру идентификации порогового значения, используя отдельные экономические переменные в качестве порогового значения переменных и далее мы использовали модель со статистически значимыми параметрами как основу тестирования. Темпы роста ВВП, наблюдаемого в 1980–2014 гг., являются предметом нашего анализа. Мы представляем результаты за более длинный период, начиная с 1973 г., и считаем, что структурные изменения чаще всего фигурируют в период кризиса 2008–2009 гг. Лучшие модели получаются с помощью следующих

пороговых значений: чистый доход от темпов роста ВВП и ЕС. Это подчеркивает важную роль инвестиций и их источника.

**Ключевые слова:** интенсивный экономический рост; Ирландия; коинтеграционный порог; проверка

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*Introduction*. The issue of economic miracles has attracted the attention of many journalists, politicians, and economists for many years. A review of the literature in this field indicates considerable interest in this issue in the processes of modern economic growth covering the period following the Second World War from many researchers who are often very well-known in the area of social sciences and history. A postulate to attempt to develop a theory of economic miracles has even appeared in recent years (Selinger, 2010). Most often, the starting point for research in this area is the historically identified examples of economic miracles in some countries. Ireland is one of them. The focus of the research is set on economic, social and institutional causes and conditions of the economic growth path in Ireland. The case of Ireland has been widely studied in the economic literature (see for example Barry et al., 2001; Barry, 2002; Kelly and Everett, 2004 and also: Przesławska, 2009; Szczepaniak, 2015). Generally, all the authors agree that institutional development is the main source of economic and social success of Ireland although different sources of the success have been stressed.

The purpose of this article is to study a case of the economic miracle in Ireland measured by GDP growth rate using a threshold cointegration approach, which allows to identify a long-run equilibrium within the context of different regimes. This provides a way of identification of asymmetric adjustment in both short and long horizons. As it comes from the methodology introduced by Enders and Siklos (2001) the long run equilibrium phenomenon can be measured in different ways, i.e., as SETAR and *Momentum* TAR. Other ways of formulating threshold are also possible (see: Kapetanios et al., 2006; Bruzda, 2007). We extended the procedure of threshold identification by using individual economic variables as threshold variables and we further used a model with statistically significant parameters as a basis of testing. The data coming from the years 1980–2014 have been used for analysis. We validate our results by using a longer time series from the years 1973–2014, which were available for selected variables only.

The article is organized as follows. In the second part, a brief description of Irish economy has been made. The econometric models used for empirical analysis of economic growth in Ireland were specified in section three, while empirical results are presented and discussed in section four. In section five, validation of the results has been performed. The conclusions and discussion are presented in the last part.

**The economy of Ireland as an example of economic miracle.** The economy of Ireland as an example of economic miracle has been a subject of a wide economic and statistical analysis in the last several years. The most recent book by O'Leary (2015) developed a multi-aspect discussion on such factors as technology, exports, as well as the taxation system and the policy of the government as very important determinants of growth of the country called ‘Celtic Tiger’. Bradley and Hannan (2001) analyzed, among others, the role of structural funds in Ireland's recent economic growth and concluded that neither the Single Market nor the Structural Funds are likely to account fully for this increase in Ireland's share. Yet another factor of success is related with the social partnership agreements. Furthermore, Bradley and Birnie (2001) analyzed whether a common united economy on the island of Ireland is possible using synergy coming from the great reforms that were introduced in both Northern Ireland and Ireland. Concerning the growth factors as the source of the economic success of the Irish economy, some economists emphasized the role of the Irish economic policy, especially stabilization policy and institutional reforms since the middle of last decade of the 20th century (changes in economic law, tax system, education) (Honohan, Walsh, 2002), others focused on the influence of FDI and financial support from EU funds (Barry, 2002) or explaining the Irish case as effective industrialization in the 1990s (Piński, 2013) and combination of economic policy, institutional reforms (especially regulatory reforms)

and membership in the EU (Szczepaniak, 2015). According to Cassidy, there are five important considerations in the discussion about the Irish economy: solid macroeconomic fundamentals, general regulatory environment supporting and encouraging business and entrepreneurship development, good access to risk capital, educational attainment of the workforce and conditions to R&D activity (Cassidy, 2004).

The arguments presented above provide a rationale for the analysis of Irish economy growth from the perspective of economic miracles. Interesting discussion on understanding the notion of the economic miracle and the characteristics, conditions, and consequences of this phenomenon is provided in a book edited by Balcerowicz and Rzońca (2014). Economic miracles are here a consequence of internal economic shocks caused by the national economic policy, at the root of which lie institutional determinants of changes in the economic system that could be barriers to, or drivers of development. The authors distinguish between two types of growth mechanisms, the first of which, based on innovations, is potentially sustainable and universal, whereas the «second type comprises specific growth mechanisms contained only in some situations formed by certain types of institutional systems, and/or deforming the economic policy, and they may be activated by respective reforms and, after some, sometimes a long time, they die out» (Balcerowicz, Rzońca, 2014). According to Balcerowicz and Rzońca, sustained acceleration of economic growth is a result of the successful introduction of a package of reforms, which must have an appropriate direction (liberal), temporal scope and structure, and be irreversible. Furthermore, the implemented reform packages should be the most productive in terms of the rate of economic growth. It is extremely difficult to answer the question of what factors could lead to raising the growth rate to very high levels. This is still one of the most important questions of the theory of development. Thus, at the current state of knowledge, the identification of periods of economic growth as a miracle always occurs *ex post*. According to Balcerowicz and Rzońca, historical experience suggests that in this case a reform package must significantly and permanently increase the pace of technology transfer from abroad, which requires a radical opening of the economy to the rest of the world, deregulation, fiscal reforms raising the rate of savings and investment, and strengthening the protection of private property rights, etc.

