STUDIA EKONOMICZNE ● ECONOMIC STUDIES
NR 1 (LXXXVIII) 2016

ARTYKUŁY

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TECHNOLOGY GAP AND ECONOMIC CRISIS IN NEW AND OLD EUROPE[1]

(Artykuł nadesłany: 26.01.2016 r. Zaakceptowany: 14.03.2016 r.)

ABSTRACT

The purpose of this paper is to study the interrelationships between economic fluctuations, dynamics of technology gap and convergence in the European Union. We presume that these processes are linked by innovation mechanisms, which are different in the markets that are at the technology frontier and in the catching up countries. In the former, we found a supply-based innovation mechanism and a demand-based innovation mechanism in the latter. This determines different adjustment processes in various phases of the cycle in these two groups of countries. We investigated the impact of technology gap on economic fluctuations (crisis) and that of economic fluctuations on technology gap reduction and convergence. We found that greater technology gaps amplified economic fluctuations whilst economic slowdowns (crises) impeded technology gap reductions and convergence. These results are explained by the interaction of different innovation mechanisms in the technology frontier and in the catching up countries. The principal factor of the gap reduction in less developed countries is the size of the gap itself (Gerschenkron's effect). The per capita GDP convergence in the EU occurred mainly through technology gap reductions in the less developed countries where also the biggest structural changes in output and trade took place. Crisis slowed down the process of convergence and the accession of new countries speeded it up.

Keywords: technology gap, economic growth, crisis, accession, convergence, innovation and diffusion, European Union.
JEL Classification: F15, F43, F44, O33, O47, O52

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[1] Acknowledgement: The study was funded by the research grant of the National Science Centre (Poland), No. DEC–2012/07/B/HS4/03131.

INTRODUCTION: LITERATURE AND THEORETICAL FRAMEWORK

Interrelationships between economic growth or, more specifically, technology development and business cycles were never the main issue on the agenda of neoclassical economics' research. The two phenomena have been investigated separately – on the one hand, growth theory was devised as a concept of long term development path, on the other, business cycle theory was conceived as a an explanation for economic fluctuations and deviations from a long-term trend, due to exogenous shocks.[2] A different approach was proposed by Schumpeter (Schumpeter 1934, 1939). In his opinion, growth and cycle should be seen as a unified phenomenon through the link of innovation processes. Economic growth is driven by innovations and diffusions that are not evenly distributed over time and space, but appear in clusters. A discontinuity of emergence of innovations in time results in discontinuity of growth in the form of business cycles. An uneven distribution of innovations over space under diffusion barriers may lead to increasing or decreasing technology gaps between countries, and, further on, to growth convergence or divergence.

In Schumpeter, we find a completely different perception of convergence than the one used in the neoclassical theory. Following Solow, the convergence of income levels between developed and developing economies is to be understood as a result of higher GDP growth of the latter that was implied by the assumption of diminishing marginal productivity of capital. Economies with lower capital/labour ratio are supposed to have higher marginal product of capital, and thus enjoying higher growth rates. Convergence thus is seen as a continuous and monotonic process without a possibility of divergence. A different approach to convergence is proposed by the Schumpeterian tradition where growth seems to be more dependent on capital quality (rather than quantity) embodied in applied technology. Catching up is an outcome of technology diffusion from innovators to imitators following the so-called Gerschenkron's hypothesis of backwardness' advantage. Less advanced economies can grow more quickly by copying and implementing technologies invented and developed in countries at the technological frontier (Gerschenkron, 1962). In that approach, convergence has technological character and is based on technology diffusion, which is constrained by absorption capability of recipient country, and is not unconditional; it may occur or not.

As we know, studies did not confirm a clear trend to convergence in diverse population of countries around the world. Instead, a tendency to convergence was found among countries at similar level of development (*club convergence*) (Baumol, 1986). Furthermore, research on more homogenous groups of countries regarding the level of development over long term secular periods revealed

[2] A departure from the separation of growth and business cycle in neoclassical economy was the proposition of real business cycle theory. In recent Neoschumpeterian school such an approach is presented by Aghion, Howitt (1998).

that convergence processes are not monotonic and linear over time but periods of convergence are intertwined with periods of divergence at various rates.

The problem of lacking evidence of absolute convergence in the world economy was smartly solved in the mainstream neoclassical economics by introducing a concept of conditional convergence. It allows for some environmental heterogeneity (saving rates, government policies etc.) across countries that determines different steady states. Each economy converges to its own steady state and the speed of convergence is inversely related to the distance from the steady state. The further an economy is from its own steady state value the faster it grows. Thus, rich economies may grow faster than poor economies and absolute divergence may be observed while the principle of conditional convergence still holds (Barro, Sala-i-Martin, 1995). However, this model cannot explain the behaviour of these external parameters over time (like shifting of production function following technology diffusion), and in consequence changing trends of convergence and divergence over time. The idea of technology gap dynamics is more useful in this context. However, there are also some mixed approaches combining neoclassical production function with Schumpeterian approach (Verspagen 1994; Madsen 2008).

Taking the Schumpeterian technology gap perspective, convergence may be treated as an effect of technology gap reduction and divergence as technology gap increase. Thus, innovations at the technology frontier will increase technology gap and cause divergence, and imitations in catching up countries will decrease technology gap and lead to convergence. In a dynamic context, higher rate of innovations at the frontier than the rate of diffusion of innovations in catching up countries will increase technology gap and divergence, and vice versa.

Exploring convergence processes among the OECD countries in the 20th century Verspagen (1994) notes that though in the prewar period there was some weak tendency towards convergence, interrupted by the great crisis and the second world war, the period of 1950–1980 was the only one in which a significant convergence trend occurred. This trend, however, came to an end with another trend break in the late 1970s and a return to divergence.[3] Moreover, two different indicators of convergence, convergence to the average of the sample of countries and that to the technological frontier (leader) did not always coincide (Verspagen, 2000). While for the postwar convergence boom and the slowdown in the mid–1970s the two indicators match relatively well, for the earlier interwar period a convergence to the leader was stronger than within the group, and the opposite is true for the last period from the 1990s onwards, when a disappearing convergence within the group has been accompanied by divergence to the leader. As diffusion is driving convergence whilst innovations at the technological frontier are leading to divergence, we can regard R&D as a factor enhancing the first process and patenting having impact on the latter one. So the author shows

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[3] Soete et al. (1999) note that after 1991, when a tendency to diverge from the leader prevailed in most of the developed countries, there was convergence among South-East Asian tigers. This means that at the same time quite opposite tendencies can occur in different groups of countries.

different relative importance of these two factors in convergence or divergence phases, between sub-periods of the time span 1966–1995. The research results by Fagerberg and Verspagen (2002) still more clearly emphasize a changing importance of innovations (patents) and diffusion (R&D) in subsequent sub-periods of the same time span. It can be seen, in particular, in changing GDP elasticities with regard to the two variables. Regression coefficient of GDP function for patents is declining in the last sub-period, which means that GDP growth requires more patenting and catching up becomes more challenging. Regression coefficient of GDP for R&D is also declining, though to a lesser degree, and diffusion among catching up countries becomes more difficult. Because less developed countries are featured by lower patenting activity, a tendency to divergence is setting in in the world economy.

An intriguing question arises as to what factors determine such divergent tendencies over time. The Schumpeterian answer is that this is caused by non-linearity of innovation and diffusion processes coupled with fluctuations of economic activity. Innovations (in particular the radical ones) appear in clusters at the technological frontier in depression. This is followed by their diffusion, with incremental innovations, which leads to recovery and expansion, until the potential of the new technological paradigm is exhausted. Then another depression comes, giving rise to a new wave of radical innovations. This simple model of causal relationships between innovations, growth and cycles was subject to hot debate among Schumpeterians. It finally led to two different theoretical propositions, *technology push* and *demand pull* models of innovation. The key question is what actually favours the occurrence of innovations: depressions unleashing technology push or demand pulling innovation and diffusion during economic expansions. We can add a related question as to how these models fit into different economies on both sides of technology gap.

Verspagen and Fagerberg suggest that crises often brought about structural break and led to *switchover* of convergence to divergence and vice versa. According to the supply (technology push) model, crises unleash motivation among entrepreneurs to search for new technical and organizational solutions, as the existing ones do not improve hard business situation (*depression trigger effect*).[4] Aghion and Saint-Paul (1991) support this argument and mention *cleaning-up effect* (eliminating inefficient firms) and *low opportunity cost in terms of forgone profits of reorganization* in depression. Saint-Paul (1992) points to disciplinary effect of increased likelihood of bankruptcy in recessions and rising discrimination between good and bad firms that eases selection. Moreover, Saint-Paul (1991) emphasizes a long term negative effect of positive demand shock for productivity arguing that relocation in depression is more important than demand effect of *learning by doing* in expansion.