An argument in favour of Balcerowicz and Rzońca's methodological proposals with regard to the research into economic development, in particular the phenomenon of miracles, could also be the studies by Acemoglu and Robinson (Acemoglu, Robinson, 2013). Similarly to Balcerowicz and Rzońca, they recognize the decisive effect of the institutional structure of the economy on its level of development, and growth rate. The so-called *inclusive* institutions, which guarantee freedom to the largest possible number of individuals, and provide strong incentives for cost- and socially effective actions, are conducive to rapid growth, whereas barriers to it are the consequence of the dominance of the so-called *extractive* institutions restricting the freedom of the individual and broad access to resources.

We found that this concept applies well to the case of Ireland, a country which succeeded in exciting the growth as well as placing itself among the best economies in the world. The facts are convincing. The dynamics of GDP in the years 1980–2014 is presented in Fig. 1. Average GDP annual growth rate of 1980–2008 was at 6.6 %. Ireland achieved the highest GDP level, i.e., 274.71 billion USD, in 2008. In the same period, GDP per capita (PPP) started from the level 13,434 USD in 1980, reached 37,276 USD in 2008 and finally 46,633 USD in 2014. According to the World Bank Group, the value of GDP in Ireland in 2014, amounting to 250.81 billion USD, represented 0.40 percent of the world economy. Ireland could be characterized as a rapidly growing economy before the last financial crisis and incredible GDP decrease after 2008. In the period of 2008–2010, average GDP growth rate was at minus 3.5 %. After negotiations with the European Union, the IMF and the World Bank Ireland has implemented a program of economic reforms. Since 2010, the Irish economy started to grow again. It is obvious that economic development of this country was supported by financial transfers from the European Union but the most important role was played by the Irish government's economic policy. In 2008 Ireland had the highest level of household debt relative to disposable income at about 190 %. Today, after the last financial crisis Ireland is the only PIIGS country growing very fast (over 7 % in 2015) with low government debt (about 1.5 % in 2015).

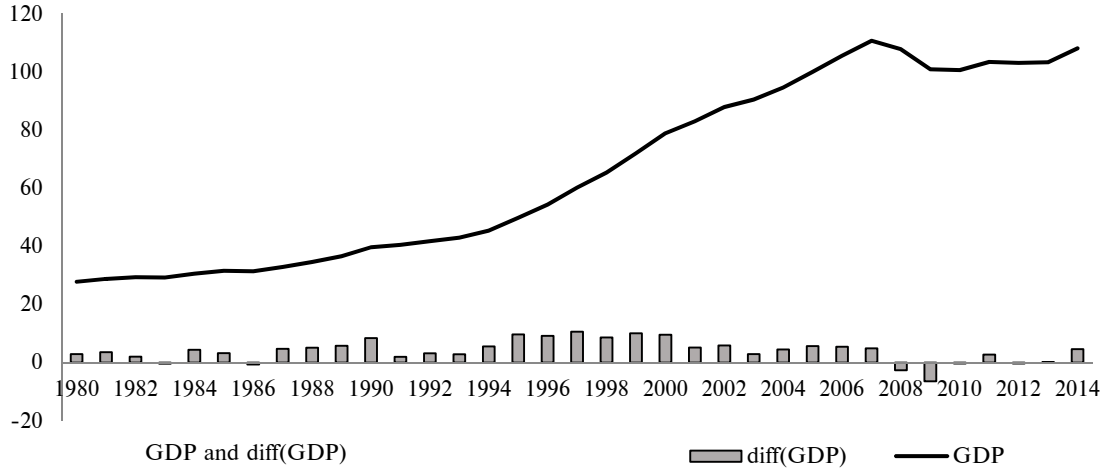


**Fig. 1.** GDP level and its dynamics in 1980–2014.
Source: Based on the data from Eurostat, http://ec.europa.eu/eurostat

Investigating the process of Irish economic development of 1980–2014, it could be observed that traditional factors lying behind relatively strong growth remained important. These include the economically efficient utilization of labor and capital in order to keep the economy operating at a level close to its economic potential. The economic growth of the Irish economy of 1980–2014 was mainly influenced by changes in multi-factor productivity, with spectacular growth observed in 1987–2000. They were determined by changes in both production factor resources and in their productivity. Unemployment rate in Ireland averaged 10.92 percent from 1983 until 2016, reaching an all-time high of 17.30 percent in December of 1985 and a record low of 3.70 percent in December of 2000. In 2016 it was established at the level of 7.8 percent. It is obvious that aggregate productivity growth depends on the productivity of firms operating in Irish economy but from the perspective of economic policy the most important issue is to ensure institutional structures and policy settings supporting investment processes, innovations, good managerial practices, efficient working incentives, entrepreneurship and risk taking.

The brake-point in Irish economic history was the accession to EEC in 1973. The most spectacular achievements were noticed in a period from 1980 to 2007. Since 1987, a voluntary «pay pact» between the government, Trade Unions and employers was a very important institution to reduce public debt and wages. Because of them the Irish economy was described as the «Celtic Tiger». In economic literature many researchers have emphasized the importance of a political consensus in the 1980s as a basic element of Irish socio-political changes. It influenced the shape and the implementation mode of economic recovery strategy, especially from the fiscal and monetary policy point of view. Strategic issues for long-term economic growth exposed changes in the structure of Irish economy by investment in infrastructure, especially in public transport, new housing, IT sector and protection of the nature environment (O′ Hagan and Newman, 2005). The very important reason of Irish economic success was also a relatively high level of human capital value as a result of centrality of investment in education sector. It had important implications for macroeconomic and regional strategy and policy. In the case of the English-speaking society, it is no accident that almost 50 % of foreign direct investments from United States and Great Britain had been allocated in that very internationally oriented country, especially in the information technology sector and financial and legal services. The case of Ireland shows an importance of opening up to the global economy but from another perspective the fact remains that cultural diversity within the country was also a great advantage in its socio-economic success.

**The threshold error-correction class of models.** After the Washington consensus being introduced, the economists have gone from the issue of real growth factors and replaced it with the institutional framework that is necessary for growth being operated. However, Durlauf (2000) showed his concern about the possibility of effectively modelling the legal, social or political factors in the

context of economic growth because most of them are endogenously related with the level of growth. Durlauf et al. (2005) continued arguing that modelling the economic growth based on time series is limited due to short series of data (available only after 1960), sensitivity of growth to business cycles and other short-run instabilities. However nonlinearity and multi-regimes in the growth patterns was from their viewpoint very important. On the other hand, after the last recession of the first decade of the 21st century it became clear that creating economic growth is still of great importance. Having in mind all these concerns, remarks and needs we tried to model economic growth in Ireland using a simple but nonlinear approach, i.e., a threshold approach (see Tong, 1990). We based our interest on the fact that before 1980s Ireland was really a poor country and the growth factors must have been introduced exogenously, possibly using a discrete threshold. This assumption determined the set of threshold variables analysed in the research. At the very beginning we assumed a long-run dynamics, that means a long-run equilibrium path and short-term adjustment. We based our research on TAR and M-TAR approaches defined by Balke and Fomby (1997), and, by Enders and Siklos (2001). A starting point of the Enders and Siklos procedure is the following long-run equation (1):

$$Y_t = \alpha_0 + \sum_{i=1}^{k} \alpha_i X_{it} + u_t, \tag{1}$$

where all variables $Y_t$, $X_{it}$ for $i = 1, \ldots, k$ are assumed to be I(1). Stationarity of the adjustment process (residual process) satisfies a threshold cointegration if:

$$\Delta u_t = I_t \rho_1 u_{t-1} + (1 - I_t)\rho_2 u_{t-1} + \sum_{i=1}^{p} \beta_i \Delta u_{t-i} + \varepsilon_t, \tag{2}$$

where

$$I_t = \begin{cases} 1 & \text{for } u_{t-1} \geq \gamma, \\ 0 & \text{for } u_{t-1} < \gamma \end{cases} \tag{3}$$

in the case of TAR-type adjustment
or

$$I_t = \begin{cases} 1 & \text{for } \Delta u_{t-1} \geq \gamma, \\ 0 & \text{for } \Delta u_{t-1} < \gamma \end{cases} \tag{4}$$

in the case of M-TAR-type adjustment.

The procedure provided by Engle and Siklos (2–4) was the subject of modifications. In 2006 Kapetanios, Shin and Snall proposed other types of indication function than (3–4) and assumed maximum one co-integration vector. In 2007 Bruzda implemented equation (5) to test the threshold co-integration, taking into account that in the case of common factors model (5) can be reduced to the form given by (2). Otherwise, a test equation in the form (5) improves the power of the procedure. The hypothesis of lack of threshold cointegration is as follows: $H_1$: $\rho_1 = \rho_2 = 0$ and implies a linear cointegration. The threshold error correction model (TECM hereafter) takes the form:

$$\begin{aligned} \Delta Y_t = {} & I_t \rho_1 u_{t-1} + (1 - I_t)\rho_2 u_{t-1} + \\ & + \omega \Delta X_t + \sum_{j=1}^{p} \psi_{yj} \Delta Z_{t-j} + e_t, \end{aligned} \tag{5}$$

where: $Z_t = (Y_t, X_{1t}, X_{2t}, \ldots, X_{kt})'$, $X_t = (X_{1t}, X_{2t}, \ldots, X_{kt})'$, $u_t$ is a residual process from eq. (1) and $I_t$ is the Heaviside function (3) or (4) and $\gamma$ is a threshold value.

The asymmetry of adjustment to long-run equilibrium is tested using the following hypothesis $H_2$: $\rho_1 - \rho_2 = 0$. If asymmetry is confirmed it means that the speed of adjustment to the long-run path differs between negative and positive sides. The mechanism of adjustment depends of the threshold variable that reveals which forces dominated over the indicated periods.

In the reported research model (5) has been used as a basis of testing, but threshold variables were taken individually from the following: the long-run regression of the form (1) and their first differences. In the next step a new testing equation of the form (6) has been proposed when regimes are split not only by lagged ECMs but also by the lagged values of exogenous and endogenous variables. The intuition for composing Eq. 6 lies in the fact that asymmetry in the adjustment process can occur in the short-run, and can result from the changes of the variables other than the ECM. A test similar to the procedure defined by Enders and Siklos is conducted using the statistically significant Eq. (6).