These Schumpeterian arguments are undermined by Stiglitz (1993) who argues that the future productivity of the economy is adversely affected by

[4] Mensch (1975), Kleinknecht (1981), van Duijn (1983).

reduced expenditures on R&D in depressions. He also points out to capital market imperfections (costly and imperfect information), which pile up and result in the deleterious effect of economic downturns on technological progress.

The demand pull model, instead, focuses on the impact of demand expansion on innovations (Schmookler, 1966; Freeman, Clark, Soete, 1982). Here, the demand dynamics in economic upturn is the main factor of diffusion, which also induces incremental productivity-increasing innovations. It is not recessions but recovery and boom that give rise to waves of innovations. The empirical demand model proposed by Schmookler (1966) corresponds to the earlier Kaldor model (1957), in turn based on Verdoorn effect of demand externalities, which was extended by Thirlwall (2002) to include the effects of export demand in open economy. The demand theory views innovation processes from the perspective of absorption, or more generally diffusion possibilities constrained by intrinsic properties of innovation and market selection determined by market competition and size.

What follows from the discussion above is that the relationship between economic fluctuations (crises) and innovations goes in two-way: fluctuations in economic activity cause fluctuations in innovation and fluctuations in innovation give rise to fluctuations in economic activity. However, these causal links may be different in economies at different level of technological development. Gomulka (2009) argues that there is a strong duality of the world economy regarding the mechanisms of economic growth, which are totally different in the most developed countries from the rest of the world. The technology frontier countries absolutely dominate the creation of new technologies, with 95% share in internationally recognized patents. In the developing and catching up countries, the growth is driven by technology diffusion from the technology frontier area. This strong duality means that in these two groups of countries the sources of technological progress are completely different. Thus, one can distinguish between the technology frontier countries as innovation-dependent and catching up countries as diffusion-dependent.[5] As crises may have different impact on innovations and diffusions, one can expect technology gap dynamics, and thus convergence and divergence processes, to be an outcome of interaction of these different factors working on both sides of technology gap.

The aim of this paper is to study the impact of the economic (financial) crisis on the European Union economies, as they often differ essentially in the level of technological development. In this context, two interrelated questions can be posed: how technology gap influenced adjustment processes of particular European economies in the last economic downturn, and how the crisis affected the dynamics of technology gap in Europe. The point is to highlight the feedback relationships between technology gap and economic fluctuations. Following the supply model, which suits best the most advanced innovation-dependent countries, the crisis should speed up innovation activities at the technological frontier

[5] Gomulka (2009) argues for the need to have two distinctly different theories of economic growth, one for the countries at the technology frontier, another one for all remaining countries.

(in old Europe), and, according to the demand model, an adverse effect on diffusion in catching up countries (in new Europe) would take place. This process would increase the technology gap between these groups of countries, leading to divergence. But the overall outcome will depend on exogenous innovation potential of the technology frontier area and sensitivity of diffusion processes to demand fluctuations. However, it must be noted that the investigated period overlaps with the accession of catching up countries to the common EU market that might have boosted technology diffusion through larger market demand effect to new member states. If the supply effect of the crisis at the frontier proved weak, or negative according to Stiglitz, then the positive demand effect of the accession would prevail and we would face technology gap reduction and convergence.

A number of research papers addressed similar issues, like convergence in Europe, covering both the periods before the EU enlargement and afterwards. Wagner and Hlouskova (2001), Matkowski and Próchniak (2004) analyze the convergence in Central and Eastern Europe (CEE) countries prior to the accession, while Rapacki and Próchniak (2009), Szeles and Marinescu (2010) investigate the process of real convergence of CEE countries after the accession. These studies find evidence of a process of real convergence and the speeding up of growth in the CEE countries that contributed to their convergence to the more advanced old EU members. From the perspective of our paper, a recent study by Dobrinsky and Havlik (2014) seems to be of special interest. They analyze the speed and patterns of economic convergence in the new EU member states of CEE during transition and the first years of EU membership, including the period of economic crisis. The authors explore various convergence measures proposed in the growth literature (sigma- and beta convergence) and employ various analytical approaches. They find that the once-off direct negative effect of the crisis on GDP growth in the new member states was considerably stronger than in the old Europe, which interrupted the growth pattern and the convergence process slowed down. The authors point to uneven economic convergence within the EU, not only between new member states and the rest of Europe, but also within each of these subgroups.

Our study attempts to test empirically two competing hypotheses:

(a) opposite supply and demand effects of the crisis on more and less technologically advanced countries that would lead to technology gap increases and divergence,

(b) positive accession effect on catching up countries that, assuming secular technology stagnation at the frontier, would lead to technology gap reduction and convergence.

We will do this in a few steps. First, we will attempt to test if there is a link between the volatility of GDP growth and the size of technology gap. If so, there must be some crucial differences in innovation mechanisms between leader and catching up countries, assuming that otherwise the size of technology gap would not lead to differences of volatility rates between the two samples of countries. In particular, we will look at different impact of supply and demand factors in their innovation mechanisms on GDP growth volatility. Then, the effect of business fluctuations on the evolution of technology gap will be explored, a reverse causality to the one above, namely the causal link from fluctuations to technology gap, not from gap to fluctuations. Having done this we will inspect how the reduction of technology gap through changes on its both sides led to income convergence or divergence in particular sub-periods. The idea is to find out which factors on both sides of the gap contributed to this process, and how. Finally, we will decompose aggregate convergence trends into sectoral level by looking at convergence processes in trade comparative advantages in particular technology sectors, in order to find out where the main and most decisive structural shifts appeared.

1. DATA AND METHODOLOGY

The research covers the period of 1995–2012 and member countries of the European Union divided into two groups labeled 'old Union' and 'new Union'. The distinction is based on differences in technological advancement and date of accession to the EU. The group of old Union covers most technologically advanced countries, regarded as leaders, like Germany, United Kingdom, France, Italy, Belgium, the Netherlands, Denmark, Sweden, Finland and Austria. The group of new Union embraces catching up countries, which are divided into new accession countries of the Central and Eastern Europe – Poland, Czech Republic, Slovakia, Hungary, Slovenia, Lithuania, Latvia, Estonia, Romania and Bulgaria, and a group of catching up countries of previous accessions, Ireland, Spain, Portugal and Greece. The research is based on the following data sources: EUROSTAT database, GGDC DATABASE, WITS of World Bank and UNCTAD.

In the first step we will describe the evolution of technology gap in the particular groups of EU countries. In order to do this, we adopted working definitions of technology gap related to R&D expenditures, patenting activity, productivity (GDP per capita) or the so-called income gap.[6] Technology gap of each country will be measured in relation to a selected technology frontier, i.e. the most advanced country regarding the adopted measure of the gap. Indicators of technology gap will be then referred to GDP fluctuations over time to find out the degree of GDP volatility with respect to the size of technology gap. This analysis should determine the relation between the depth of the downturn in 2008–2009 and the size of technology gap in particular countries before the crisis.

As a next step, a panel regression analysis will be applied to determine the most important factors for GDP growth in the investigated countries and period,

[6] Income gap, calculated on the base of GDP per capita, is most frequently used in literature as a proxy measure of technology gap, or equivalently as a measure of distance to technology frontier.

and in particular those concerning supply and demand factors, size of technology gap and absorption capabilities. The results are expected to help identify the features of innovation mechanisms in distinguished groups of countries, leaders and catching up countries. The identified mechanisms would provide guidelines to understanding the links between the technology gap and the crisis.

The following part of research will be devoted to the analysis of convergence and divergence processes in the studied period in two approaches: convergence to average within the group, and convergence to the technology frontier. The results should highlight the impact of the crisis on the dynamics of technology gap.

In another panel analysis, two distinct effects on the dynamics of technology gap will be explored and compared: accession effect and crisis effect. We would then obtain a view of relationship between gap dynamics, accession, crisis, and a natural path of gap evolution driven by supply factors (not disturbed by shocks).

In the last section, we will analyze structural and relocation changes in the EU economies before and after the crisis, in particular comparing new and old Europe from the perspective of structural convergence. The analysis will be focused on export trends and changes in comparative advantages in trade using two-digit SITC aggregation.