Then the proposed TECM model takes the following form:

$$\begin{aligned} \Delta Y_t = {} & I_t \rho_1 u_{t-1} + (1 - I_t)\rho_2 u_{t-1} + I_t \omega_1 \Delta X_t + \\ & + (1 - I_t)\omega_2 \Delta X_t + \sum_{j=1}^{\max\{p;q\}} I_t \psi_{1yj} \Delta Z_{t-j} + \\ & + \sum_{j=1}^{\max\{p;q\}} (1 - I_t)\psi_{2yj} \Delta Z_{t-j} + e_t, \end{aligned} \tag{6}$$

where: $Z_t$, $X_t$, $u_t$ and $\gamma$ are defined as in (5) and $I_t$ for individual variables is constructed similarly to (3) and (4).

As mentioned above, Eq. (6) was not only the testing formula. Eq. (6) shows the possibility of a discrete threshold coming from: an adjustment to the long-run path (1), an exogenous threshold $\Delta X_{it-j}$ or an endogenous change $\Delta Y_{t-s}$. All elements exhibit different sources of the short-run regime changes and short-run asymmetry.

**Empirical study.** The empirical research was focused on modelling the GDP process in Ireland observed in 1980–2014, yearly observations. Its aim was to identify possible structural breaks and further to explain the causes for structural breaks with threshold models. The set of time series taken into account is summarized in Tab. 1. The data were taken in both: levels and logs. The original GDP series were filtered with the Hodrick-Prescott filter to remove cyclical pattern.

Table 1

**Variables used in the study (constant prices)**

| variable | variable name | variable unit |
|---|---|---|
| $GDP_t$ | Gross Domestic Product | billion of euro |
| $FDI_t$ | Foreign Direct Investment | millions of euro |
| $NI\_EU_t$ | Net income from EU | millions of euro |
| $EMP_t$ | Employment | Thousand |
| $PD_t$ | Public Debt | billions of euro |
| $Deflator_t$ | GDP deflator | [%] of GDP |
| $I_t$ | Investments | billions of euro |
| $N\_Ex_t$ | Net Exports | billions of euro |
| $SR_t$ | Short-term interest rate | [%] |
| $LR_t$ | Long-term interest rate | [%] |
| $MFP_t$* | Multi-factor productivity | [ %] change |
| $FDI_t/GDP_t$ | | [%] |
| $NI\_EU_t/GDP_t$ | | [%] |
| $I_t/GDP_t$ | | [%] |
| $GNP_t$ | Gross National Product | billion of euro |

The data were downloaded from http://www.economywatch.com/economic-statistics/country/Ireland/, http://www.cso.ie/en/statistics/ , http://stats.oecd.org/

*$MFP_t$ was observed only in 1980–2011.

At the first step we tested the time series for unit roots/stationarity using both: the Philips and Perron – PP (1988) and the KPSS (Kwiatkowski et al. 1992) tests. Then, the Andrews and Zivot (1992) endogenous structural break test has been applied. Based on the PP test, all the variables have one unit root, whereas four variables, i.e., $Deflator_t$, $PD_t$, $EMP_t$ and $GDP_t$ (with and without cyclical component) have two unit roots. KPSS test results show that all the variables have one unit root beside $NI\_EU_t$. We have to keep in mind that time series are quite short (n=35 observations) and it could affect the conclusions. Thus in further steps we assumed that all variables were I(1). Concerning the Andrews and Zivot test results, it can said that only two variables do not have one unit root ($PD_t$ and $Sr_t$) at a 5 % significance level. The break date has been identified around 2008 year, which predominates for levels and differences. This is due to the financial and economic crisis which interrupted the fast growth in Ireland. This fact stays in line with other general findings and implies nonlinearity, as, for example, in Woo and Kumar (2015). However, structural breaks in the 1990s were also supported by the data. The breaks located in 1980s and 1990s were shown in short interest rate and net income from the EU when original data were considered and net exports when logs were analysed[1].

At the second stage the procedure described in section 3 (Eqs. 1–8) has been applied. The results of the original Engle and Siklos test showed that in three cases out of four the Engle and Siklos test supports the hypothesis of threshold cointegration (see Tab. 2 for comparison). This means that around the long-run path, asymmetry of short-term adjustment can be observed. This finding provides a basis for further investigation in order to reveal the possible significant threshold variables that influence the economic growth pattern in Ireland.

The results of testing for threshold cointegration and asymmetry using the approach proposed in the paper are given in Tab. 3 and 4.

[1] The results of PP, KPSS and Andrews and Zivot test are available from the authors on request.

Table 2

**Enders and Siklos test results based on Eq. 2**

| Threshold variable | Value of threshold | Long-term equation | Hypothesis | p-value | Remarks |
|---|---|---|---|---|---|
| ECM(t-1)_SETAR | 0 | Original data | H0: ($\rho_1 = \rho_2 = 0$) | 0.0014 | Cointegration |
| ECM(t-1)_SETAR | 0 | Original data | H2: ($\rho_1 - \rho_2 = 0$) | 0.8651 | No-asymmetry |
| ΔECM(t-1)_M-TAR | 0 | Original data | H0: ($\rho_1 = \rho_2 = 0$) | 0.0490 | Threshold cointegration |
| ΔECM(t-1)_M-TAR | 0 | Original data | H2: ($\rho_1 - \rho_2 = 0$) | 0.1240 | Asymmetry |
| ECM(t-1)_SETAR | 0 | Logarithmic data | H0: ($\rho_1 = \rho_2 = 0$) | <0.0001 | Threshold cointegration |
| ECM(t-1)_SETAR | 0 | Logarithmic data | H2: ($\rho_1 - \rho_2 = 0$) | 0.0391 | Asymmetry |
| ΔECM(t-1)_M-TAR | 0 | Logarithmic data | H0: ($\rho_1 = \rho_2 = 0$) | <0.0001 | Threshold cointegration |
| ΔECM(t-1)_M-TAR | 0 | Logarithmic data | H2: ($\rho_1 - \rho_2 = 0$) | 0.1066 | Asymmetry |

Table 3

**Enders and Siklos test results based on Eq. 6. Threshold variable: original data – levels and differences**

| Threshold variable | Threshold value | Long-term equation* | Hypothesis | p-value | Remarks |
|---|---|---|---|---|---|
| HP_GDP(t-5) | 162.57 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| FDI(t-5) | 18210.64 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| NI_EU(t-2) | 1627.90 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0135 | **Threshold cointegration** |
| NI_EU(t-2) | | | H2: ($\rho_1 - \rho_2 = 0$) | 0.0005 | Asymmetry |
| EMP(t-4) | 1901.60 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| PD(t-4) | 46.68 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| Deflator(t-3) | 64.90 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.0076 | **Threshold cointegration** |
| Deflator(t-3) | | | H2: ($\rho_1 - \rho_2 = 0$) | 0.1215 | Asymmetry |
| I(t-3) | 38.22 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| Lr(t-3) | 7.28 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.4730 | Lack of cointegration E–S |
| Lr(t-3) | | | | | TAR model |
| N_Ex(t-4) | 39.05 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| Sr(t-5) | 6.25 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.2897 | Lack of cointegration |
| Sr(t-5) | | | | | TAR model |
| ECM(t-1) | 0 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0944 | Partial cointegration |
| ECM(t-1) | | | | | Insignificant parameter pECM |
| ΔHP_GDP(t-4) | 2.98 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0003 | Partial cointegration |
| ΔHP_GDP(t-4) | | | | | Insignificant parameter pECM |
| ΔFDI(t-5) | −6542.51 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔNI_EU(t-5) | −11.50 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | <0.0001 | Partial cointegration |
| ΔNI_EU(t-5) | | | | | Insignificant parameter pECM |
| ΔEMP(t-5) | 15.40 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | <0.0001 | Partial cointegration |
| ΔEMP(t-5) | | | | | Insignificant parameter pECM |
| ΔPD(t-3) | 2.44 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0293 | Partial cointegration |
| ΔPD(t-3) | | | | | Insignificant parameter nECM |
| ΔDeflator(t-1) | 1.7 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.1177 | Partial cointegration |
| ΔDeflator(t-1) | | | | | Insignificant parameter nECM |
| ΔI(t-5) | −0.91 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔLr(t-5) | 0.34 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔN_Ex(t-5) | 2.82 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔSr(t-4) | 0.58 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔMFP(t-1) | 2.5 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.0500 | Partial cointegration |
| ΔECM(t-1) | 0 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0136 | Partial cointegration |
| ΔECM(t-1) | | | H2: ($\rho_1 - \rho_2 = 0$) | | Positive sign nECM |

* The term «long-term equation» in Tab. 6–7 denotes the presence of the threshold variable in the long-term equation.

Table 4

**Enders and Siklos test results based on Eq. 6. Threshold variable: logarithmic data and differences of logarithms**

| Threshold variable | Threshold value | Long-term equation | Hypothesis | p-value | Remarks |
|---|---|---|---|---|---|
| HP_GDP(t-5) | 4.33 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.1147 | **Threshold cointegration** |
| HP_GDP(t-5) | | | H2: ($\rho_1 - \rho_2 = 0$) | 0.1480 | Asymmetry |
| FDI(t-5) | 9.81 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| NI_EU(t-5) | 6.16 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| I(t-5) | 2.51 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| Sr(t-5) | 6.25 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.0856 | Partial cointegration |
| Sr(t-5) | | | H2: ($\rho_1 - \rho_2 = 0$) | | Insignificant parameter nECM |
| N_Ex(t-5) | 1.15 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| EMP(t-4) | 0.64 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| PD(t-3) | 3.84 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| Lr(t-3) | 7.29 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.7999 | Lack of cointrgration |
| Lr(t-3) | | | | | TAR model |
| ECM(t-1) | 0 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0107 | Cointegration |
| ECM(t-1) | | | H2: ($\rho_1 - \rho_2 = 0$) | 0.6128 | No-asymmetry |
| ΔHP_GDP(t-4) | 0.022 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔFDI(t-5) | -0.252 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔNI_EU(t-4) | -0.273 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔLr(t-5) | 0.340 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔSr(t-4) | 0.580 | No | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔN_Ex(t-2) | 0.054 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0086 | Partial cointegration |
| ΔN_Ex(t-2) | | | | | Insignificant parameter nECM |
| ΔI(t-4) | -0.017 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.6627 | Lack of cointegration |
| ΔI(t-4) | | | | | TAR model |
| ΔPD(t-4) | 0.051 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔEMP(t-5) | 0.005 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔDeflator(t-1) | 0.052 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | | Too few observations in the regime |
| ΔMFP(t-1) | 2.5 | No | H0: ($\rho_1 = \rho_2 = 0$) | 0.0093 | **Threshold cointegration** |
| ΔECM(t-1) | 0 | Yes | H0: ($\rho_1 = \rho_2 = 0$) | 0.0104 | Partial cointegration |
| ΔECM(t-1) | | | H2: ($\rho_1 - \rho_2 = 0$) | | Insignificant parameter nECM |