As a framework for empirical analysis we adopted an evolutionary model of technology gap developed by Verspagen (1992), but slightly modified it to meet our research goals. The model considers the case of two countries, one of which is technologically advanced North, and the other technologically backward South. The model is based on assumptions and definitions as follows:

$$G = \ln(T_n/T_s), \text{ definition of technology gap} \qquad (1)$$

T_n i T_s knowledge (technology) stock in North and South

Growth of the knowledge stock results from exogenous factors (β) and from dynamic learning effects as in the Verdoorn-Kaldor law (*learnng by doing*), (λQ), and in the catching up South additionally from technology diffusion determined by the size of technology gap (G) and absorption capabilities of the South.

$$\hat{T}_s = \beta_s + \lambda\hat{Q}_s + aGe^{-G/\delta} \text{ – equation for knowledge stock growth in South} \qquad (2)$$

$$\hat{T}_n = \beta_n + \lambda\hat{Q}_n \text{ – equation for knowledge stock growth in North} \qquad (3)$$

β – exogenous rate of knowledge growth;
λ (Q = product) – Verdoorn-Kaldor learning rate;
δ – intrinsic learning (absorption) capability of South

Actual spillovers (diffusion) of technology from North to South are proportional to the size of the gap and absorption capabilities of the South. However, the capabilities to assimilate spillovers by the South are inversely related to the

size of the gap. This negative influence of the gap on absorption is moderated by the intrinsic absorption capability of the South, or
aG – potential spillovers; $aGe^{-G/\delta}$ – actual spillovers;
$e^{-G/\delta}$ – factor of absorption capabilities.

Output growth is determined by the stock of knowledge (T) and exports (X).

$$\hat{Q}_i = \alpha\hat{T}_i + \varepsilon\hat{X}_i \quad i = n, s \quad \text{growth rate of output.} \tag{4}$$

However, note that export growth is proportional to the technology gap in the North but inversely related to the gap in the South. It also depends on the growth rate of the volume of the world market (Z).

$$\hat{X}_n = \eta \ln\left(\frac{T_n}{T_s}\right) + \hat{Z} \quad \hat{X}_s = \eta \ln\left(\frac{T_s}{T_n}\right) + \hat{Z} \quad \text{rates of export growth.} \tag{5}$$

Under the above assumptions we can derive an equation for the dynamics of technology gap over time as follows.

$$\dot{G} = \hat{T}_n - \hat{T}_s = \frac{1}{1-\alpha\lambda}(\beta_n - \beta_s) + \frac{2\varepsilon\eta\lambda}{1-\alpha\lambda}G - \frac{a}{1-\alpha\lambda}Ge^{-G/\delta}. \tag{6}$$

Verspagen assumes that the Kaldor learning factor (learning demand externality) is identical in both countries, which means that there is the same innovation mechanism at work everywhere. When we relax this assumption, $\lambda_n \neq \lambda_s$, then the equation (6) takes the form,

$$\dot{G} = \underset{\textbf{(a)}}{\left[\frac{\beta_n}{1-\alpha\lambda_n} - \frac{\beta_s}{1-\alpha\lambda_s}\right]} + \underset{\textbf{(b)}}{\left[\frac{\lambda_n}{1-\alpha\lambda_n} - \frac{\lambda_s}{1-\alpha\lambda_s}\right]\varepsilon\hat{Z}} + \underset{\textbf{(c)}}{\left[\frac{\lambda_n}{1-\alpha\lambda_n} + \frac{\lambda_s}{1-\alpha\lambda_s}\right]\varepsilon\eta G} - \underset{\textbf{(d)}}{\left[\frac{a}{1-\alpha\lambda_s}Ge^{-G/\delta}\right]} \tag{7}$$

The equation (7), in contrast to (6), has four terms. The first one (a) indicates the impact of exogenous technology supply differential in North and South, the second one (b) which does not exist in (6), shows the net effect of demand factors (Kaldor) on both sides of technology gap. The third term (c) refers to cumulativeness of technological accumulation expressed as a circular chain impact of output on technology, technology gap on exports, and exports on output. The last term (d) describes the Gerschenkron effect of catching up through spillovers. The specification of the Gerschenkron effect allows both for convergence and divergence in dependence to nonlinear relationship between the gap and the absorptive capabilities.

In relation (a), the advanced country usually enjoys economic advantage, similarly as in relation (c), where cumulative effects of technology accumulation allow to retain and raise a large share in the world market. Hence, a reduction of technology gap is only possible through relation (b) and (d). Both a more demand dependent innovation mechanism in South, when ($\lambda_n < \lambda_s$), and technology spillovers from North to South will work towards closing up technology gap. The distinction of these four effects will facilitate interpretation of the results obtained in our empirical research.

2. TECHNOLOGY GAP AND VOLATILITY OF GDP GROWTH

Technology gap is usually defined as a distance (difference) in technological advancement between a country under investigation and the most advanced country called a technology frontier. Technology frontier is then a point of reference (benchmark), against which the size of technology gap is measured. A productivity difference between these countries defined at the aggregate level in terms of GDP per capita is most frequently applied in the literature as the measure of technology gap. Also other measures are commonly used, like R&D expenditures, patent applications (expressed in numbers per head), output and exports of high-tech products. In our study, we apply the following indicators:

(1) GDP per capita, in Euro (PPP), from EUROSTAT database (GDP p.c.)
(2) GERD per capita: *Gross Expenditures on Research and Development*), in Euro (PPP) per capita in 2005 prices, from EUROSTAT database, (GERD p.c.)
(3) Number of patent applications in *European Patent Office*, per inhabitant, from EUROSTAT database, (EPO p.c.).

The measure of the gap is calculated as the ratio of the value of a given indicator for the technology frontier to its value for the country in question:

$$GAP = \frac{\overline{Y}}{Y_i} \tag{8}$$

where $\overline{Y}$ denotes the indicator for technology frontier, Y_i is the indicator for a country investigated. The value of *GAP* increases with the size of the gap. In some parts of the analysis, we express these variables in logarithms.[7]

Countries most advanced in a given area are selected as technology frontier (benchmark). Thus, the United States of America were chosen for GDP and GERD indicators, and Switzerland for patent indicator EPO as a country with the largest number of patent applications filed with the European Patent Office.

First, we have to look at the evolution of technology gaps in the EU in the period of 1995–2012. Because of huge variation of the gaps in the whole sample we have divided it into three more homogenous groups:

(1) Most advanced countries of the old EU (Old EU–1) – Germany, United Kingdom, France, Italy, Belgium, Netherlands, Denmark, Sweden, Finland and Austria,
(2) Less advanced countries of the old EU (Old EU–2), still catching up – Ireland, Spain, Portugal and Greece,

[7] For some regression equations, we use a simplified measure of the gap – the value of GDP per capita. Then the size of the gap is inversely related to the value of this variable. The higher the value of this variable the smaller the gap.

(3) Catching up countries of the new EU, called Central and Eastern Europe countries (CEE) – Poland, Czech Republic, Slovakia, Hungary, Slovenia, Lithuania, Latvia, Estonia, Romania and Bulgaria.

As shown in Table 1, in the most developed group of countries (Old EU–1) gaps measured by GDP p.c. are relatively small and stay within the interval 1,15–1,6, without a clear tendency to reduction. Slight reductions are seen in the sub-period before 2002 followed by increasing dispersion up to 2005, and especially during the crisis.

In the second group (Old EU–2), a clear trend towards reduction of productivity gaps during almost entire period can be observed, except for the time of crisis. In this group, the gap dispersion is higher with gap values of 1,2 in Ireland, 2,1 in Portugal, and 2,2 in Greece.

The highest values of the gap, and also the strongest tendency to its reduction, could be observed in the CEE countries during the whole period excluding temporary gap increases in Bulgaria and Romania in 1996–2000. In this group, the variation of the gap is much bigger than in the other two groups and ranges between 2 and 6,5 at the beginning, but is significantly reduced to between 1,8 and 3,2 at the end of the period.

Gaps measured by GERD p.c. in the group OLD EU–1 are similar to those measured by GDP p.c. in the same group, between 1 and 2, except for Italy with the size of the gap 3,5. Similarly, GERD gaps are clearly stable in the whole period.

Quite differently, the dispersion of GERD gaps was much wider in the group OLD EU–2 and ranged between 3 and 10 with a visible tendency to reduction. Similarly to GDP measure, the largest gaps were found in Greece and Portugal at the beginning, but the latter country succeeded to reduce the gap substantially to a level comparable with the other members of the group.

The greatest variation of GERD gaps appeared in the CEE countries, ranging from 4 to 40 at the beginning, but with a strong tendency to convergence to the range between 2 and 20 at the end of the period. However, in some countries of the group, the gaps began to rise in the final period of the crisis.

The most spectacular contrast between the groups could be seen in gaps measured by EPO patents. In the group of OLD EU–1, the gaps were rather stable in the whole period, and their dispersion was contained between the values 1,5 and 5,5. In the other two groups, we observe both much greater gap variation and a trend to gap reduction, in particular after the year 2004, when filing patent applications with EPO became more widely spread. In the group of OLD EU–2, the gaps were initially spread over the interval between 9 and 170 that was finally reduced to between 6 and 60, with still a large difference between Ireland and Spain on one side and Portugal and Greece on the other side. In the group of the CEE countries, the dispersion ranged initially between 20 and 720 and was finally reduced to between 10 and 440, and the strongest reduction took place in the years 2003–2004.

As we can see, the distance to technology frontier is much differentiated in particular country groups; it is the smallest in OLD EU–1, larger in OLD EU–2, and the largest in the CEE countries. Also, it depends on the indicator applied to measure the gap. With GDP p.c., the dispersion of gaps between the groups is relatively small; with GERD p.c. it is much larger and with EPO p.c. it is gigantic. It can also be easily noted that larger gaps tend to decline at a faster pace. In the first group, they almost do not change and seem to have attained an equilibrium while innovation diffusion makes them decline in the other groups.

Taking into account this variation in technology gaps, we may reasonably ask the question how the size of the gap influenced the sensitivity of a country to economic fluctuations. To answer this question we carried out regressions of standard deviations of annual GDP and TFP growth rates on the average technology gaps in the countries in the period 1995–2012. The average technology gaps were calculated according to the equation (8) and measured in terms of GDP p.c., GERD p.c. and EPO p.c., respectively In the regressions using GDP p.c. and GERD p.c. the sample was extended to include three additional countries: Norway, Switzerland and the USA. For gaps measured by EPO p.c., the USA was skipped because of incomparability of data.[8]

In order to capture indirectly the effect of the size of technology gap on the economic downturn in the crisis, we have run regressions of the difference of GDP growth rates (measured as geometric averages) in the prosperity years before the crisis (2005–2008) and in the crisis (2009–2012) on the technology gaps before the crisis in 2008. As above, we used three measures of technology gap – GDP p.c., GERD p.c. and EPO p.c.. Similar regressions were run with respect to TFP as dependent variable.[9] The OLS method was applied for estimations.

As shown in Table 2, the results indicate a positive correlation of GDP and TFP fluctuations with the size of technology gap in the whole period. Though coefficients of determination are not very high, the estimated coefficients of technology gap are statistically significant under all measures of the gap, and in both regressions for GDP and TFP as dependent variables. This means that the volatility of economy during changing business situation is enhanced by technology gaps.

A slightly different result was obtained for GDP and TFP fluctuations in the very period of crisis 2009–2012. Here, the decreases of GDP growth rates are similarly positively correlated with the size of technology gap, which is not true in the case of TFP. It seems that the size of technology gap had no impact on changes of TFP during the crisis. An estimation of the regression of the difference between GDP and TFP growth rates in the crisis on the size of technology

[8] In the USA, patent applications are filed with USPTO rather than EPO, in Europe the opposite is the case.

[9] Total Factor Productivity Growth is estimated as Törnqvist Index. The data comes from *The Conference Board Total Economy Database 2014*. Groningen Growth and Development Centre GGDC.

Table 1. Size and evolution of technology gap in the UE 1995–2012

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
GDP p.c. Old EU-1																		
Average	1,34	1,35	1,35	1,35	1,37	1,34	1,33	1,31	1,35	1,36	1,39	1,35	1,32	1,28	1,28	1,28	1,27	1,30
St. deviation	0,09	0,10	0,08	0,07	0,07	0,08	0,06	0,07	0,08	0,09	0,09	0,10	0,09	0,10	0,09	0,10	0,11	0,12
Minimum	1,22	1,23	1,25	1,25	1,27	1,24	1,21	1,19	1,25	1,26	1,26	1,22	1,18	1,13	1,13	1,16	1,15	1,17
Maksimum	1,53	1,56	1,50	1,46	1,47	1,44	1,41	1,41	1,45	1,52	1,57	1,53	1,50	1,45	1,44	1,47	1,47	1,52
GDP p.c. Old EU-2																		
Average	1,93	1,92	1,89	1,86	1,85	1,75	1,68	1,62	1,63	1,65	1,66	1,59	1,57	1,54	1,52	1,57	1,63	1,70
St. deviation	0,29	0,32	0,35	0,39	0,41	0,36	0,34	0,36	0,37	0,40	0,39	0,39	0,39	0,33	0,29	0,31	0,36	0,40
Minimum	1,59	1,53	1,45	1,37	1,33	1,26	1,22	1,15	1,14	1,14	1,14	1,10	1,07	1,15	1,17	1,17	1,16	1,18
Maksimum	2,19	2,21	2,20	2,23	2,27	2,05	2,01	1,99	2,04	2,11	2,07	2,02	1,98	1,93	1,87	1,88	1,94	2,02
GDP p.c. CEEC																		
Average	3,95	4,00	3,96	3,89	3,98	3,89	3,62	3,40	3,27	3,16	3,08	2,85	2,64	2,45	2,46	2,44	2,32	2,31
St. deviation	1,17	1,37	1,44	1,39	1,43	1,38	1,24	1,13	1,05	0,96	0,93	0,80	0,71	0,56	0,54	0,52	0,48	0,47
Minimum	2,15	2,10	2,12	2,10	2,08	2,08	2,02	1,93	1,93	1,88	1,89	1,82	1,76	1,66	1,74	1,79	1,76	1,81
Maksimum	5,24	6,51	6,56	6,24	6,36	6,32	5,80	5,42	5,14	4,76	4,74	4,19	3,89	3,46	3,41	3,41	3,20	3,23
GERD p.c. Old EU-1																		
Average	1,79	1,80	1,77	1,78	1,76	1,78	1,70	1,63	1,65	1,64	1,69	1,69	1,70	1,71	1,70	1,68	1,64	1,65
St. deviation	0,64	0,65	0,65	0,65	0,74	0,73	0,71	0,65	0,70	0,70	0,74	0,73	0,72	0,77	0,76	0,75	0,76	0,79
Minimum	1,05	1,09	1,03	1,08	1,01	1,07	0,88	0,89	0,91	0,93	0,95	0,92	0,99	0,97	1,01	0,99	0,99	1,02
Maksimum	3,44	3,51	3,45	3,48	3,72	3,70	3,51	3,27	3,41	3,41	3,53	3,58	3,48	3,59	3,58	3,53	3,57	3,63
GERD p.c. Old EU-2																		
Average	6,78	6,71	6,57	6,36	5,62	5,78	5,63	5,43	5,35	5,15	4,99	4,66	4,40	4,27	4,12	4,14	4,27	4,42

cont.

St. deviation	3,23	3,36	3,20	3,29	2,26	2,56	2,54	2,61	2,66	2,63	2,49	2,35	2,27	2,55	2,55	2,53	2,60	2,71
Minimum	3,12	2,87	2,79	2,77	2,79	2,85	2,82	2,63	2,47	2,28	2,25	2,27	2,25	2,18	1,99	2,02	2,02	1,95
Maksimum	9,81	10,23	9,82	10,25	7,66	8,67	8,70	8,45	8,09	8,00	7,55	7,63	7,48	7,97	7,82	7,82	8,02	8,28
GERD p.c. CEEC																		
Average	17,18	15,66	16,26	16,65	18,28	18,11	17,02	15,63	15,09	13,70	12,68	11,49	11,00	10,38	11,28	10,02	8,89	8,62
St. deviation	11,49	8,92	10,02	9,78	11,86	12,12	11,69	10,36	9,87	8,85	8,31	7,68	6,84	6,11	7,22	6,63	6,32	6,98
Minimum	3,48	4,13	4,16	4,00	3,90	3,91	3,52	3,37	3,84	3,35	3,26	2,97	3,11	2,73	2,62	2,30	1,95	1,77
Maksimum	39,18	32,41	33,57	31,83	37,95	42,54	37,99	35,25	32,89	30,28	28,27	24,48	23,06	21,59	22,56	23,12	20,76	24,40
EPO p.c. Old EU-1																		
Average	2,69	2,60	2,62	2,69	2,51	2,59	2,71	2,52	2,53	2,66	2,71	2,64	2,70	2,63	2,64	2,65	2,64	2,62
St. deviation	1,22	1,21	1,27	1,33	1,24	1,28	1,35	1,17	1,18	1,28	1,28	1,27	1,35	1,35	1,41	1,46	1,51	1,29
Minimum	1,39	1,30	1,30	1,41	1,27	1,37	1,44	1,39	1,42	1,49	1,49	1,48	1,43	1,37	1,41	1,39	1,36	1,43
Maksimum	5,50	5,25	5,48	5,73	5,34	5,41	5,57	4,96	4,98	5,25	5,15	5,01	5,24	5,16	5,47	5,65	5,82	5,33
EPO p.c. Old EU-2																		
Average	73,78	62,22	56,23	53,92	48,82	48,02	45,01	41,80	32,84	41,03	24,99	27,05	25,75	26,49	27,65	27,94	29,25	34,12
St. deviation	74,13	58,70	56,45	53,76	43,74	41,52	41,37	38,99	25,31	35,68	17,73	19,88	19,01	20,71	22,15	23,05	25,18	27,44
Minimum	8,63	8,79	8,43	6,66	5,57	6,90	5,95	6,39	6,58	6,08	6,40	6,21	5,82	5,52	5,27	4,93	4,63	6,10
Maksimum	171,29	138,50	133,45	126,91	97,92	92,49	96,67	92,04	59,56	74,14	43,22	45,52	46,27	49,62	47,74	48,65	52,29	60,28
EPO p.c. CEEC																		
Average	265,75	438,20	308,54	456,15	297,40	293,83	225,37	192,70	115,81	117,22	106,13	105,30	98,56	74,53	89,21	89,03	86,95	120,51
St. deviation	246,73	663,87	338,87	633,04	313,88	416,01	252,91	225,88	144,89	109,71	92,80	132,88	103,50	80,75	95,25	96,84	94,59	132,26
Minimum	19,88	29,02	30,55	17,17	22,10	14,96	15,24	8,71	10,37	7,37	7,94	8,64	7,29	5,86	6,62	6,12	5,75	9,34
Maksimum	726,7	2227,6	981,5	1776,7	1031,1	1411,3	849,0	708,0	509,0	389,4	327,1	457,6	284,3	261,9	287,1	253,5	243,9	444,2