The results presented in Tab. 3–4 show the problem that was indicated at the very beginning of the paper, i.e., low number of observations applicable for the research. The severe limitations resulting from that fact are indicated in tables by the comment «too few observations in the regime». However, we were able to find out that in cases when net income from the EU lagged by 2 years, the deflator lagged by 3 years (for original data) and HP_GDP lagged by 5 periods and multifactor productivity (MFP) lagged by 1 (for logs), significant threshold cointegration took place. These variables, apart from the GDP deflator and MFP, were present in the long-run relationship. Thus the case of deflator puts our attention on the prices level in Ireland in 1980–2014. It is worth noting that for original data the threshold value of net income from the EU was equal to 1,627.9 (mln euro) and in the case of deflator the cumulated prices change was about 64.90 %. The value of the HP_GDP threshold for logs is equal 4.33.

In the third stage of the research the estimation of TECM parameters and testing for threshold cointegration and asymmetry of adjustment in the TECM model was carried out. The aim of this stage was to estimate (symmetric or asymmetric) reaction of the economy (measured in GDP) on the growth factors measured as threshold variables. The long-run models (ECM-terms) are shown in Tab. 5, while the best TECM models indicated by BIC are presented in Tab. 6 and 7.

Table 5

**The long-run models for GDP**

| Variable | HP_GDP | | HP_log_GDP | |
|---|---|---|---|---|
| | parameter estimate | p-value | parameter estimate | p-value |
| Const | −27.367 | 0.0010 | −4.287 | 0.0000 |
| NI_EU | 0.005 | 0.0000 | | |
| EMP | 0.066 | 0.0000 | 1.033 | 0.0000 |
| N_Ex | 0.848 | 0.0000 | 0.066 | 0.0000 |
| Sr | −0.566 | 0.0096 | −0.008 | 0.0520 |
| I | 0.367 | 0.0131 | | |
| PD | 0.127 | 0.0000 | 0.070 | 0.0000 |
| Deflator | | | 0.228 | 0.0002 |
| DW test | | 1.5313 | DW test | 1.0813 |
| $R^2$ | | 0.9988 | $R^2$ | 0.9960 |
| QLR test | | 0.0001 | QLR test | 0.0000 |

QLR test represents Quandt's test for structural breaks (Quandt, 1960).

Table 6

**The best TECM models for non-logarithmic data**

| **Dependent variable** | **Threshold variable** | | **Value of threshold** | | **Threshold variable** | | **Value of threshold** | |
|---|---|---|---|---|---|---|---|---|
| **ΔHP_GDP** | **NI_EU(t-2)=** | | 1.6 | | **deflator(t-3)=** | | 64.9 | |
| | **N1=** | 10 | **N2=** | 22 | **N1=** | 16 | **N2=** | 14 |
| | **AIC=** | | −61.40 | | **AIC=** | | −60.14 | |
| **variable** | **I_ regime** | **p-value** | **II_ regime** | **p-value** | **I_ regime** | **p-value** | **II_ regime** | **p-value** |
| const | 4.5271 | <0.0001 | −0.8729 | 0.0186 | −0.2375 | 0.1396 | 0.1155 | 0.1713 |
| ΔSr | | | −0.2440 | 0.0183 | −0.1818 | 0.0002 | −0.0514 | 0.0001 |
| ΔLr | −0.0407 | 0.0107 | | | | | 0.0952 | 0.0011 |
| ΔI | 0.3237 | <0.0001 | 0.1302 | 0.0273 | | | −0.0402 | 0.0162 |
| ΔPD | 0.0911 | <0.0001 | 0.0731 | 0.0002 | 0.0148 | 0.0160 | −0.0240 | 0.0023 |
| ΔFDI | −0.0001 | <0.0001 | 0.0000 | 0.0004 | | | 0.0001 | 0.0163 |
| ΔNI_EU | 0.0012 | <0.0001 | 0.0022 | 0.0001 | 0.0005 | 0.0462 | −0.0001 | 0.0772 |
| ΔEMP | 0.0494 | <0.0001 | 0.0267 | <0.0001 | 0.0079 | <0.0001 | 0.0029 | 0.0999 |
| ΔDeflator | | | 0.2890 | 0.0008 | 0.2100 | <0.0001 | 0.0813 | 0.0207 |
| ΔN_Ex | −0.2670 | <0.0001 | 0.3325 | <0.0001 | 0.0888 | 0.0001 | | |
| ΔECM(t-1) | −0.2458 | <0.0001 | −0.4437 | 0.0002 | −0.1926 | <0.0001 | −0.0446 | 0.0073 |
| ΔHP_GDP(t-1) | | | 0.6109 | <0.0001 | 0.7539 | <0.0001 | 1.0815 | <0.0001 |
| ARCH LM(4) | 4.298 | (0.367) | 3.278 | (0.512) | 3.047 | (0.550) | 3.967 | (0.411) |
| Ljung-Box Q(2) | 2.58 | (0.276) | | | | | 1.08 | (0.583) |
| Ljung-Box Q(3) | | | | | 3.64 | (0.303) | | |
| Ljung-Box Q(4) | | | 3.06 | (0.547) | | | | |

In last four rows p-values are given in brackets. N1 and N2 mean the number of observations in the I and II regime respectively.