Source: Own calculation based on EUROSTAT database.

Table 2. GDP and TFP growth rate fluctuations and technology gap in the UE

Dependent variable	Explanatory variable -gap	Coefficient	t-Stat	P value	Obs.	R^2 Adj.	F-test
S.D.(GDP) 1995–2012	GDP p.c. Av.	–0,12287	–4,2071***	0,000	27	0,391	17,69
	GDP p.c. (US/x)	1,014074	4,2130***	0,000	27	0,391	17,75
	GERD p.c. Av.	–0,00237	–3,4648***	0,002	27	0,297	12,00
	GERD p.c. (US/x)	0,052288	3,0087***	0,006	27	0,236	9,05
	EPO p.c. Av.	–0,00758	–2,9389***	0,007	26	0,234	8,64
	EPO p.c. (Swiss/x)	0,006551	2,2601**	0,033	26	0,141	5,11
S.D.(TFP) 1995–2012	GDP p.c. Av.	–0,11447	–5,2380***	0,000	27	0,504	27,44
	GDP p.c. (US/x)	1,050489	6,7833***	0,000	27	0,634	48,01
	GERD p.c. Av.	–0,00176	–3,2216***	0,003	27	0,265	10,38
	GERD p.c. (US/x)	0,050675	5,3524***	0,000	27	0,515	28,65
	EPO p.c. Av.	–0,00582	–2,712***	0,012	26	0,203	7,36
	EPO p.c. (Swiss/x)	0,009461	5,4202***	0,000	26	0,550	29,38
GDP growth rate fall in 2009–2012 as against 2005–2008	GDP p.c. (US/x) 2008	2,19833867	3,3908***	0,003	24	0,314	11,50
	GERD p.c. (US/x) 2008	0,1484238	3,1268***	0,005	24	0,276	9,78
	EPO p.c. (Swiss/x) 2008	0,0218009	2,9299***	0,008	24	0,248	8,58
TFP growth rate fall in 2009–2012 as against 2005–2008	GDP p.c. (US/x) 2008	0,164018	0,3000	0,766	24	0,041	0,09
	GERD p.c. (US/x) 2008	0,013516	0,3469	0,732	24	0,039	0,12
	EPO p.c. (Swiss/x) 2008	0,008014	1,3916	0,178	24	0,039	1,94
GDP–TFP growth rate fall in 2009–2012 as against 2005–2008	GDP p.c. (US/x) 2008	2,03432	2,8622***	0,009	24	0,238	8,19

Significance: * 10%; ** 5% to 1%; *** below 1%. Av.= average, US/x = relative to US, In each row we report parameters of a simple regression model estimated separately.

Swiss/x= relative to Switzerland.

Source: Own calculations based on EUROSTAT and GGDC DATABASE.

gap shows that all the impact of the gap was mostly concentrated on GDP and not on TFP changes. Thus, during the crisis we witnessed mainly a demand effect of the gap as changes in TFP are usually regarded as linked to supply or exogenous factors (exogenous changes in technology). The latter seem to be more stable even in economic slump.

3. THE STRUCTURE OF INNOVATION MECHANISM AND GDP DYNAMICS

Having seen different depth of economic fluctuations among countries at various levels of technological development, it seems interesting to explore the impact of supply and demand factors of innovation mechanism on changes of GDP growth rates. We can expect that differences of innovation mechanism on the opposite sides of the technology gap might determine different paths of its evolution. To test this, we applied a model developed by Fagerberg (1987), which explains growth rates by supply factors like own technology activities (patenting), technology gap (distance to frontier), absorption capacity (investment share in GDP) on one side, and by demand factors like growth of world trade on the other side. In our study, the model is extended to include two other supply factors, R&D and TFP, the latter one to reflect the impact of exogenous supply factors. The approach is compatible with the Verspagen model, where technology gap dynamics is also dependent on exogenous supply of technology in leader and catching up country, and on demand factor as expressed by Kaldor effect.

The period under investigation was divided into four sub-periods differing in the level of business activity:

1. 1996–2000, before the crisis in 2001.
2. 2001–2004, pre-accession sub-period.
3. 2005–2008, post-accession sub-period.
4. 2009–2012, recession sub-period after 2008.

The research involved a panel regression analysis for the following groups of countries: Full panel (all sample), old Union (OLD EU), new Union (NEW EU: CEEC plus Greece, Spain, Portugal, Ireland), and Central and Eastern European countries (CEEC). The division ensues from significant differences of innovation mechanisms expected to work in those samples, which should be analytically compared.[10]

Full empirical model is as follows:

$$GDP = f(TFP, EPO, GERD, GDPpc, GFCF/GDP, WTO) \qquad (9)$$

where (calculated for a given period)

GDP average annual GDP growth rate measured as geometric average,
TFP average annual TFP growth rate measured as geometric average,

[10] Here, differently from the former study we merged in one panel CEEC and former OLD EU–2.

EPO average annual growth rate of patent applications filed with the European Patent Office (EPO) measured as geometric average,
GERD average annual growth rate of gross expenditures on R&D (GERD), in Euro (PPP) and 2005 prices measured as geometric average,
GDPpc average level of GDP per capita, in Euro (PPP) measured as arithmetic average; this variable can be treated as a proxy measure of distance to the frontier,
GFCF/GDP average gross fixed investment as percentage of GDP in constant prices measured as arithmetic average,
WTO average annual growth rate of world exports in constant prices (according to WTO) measured as geometric average.

The equation (9) was estimated using a panel regression analysis, applying *fixed-effects* or *random-effects* models (according to Hausman test) as indicated in the Tables 3abcd by FE and RE, respectively. For each group of countries, six versions of equation (9) were estimated using various sets of independent variables.

The research results allow to approximate the impact of specific factors of innovation mechanism in particular groups of countries on GDP growth. First, in equations (1) to (4) for the full panel (Table 3a) we estimated coefficients for supply factors, and omitted demand factor, which was included in equations (5) and (6).[11] In equation (1), the variable TFP is significant and has the strongest influence on growth ahead of GFCF/GDP. EPO and GERD are also significant but, surprisingly, the technology gap variable (GDPpc) appears to be statistically insignificant in the whole panel. This result is still enhanced in estimation of the equation for the old Union (OLD EU), Table 3b, when TFP is not only significant but the coefficient assumes a value above one. This indicates a strong impact of exogenous supply factors in countries close to the technology frontier, where the technology gap itself is of minor importance. If we omit TFP in equations (2), (3), (4), then technology gap gains importance in the whole panel but again not in countries close to the technology frontier (OLD EU).[12] Then also the variables EPO and GERD remain significant in the whole panel but in the old Union only GERD does. When we include the variable WTO in the complete equation (5) for the whole panel the technology gap again loses importance while the other variables remain significant with a dominant influence of TFP above the demand variable WTO.[13] A similar picture emerges from the estimation of complete equation for the old Union, but here EPO and GERD lose importance and the demand factor impact WTO is enhanced.