Table 7

**The best TECM models for logarithmic data**

| **Dependent variable** | | **Threshold variable** | | **Value of threshold** | | **Threshold variable** | | **Value of threshold** | |
|---|---|---|---|---|---|---|---|---|---|
| **ΔHP_GDP** | | **HP_log_GDP(t-5)** | | 4.335 | | **MFP(t-1)** | | 2.5 | |
| | | **N1=** | 16 | **N2=** | 12 | **N1=** | 15 | **N2=** | 11 |
| | | **AIC =** | | −371.99 | | AIC = | | −267.53 | |
| **variable** | | **I_ regime** | **p-value** | **II_ regime** | **p-value** | **I_ regime** | **p-value** | **II_ regime** | **p-value** |
| const | | −0.0011 | 0.1421 | 0.0031 | 0.0002 | −0.0098 | 0.0018 | 0.0252 | <0.0001 |
| ΔSr | | −0.0018 | <0.0001 | | | −0.0016 | <0.0001 | | |
| ΔLr | | | | | | −0.0030 | <0.0001 | | |
| ΔI | | | | −0.0162 | <0.0001 | | | 0.2141 | <0.0001 |
| ΔFDI | | −0.0002 | 0.0316 | 0.0029 | <0.0001 | | | | |
| ΔNI_EU | | | | −0.0088 | <0.0001 | 0.0312 | <0.0001 | −0.0111 | 0.1627 |
| ΔEMP | | 0.0366 | 0.0573 | 0.1075 | <0.0001 | 0.2275 | <0.0001 | | |
| ΔDeflator | | 0.1479 | <0.0001 | 0.0820 | <0.0001 | | | | |
| ΔN_Ex | | | | −0.0058 | <0.0001 | 0.0538 | <0.0001 | 0.0503 | 0.0005 |
| ΔECM(t-1) | | −0.0848 | 0.0021 | −0.0308 | <0.0001 | −0.1898 | <0.0001 | −0.6201 | 0.0012 |
| ΔHP_GDP(t-1) | | 0.7864 | <0.0001 | 0.9846 | <0.0001 | 0.8589 | <0.0001 | | |
| ARCH LM(4) | | 4.499 | (0.343) | 2.546 | (0.636) | 4.788 | (0.310) | 1.373 | (0.849) |
| Ljung-Box | Q(2) | | | 3.32 | (0.191) | | | 2.13 | (0.346) |
| | Q(3) | 2.78 | (0.427) | | | 4.098 | (0.251) | | |

In last two rows p-values are given in brackets. N1 and N2 mean the number of observations in the I and II regime respectively.

The results of both the long-term equations and TECM estimation show that reasonable estimates were obtained for the parameters. In general, parameter estimates in the long-run equations were greater in magnitude than the short-term adjustment coefficients for logarithmic and non-logarithmic data. The parameter estimates standing for the adjustment to the long-run path are different for negative and positive side of the long run equilibrium. They are presented in tables as ΔECM(t-1) in the I regime and in the II regime. For net income from the EU playing a role of the threshold variable the adjustment form was faster in magnitude (−0.44) from the negative side than from the positive side (−0.24). In the case of deflator the magnitude was as follows: −0.19 from the positive side and −0.04 from the negative one. In the case of HP_log_GDP lagged by 5 periods, the magnitude was much lower: −0.08 and −0.03, respectively.

Fig. 2 shows the division of the growth period in Ireland according to NI_UE. In the case of net income from the EU that flowed to Ireland in the observed period the following division can be observed: from 1981 to 1990, from 1991 to 2000 and from 2001 to 2014. These periods are quite reasonable taking into account the Irish economic policy in the past. Since putting the reforms into operation and getting more money from abroad (net income from the EU, FDI) in the 1980s, it took a decade to build the mechanism of growth. This type of growth was of exogenous nature, influencing by institutional changes as well as the money from external sources, which was supported by other research results discussed in section 3 of this article. In this period the adjustment to the long-run path from the negative side was dominating. In the decade of 1991−2002 the most spectacular economic growth took place, amounting to 8 % per year. In this time a greater economic force acted to push up the economy and to enable catching up processes. In the last twelve years of the analyzed period the growth was slowed down and then economic recession took place.

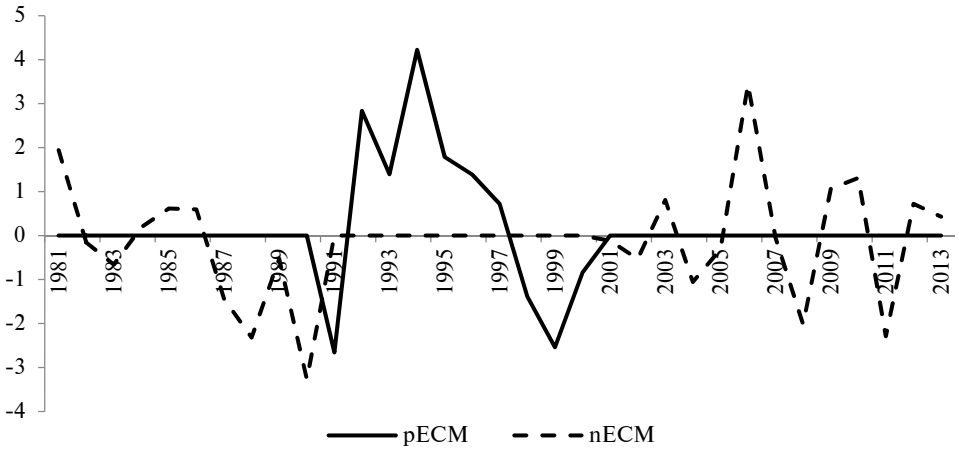


**Fig. 2.** ECM for the threshold variable: NI_EU(t-2)

It was a heavy time for the economy that suffered from recession very much. However, after 2010, the Irish economy has been recovering. Again the adjustments form negative side was of greater magnitude.