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[11] It can be discussed whether GFCF/GDP is a pure supply factor as it is a component of aggregate demand but from the point of view of absorption process it is a factor in the implementation of new technologies supplied.

[12] It seems that in the whole panel there is a trade-off between TFP and technology gap as supply factors with varying importance for countries of different level of technological development.

[13] Now there seems to be a trade-off between technology gap and demand factor WTO.

Table 3a. Innovation mechanism and GDP dynamics – Full panel*

	Dependent variable					
	1	2	3	4	5	6
	Average GDP growth rate					
Countries – Period	Full panel 1996–2012					
Explanatory variables						
tfp	.9860563 (8.76)				.928246 (8.22)	
epo	.0420805 (2.33)	.0715855 (2.78)	.0896584 (3.55)		.0400946 (2.28)	.0644517 (2.63)
gerd	.0898342 (2.91)	.1023754 (2.28)		.1407674 (3.15)	.0786668 (2.57)	.0795234 (1.84)
gdp pc	–.0673709 (–1.41)	–.2294515 (–3.58)	–.2017341 (–3.12)	–.3227512 (–5.65)	.0025199 (0.04)	–.0770237 (–0.97)
gfcf/gdp	.3860432 (7.67)	.3689124 (5.05)	.4008852 (5.42)	.4244686 (5.76)	.3317667 (6.01)	.2666348 (3.46)
wto					.2304165 (2.14)	.4423785 (2.99)
No. of obse-rvations	96	96	96	96	96	96
Adjusted R^2	0.6300	0.3922	0.3871	0.3191	0.6985	0.5614
Hausman test	179.42 0.0000	31.25 0.0000	26.32 0.0000	50.80 0.0000	33.55 0.0000	7.50 0.1862
FE Test F (*p* – value)	63.33 0.0000	28.38 0.0000	34.03 0.0000	32.13 0.0000	56.35 0.0000	27.16 0.0000

* Notice: In the Tables 3abcd and the following RE indicates that *random-effects* and FE that *fixed-effects* models were estimated.

Source: Own calculations based on EUROSTAT database, GGDC DATABASE and WTO.

Table 3b. Innovation mechanism and GDP dynamics – old EU

	Dependent variable					
	1	2	3	4	5	6
	Average GDP growth rate					
Countries – Period	OLD EU 1996–2012					
Explanatory variables						
tfp	1.137031 (6.58)				.7408406 (4.86)	
epo	.079759 (2.05)	.0039871 (0.07)	.0452951 (0.66)		.0477883 (1.61)	.0121621 (0.32)
gerd	.0688792 (1.38)	.2313303 (3.28)		.2323047 (3.44)	.0316055 (0.79)	.0990118 (1.96)
gdp pc	.0350306 (0.57)	–.1437434 (–1.62)	–.1767767 (–1.72)	–.1484353 (–2.83)	.0462839 (1.05)	.011598 (0.21)
gfcf/gdp	.273899 (2.96)	.3132774 (2.09)	.3510807 (2.01)	.3162881 (2.26)	.031528 (0.45)	–.0576693 (–0.67)
wto					.3581649 (4.67)	.5637702 (6.50)
No. of observa-tions	40	40	40	40	40	40
Adjusted R^2	0.6504	0.3797	0.2695	0.3781	0.8328	0.7459
Hausman test	12.42 0.0295	11.78 0.0191	8.13 0.0434	54.73 0.0000	3.37 0.7612	3.49 0.6245
FE Test F (*p* – value)	36.30 0.0000	13.17 0.0000	10.24 0.0001	18.23 0.0000	RE	RE

Source: Own calculations based on EUROSTAT database, GGDC DATABASE and WTO.

Table 3c. Innovation mechanism and GDP dynamics – NEW EU

	Dependent variable					
	1	2	3	4	5	6
	Average GDP growth rate					
Countries – Period	NEW EU 1996–2012					
Explanatory variables						
tfp	.943927 (6.01)				.9125913 (5.84)	
epo	.0396733 (1.67)	.0712077 (2.21)	.0914191 (2.92)		.0355512 (1.50)	.0738411 (2.51)
gerd	.1015212 (2.33)	.1136409 (1.88)		.1581104 (2.65)	.0942918 (2.18)	.0906353 (1.67)
gdp pc	–.1187584 (–1.50)	–.3214949 (–3.23)	–.2591489 (–2.67)	–.4280704 (–4.69)	–.0329223 (–0.33)	–.0233128 (–0.43)
gfcf/gdp	.3904759 (5.90)	.3713147 (4.05)	.4068498 (4.39)	.4243444 (4.57)	.3322118 (4.32)	.1475053 (1.84)
wto					.2685281 (1.43)	.1863072 (3.70)
No. of obse-rvations	56	56	56	56	56	56
Adjusted R2	0.6198	0.3915	0.3951	0.2990	0.6826	0.5968
Hausman test	81.19 0.0000	20.91 0.0003	16.61 0.0009	53.65 0.0000	20.22 0.0025	4.08 0.5379
FE Test F (p – value)	3.73 0.0008	2.08 0.0397	1.83 0.0719	2.67 0.0090	2.42 0.0183	RE

Source: Own calculations based on EUROSTAT database, GGDC DATABASE and WTO.

Table 3d. Innovation mechanism and GDP dynamics – CEEC

	Dependent variable					
	1	2	3	4	5	6
	Average GDP growth rate					
Countries – Period	CEEC 1996–2012					
Explanatory variables						
tfp	.9499524 (4.86)				.8977141 (4.88)	
epo	.0476848 (1.77)	.0844624 (2.73)	.0987297 (3.17)		.0433098 (1.71)	.0655773 (2.23)
gerd	.1198335 (2.09)	.1256258 (1.91)		.1691316 (2.44)	.1130475 (2.11)	.1450811 (2.37)
gdp pc	–.0763973 (–0.69)	–.2265182 (–2.59)	–.170822 (–2.00)	–.3026477 (–3.37)	.1113151 (0.83)	–.0979969 (–1.05)
gfcf/gdp	.3834679 (4.51)	.2584202 (2.86)	.2890453 (3.14)	.31928 (3.36)	.2898784 (3.21)	.1599046 (1.76)
Wto					.4900705 (2.17)	.6210663 (2.69)
No. of obse-rvations	40	40	40	40	40	40
Adjusted R2	0.6191	0.5342	0.4858	0.4350	0.6347	0.6158
Hausman test	25.59 0.0001	2.60 0.6263	1.86 0.6009	4.41 0.220	15.76 0.0151	1.08 0.9558
FE Test F (p – value)	2.18 0.0600	RE	RE	RE	2.15 0.0653	RE

Source: Own calculations based on EUROSTAT database, GGDC DATABASE and WTO.

Comparing estimation results of equation (1) for the old Union to those of the new Union (Table 3c) we note that though TFP impact is positive and statistically significant in both cases the strength of the influence is much lower in the new Union. In the new Union, also the variable EPO is less significant, but GERD and GFCF/GDP become more important and have more powerful impact. This confirms the hypothesis that in diffusion economies the factors enhancing absorption like R&D and investments are more important than indigenous innovations.

As in the countries of the old Union in the equation (1) including TFP, for the new Union the technology gap (GDP p.c.) is insignificant, but gains importance in equations (2) to (4) when TFP is omitted, contrary to the case of the old Union. What is interesting, in the new Union without the variable TFP the variable EPO becomes significant, contrary to that in the old Union. In the estimation of complete equation (5) for new EU, including the demand variable WTO, technology gap and EPO lose significance while GERD still remains significant. In this regression, however, the demand variable appears insignificant and only when TFP is omitted in equation (6) regains statistical significance just like the variable EPO. It can be ascertained that in diffusion countries we see a clear influence of absorption factors on growth both on supply and demand side (GERD, GFCF/GDP, WTO). What is also noteworthy, both in old and new Union, technology gap becomes insignificant after inclusion of the demand factor.

The estimation results for the CEE countries (Table 3d) are basically similar to those obtained for the group of the new Union, with one noticeable difference. In the complete equation (5), with both TFP and WTO variables, the WTO variable appears significant unlike in the new Union and with a stronger impact. This confirms a greater role of demand factor in diffusion economies more distant from the technology frontier.

4. CRISIS, ECONOMIC FLUCTUATIONS AND TECHNOLOGY GAP

The next step in our research consists in investigating the effect of business fluctuations on the evolution of technology gap. Now the point is to explore a reverse causality to the one studied in section 3, namely the causal link from fluctuations to technology gap, not from the gap to fluctuations. To this purpose, a panel regression analysis was carried out for the variables calculated in section 4 for the four sub-periods, GDP (growth rates), GDP p.c., and WTO, which were used as independent variables this time. Dependent variables of the regression are differences between technology gaps at the beginning and the end of respective sub-periods.[14]

[14] In the case of gap reduction, the variable will take on negative sign and it will be positive in the case of gap growth.

The first independent variable (GDP) is the most important as it shows the effect of GDP growth on the evolution of technology gap. GDP p.c. isolates the pure effect of the size of technology gap, and WTO stands for demand Kaldor effect. We expect negative sign for GDP; the higher the GDP growth the larger the technology gap reduction (the difference will take more negative values). Also, the size of the gap should have positive influence on gap reduction; but because we used here a simplified measure of the gap (GDP p.c., and not relative to the frontier) we expect positive coefficient as the lower the value of this variable (the larger gap) the greater the gap reduction (more negative value of the dependent variable).[15] The last independent variable WTO may take on different signs depending on the force and direction of Kaldor effect in technology frontier and catching up countries. In the study, we applied the division into four groups of countries: Full panel, OLD EU, NEW EU, CEEC.

As shown in Table 4, in all the equations for all panel groups we obtained the expected sign of the influence of GDP growth on technology gap reduction and statistically significant results. Higher GDP growth rates mean a faster rate of gap reduction. Gaps diminish in boom and rise or diminish less strongly in slump.

In the estimation of the full equation, the importance of other independent variables is varying among groups of countries. The variable of technology gap GDP p.c. is in all groups significant and has expected positive sign in full panel, NEW EU and CEEC; the strongest impact in the latter case. Only in OLD EU group technology gap has negative sign and relatively weak effect on the explained variable. This might mean that a smaller technology gap in that group facilitates gap reduction since economies close to the technology frontier possess higher absorption capabilities to overcome the distance to the frontier.

The most interesting result was obtained for the variable WTO. In all groups estimated coefficient appeared to be positive and statistically significant, except for the case of OLD EU, where though positive it was found insignificant and low. This would suggest that demand effects (cumulative Kaldor effect) make the reduction of the gap for countries more distant from the frontier more difficult and improve the position of advanced countries. This is all the more striking as we found that innovation-diffusion mechanism in catching up countries is more demand oriented. However, we can explain this paradox by some conclusions drawn from the Verspagen model. While a pure Kaldor effect (term b in equation 7) eases technology diffusion in diffusion countries during world demand expansion, the cumulated demand effect (term c in equation 7), resulting from competitive advantage of leaders based on accumulated technologies, makes the catching up in boom for less developed countries more difficult.

The four sub-periods differ in the level of economic activity. The first one (1996–2000) was characterized by progressing slowdown that ended up in a breakdown of 1999–2000. The second (2001–2004) and third (2005–2008) periods were times of a growing boom while the fourth period is called a crisis.

[15] A higher value of GDP p.c. means a smaller gap and a smaller gap reduction expected.

Table 4. Factors influencing the reduction of technology gap

Independent variables	Dependent variable change of technology gap in sub-periods							
	Full Panel		OLD EU		NEW EU		CEEC	
	1	2	1	2	1	2	1	2
GDP	−.1409299 (−12.14)	−.100713 (−9.04)	−.062722 (−5.01)	−.021408 (−3.24)	−.154889 (−10.19)	−.10412 (−6.91)	−.187677 (−10.51)	−.127347 (−6.45)
GDP p.c.	.0122733 (3.64)		−.015927 (−5.58)		.0203319 (3.26)		.0282105 (2.48)	
WTO	.1200262 (7.47)		.013469 (1.48)		.1614636 (6.08)		.1945754 (6.02)	
No. of obs.	96	96	40	40	56	56	40	40
Adj.. R^2	0.6900	0.4680	0.5570	0.2165	0.7018	0.4693	0.7623	0.5223
Hausman	16,62	6,75	11.99	0.19	7.33	0.85	3.27	0.08
F Test p value	RE	RE	18.31 0.000	RE	RE	RE	RE	RE

Notice: *t* statistics in parentheses

Source: Own calculations based on EUROSTAT and WTO.

Table 5. Changes in technology gap in particular sub-periods

	1996_00	2001_04	2005_08	2009_12
	Absolute change of gap			
Full panel	–0,05	–0,31	–0,35	–0,02
OLD EU	0,00	0,01	–0,08	0,01
NEW EU	–0,10	–0,55	–0,54	–0,05
CEEC	–0,06	–0,73	–0,71	–0,13
	Gap change relative to the beginning of the sub–period			
Full panel	–0,02	–0,13	–0,16	–0,01
OLD EU	0,00	0,01	–0,06	0,01
NEW EU	–0,03	–0,17	–0,20	–0,02
CEEC	–0,02	–0,19	–0,23	–0,05

Notice: Gap calculated according to the formula GDP p.c. US/x. The upper panel shows an absolute change of the gap over the sub-period while the lower panel a gap change relative to the gap level at the beginning of the sub-period.

Source: Own calculations based on EUROSTAT database.

Table 5 shows changes of technology gaps in these particular periods and groups of countries. We can hardly see any changes in the group of OLD EU, only a small reduction in the years 2005–2008. The greatest reduction of the gap occurred in the CEEC group in the period before the accession or just after the accession. Similar but slightly weaker effect was seen in the NEW EU. During the crisis (2009–2012) technology gap reduction slows down in these two groups and the gap increases in the OLD EU. This confirms the results obtained above that economic slowdown and crisis impede technology diffusion and gap reduction.

It is noteworthy that the strongest gap change took place in the CEEC after the accession. We then tried to check the importance of the CEEC accession in that process by comparing gap changes in two periods, before and after accession, for the full panel and introducing a binary variable for the CEEC. Regression functions were estimated for all the three measures of technology gap. As expected, gap changes appeared to be negatively correlated with the size of the gap, and the results were statistically significant for all measures of the gap (Table 6). Surprisingly, the coefficient of binary variable proved to be positive, which means that the accession alone did not contribute to increasing of the rate of technology gap reduction in accession countries compared to the rest of the

Table 6. Accession and crisis effect on technology gap reduction

Independent variables	Dependent variables					
	1	2	3	4	5	6
	Accession effect Gap change in GDP p.c	Accession effect Gap change in GERD	Accession effect Gap change in EPO	Crisis effect Gap change in GDP p.c	Crisis effect Gap change in GERD.	Crisis effect Gap change in EPO
Initial gap	–.483489 –13.47***	–.2842056 –7.48***	–.4540528 –5.54***	–.3583601 –13.12***	–.251897 –8.47***	–.159733 –2.25**
DUM	.1641783 2.00**	.026486 0.04	22.30831 1.30	.2163984 4.21***	.2483235 0.54	24.10589 1.91*
No. of obs.	24	24	24	48	48	48
Adj. R^2	0,9461	0.8219	0.5786	0.8234	0.6053	0.134
Test F (*p* value)	202,86 0,000	54.08 0.0000	16.79 0.0000	110.59 0.0000	37.05 0.0000	4.67 0.0144

Source: Own calculations based on EUROSTAT database.

panel. The result was statistically significant only with GDP p.c. measure of the gap. Actually if we compare rates of gap reduction relative to the beginning of the period then the relative reduction increase in the period after accession was higher in the full panel – 23% (16/13), than in the CEEC – 21% (23/19). The accession effect most probably worked in both directions; also, the old EU gained from the EU enlargement and the accession of new countries. Leader countries reaped again benefit from a cumulated Kaldor effect.

A similar method was used to assess the crisis effect on technology gap (Table 6). The analysis was based on a comparison of gap reductions in the period of crisis 2009–2012 and before the crisis 2005–2008 relative to the beginning of each period for the full panel while introducing the binary variable for the period of crisis. Here, the initial gap also affected gap reductions by all measures of the gap and in all periods, with statistically significant results. In this case, instead, as expected, the estimated coefficient of binary variable appeared to be positive, suggesting a weakening of gap reduction during the crisis. However, this result was only significant with GDP measure of the gap.

5. TECHNOLOGY GAP AND CONVERGENCE

As noted earlier, reductions of technology gaps between leaders and catching up countries should lead to convergence in terms of GDP p.c. in the whole sample of countries. This process is analyzed in two approaches: as a convergence to a sample average and as a convergence to the technological frontier (leader). In both cases a simple regression model proposed by Verspagen (1994) is applied.

In the first case we analyzed the difference of logarithm of GDP p.c. of a country and that of the sample average as follows,

$$W_{it} = \ln\frac{Q_{it}}{P_{it}} - \ln\left(\frac{Q_t}{P_t}\right)^{*} \tag{10}$$

where Q denotes GDP, P is population, subscripts i and t denote a country and time, respectively, and superscript * denotes a sample average.