**Validation of the estimated tecm models** In this part of the paper we described briefly the validation procedure of the results obtained above. To do so, we prolonged a sample to have more observations for analysis. As the longer time series were not available for some variables, the following data were taken into account: $HP\_GDP_t$, $FDI_t$, $NI\_EU_t$, $EMP_t$, $Deflator_t$, $N\_Ex_t$, $SR_t$, $LR_t$ (notation as above). We had to omit two variables, i.e., investment and debt/GDP ratio. The longer period of the analysis covered the following years: 1973–2014. Thus the whole procedure was repeated for a longer time series. The results of the Enders and Siklos procedure let us accept threshold cointegration only for the case of the logarithms. This result is affected by the two following reasons. The first one is obviously related with the longer sample but the second one is that the empirical ECM model has been changed according to available information.

We followed the procedure for all types of the models described in section 4. However, the most important question was which of the threshold variables (if any) that were described in section 4 remained the same in the longer period of the analysis. The results of testing are shown in Tab. 8.

Using the proposed procedure based on model (6), we found out that only the net income from the EU remained as the important threshold for the growth pattern in the economy of Ireland. Besides the error correction mechanism in differences is a significant threshold as well.

Table 8

**The modified Enders and Siklos test – TECM model**

| Threshold variable – differences | Threshold value | Long run eq. – sect 4. | Threshold variable present in the long run eq. | H0: ($\rho_1 = \rho_2 = 0$) p-value | H2: ($\rho_1 = \rho_2 = 0$) p-value |
|---|---|---|---|---|---|
| ΔECM(t-1) | 0 | 1 | Yes | 0.0019 | 0.0000 |
| ΔDeflator(t-1) | 1.7 | 1 | No | 0.0000 | 0.8471 |
| ΔNI_UE(t-5) | 153.9 | 1 | Yes | 0.0000 | 0.0009 |
| Threshold variable – differences | Decision | | Remarks | | |
| ΔECM(t-1) | Threshold cointegration | | Asymmetry | | |
| ΔDeflator(t-1) | Cointegration | | No-asymmetry | | |
| Δ NI_UE (t-5) | Threshold cointegration | | Asymmetry | | |

*Conclusions.* In the paper, the economic growth in Ireland was considered from the economic miracle point of view. Despite a small number of observations that was an important limitation for empirical research, we managed to indicate the most important thresholds and asymmetries in the GDP growth rate in Ireland in 1980–2014. The investigation has been repeated for GDP in the years 1973–2104. The time series in interest were nonstationary and exhibited structural change in different moments in time. The structural change was most often identified in the period of recession of 2008–2009 (12 cases, and 1991/92 – ΔHP_GDP). It is noteworthy that threshold cointegration was confirmed in all cases using the original Enders-Siklos test. Moreover, individual threshold variables (other than ECM) are related to: asymmetry of the short-run adjustment (1), possibility that the threshold variables are not present in the long-run equation (2). The following threshold variables were identified such as: net income from the EU (NI_EU), GDP deflator (deflator), lagged GDP (HP_GDP) and multifactor productivity (MFP). Best models are obtained with the following thresholds: net income from the EU and lagged HP_GDP which represents the endogenous growth factor. It shows the important role of investment in the growth creation process and the source of its funds. In the case of NI_EU: the adjustment from the negative side of the threshold is faster than from the positive side. In the case of deflator, an opposite direction was shown by the data. In the case of lagged HP_GDP, a faster short-run adjustment was from the positive side (above the threshold). It can be explained by the fact that an exogenous factor like net income from the EU accelerated the economic growth when it was at a lower level. While endogenous forces (represented by the deflator and the GDP itself) were put into operation, the system was never overheated in comparison to the long-run equilibrium level. Threshold variables allowed to divide the periods of economic growth in Ireland showing the most important forces that accelerated the Irish economy in the 1990s. The asymmetry of short-run adjustment was due to net income from the European Union, the inflation represented by the deflator of GDP as well as by endogenous growth. Additionally, it should be mentioned that the obtained results can be helpful for policy decision-makers or European institutions in order to better understand the properties of economic growth.

It is worth mentioning that the validation of the model in the longer time period, i.e., 1973–2014 confirmed that net income from the European Union was the most important exogenous force driving the growth pattern in Ireland. Other variables considered in the long run ($\Delta ECM_{t-1}$) were also of great importance.

The impact of net income from the EU was possible because of the preceding institutional reforms consisting in the dominance of inclusive institutions in national economy as well as the successive changes in the economic policy rules. Thus Ireland is a case of the economic miracle which can be perceived as a period of rapid economic growth in one of the highly developed (core) countries in the world's economic system.

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