In the second case, we analyzed the difference of logarithm of GDP p.c. of a country and that of the value of this indicator for the technology frontier (USA) denoted by superscript ** as follows,

$$W_{it} = \ln\frac{Q_{it}}{P_{it}} - \ln\left(\frac{Q_t}{P_t}\right)^{**}. \tag{11}$$

W_{it} indicates technology gaps and changes according to the following process:

$$W_{it+1} = \Psi W_{it}. \tag{12}$$

If $\Psi > 1$, per capita income diverge. If $\Psi < 1$, convergence takes place. Using these definitions, Ψ is estimated for different periods by regression function, and additionally the interval $\Psi \pm 2\sigma$ is calculated for each period, where σ denotes the standard error of the estimated Ψ. The deviations of $\Psi \pm 2\sigma$ from the level 1 indicate the significance of convergence or divergence in a given year.

Figure 1 presents the estimated values of Ψ using the procedure of regression on the sample average. No clear tendency towards convergence can be seen in the first period 1996–2000, and a divergence is rather observed in the slowdown of 1999–2000. A definitely strong convergence trend took place in the following two periods, 2001–2004 and 2005–2008. It appeared before the accession and weakened a bit just after the accession (2004–2005) to revive in the last years before the crisis. In the last period of crisis, we see a clear slowdown of convergence.[16]

Figure 2 presents the results of the regression on the technology frontier. It appears that the estimated parameters are almost identical as in the regression on the sample average. Since the diffusion within the group seems to be equally strong as catching up with the leader, we did not yet approach a new radical innovation wave, a structural break leading to a flight of the technology frontier.

Let's try to sum up the findings of the preceding sections and relate them to the observed convergence trends. We found a positive correlation of GDP and TFP fluctuations with the technology gap, which means that less advanced countries are more exposed to dropping GDP growth rates during crisis. This involves a fall in the technology gap reduction in line with their demand oriented diffusion mechanism. At the same time, innovation mechanism in advanced countries relies more on supply factors like TFP, which is not greatly susceptible to crisis breakdowns and makes those countries advantaged due to exogenous factors in such periods. Since an exogenous supply factor (TFP) dominates over a demand factor (WTO) in the innovation mechanism of the old Union and vice versa in the CEEC, the technology gap reduction was positively influenced by GDP growth and the size of the gap, but negatively by the demand factor (WTO), which benefited the advanced countries.

Since the technology gap dynamics driven by the interaction of different innovation mechanisms in various groups of countries determines convergence processes, it seems that advanced countries are advantaged in crisis due to exogenous factors and the cumulated Kaldor effect. This impedes the convergence trend in crisis and explains our results obtained in this section. As the gap reduction concerned only the groups of NEW EU and CEEC, the convergence was basically determined by what happened in those countries. The countries of the old Union did not show any clear reductions of the gap.

[16] A slowdown of convergence in the EU during the last crisis is also evidenced in *Innovation Union Scoreboard 2013* (p.11).

In terms of a modified Verspagen model of technology gap, exogenous supply factors and cumulated Kaldor effect impeded convergence that was, however, speeded up by a pure Kaldor effect and Gerschenkron effect.

Figure 1. GDP convergence and divergence to the technology frontier

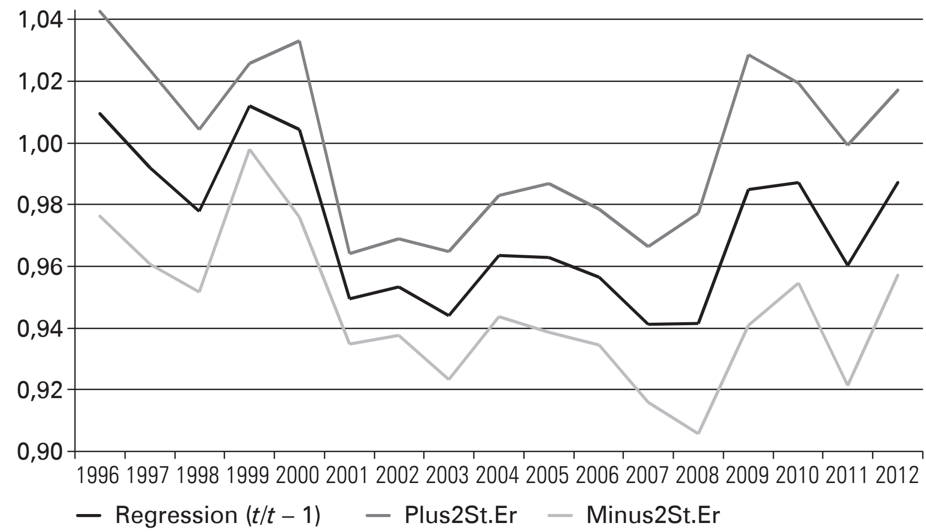
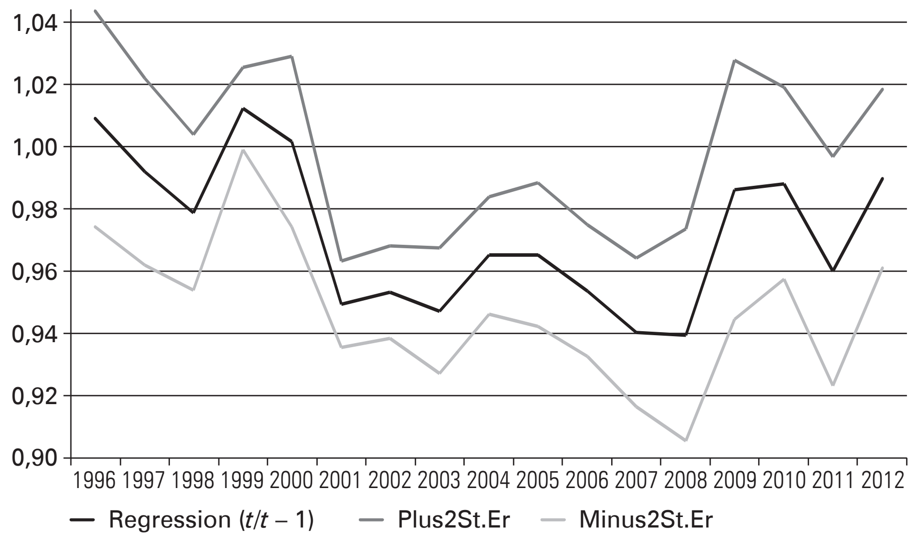


Figure 2. GDP convergence and divergence to the sample average



6. STRUCTURAL EFFECTS

Changes in technology gap and convergence were accompanied by a structural transformation of the economies, which contributed to these trends. We assume that these structural effects can be adequately explored in the analysis of changes in comparative advantages and export patterns of countries. According to the Ricardian theory of technology gap, changes in output structure caused by variations in productivity lead to changes in comparative advantages in international trade and consequently to varying trade patterns.[17]

As a tool for the analysis we apply indices of *Revealed Comparative Advantage* (*RCA*) proposed by Balassa (1965), defined as a ratio of the share of a given sector in the total exports of a country to the share of this sector in total world exports:

$$RCA_{ij} = \frac{X_{ij} / \sum_i X_{ij}}{X_{iW} / \sum_i X_{iW}} \tag{13}$$

where X denotes exports, i and j denote sector and country, respectively, and W stands for world.

Standard Balassa indices assume asymmetric positive values that makes inter-country comparisons difficult. To avoid this problem, the indices are transformed into symmetric measures through the following procedure $(RCA - 1)/(RCA + 1)$. Such an index assumes values between –1 and +1. Total world exports are adopted as a *benchmark*.

Based on a technology taxonomy of industrial branches proposed by Pavitt (1984) six sectors are singled out[18]: science-based sector (P1), specialised suppliers sector (P2), supplier dominated sector (P3), technology scale-intensive sector (P4), and resource scale-intensive sector (P5) that is additionally divided into mineral resource scale-intensive sub-sector (P5a) and agricultural resource scale-intensive sub-sector (P5b). A special feature of this taxonomy is that it is based on sourcing of innovations, which enables tracing the paths of intersectoral innovation diffusion. And thus, innovation sourcing is located: in R&D in the science-intensive sector; in meeting the sophisticated requirements of capital goods users in the specialized suppliers sector; in assimilation of innovations produced in other sectors in the supply dominated sector; in building up complex production systems in order to manage a large scale of production in the scale-intensive sectors.[19] The sectors can be ordered depending on their technological intensity with the highest rank of the science-based sector 1P, followed by 2P, 4P, then 5P(b) and 5P(a), and the least technologically advanced sector 3P.

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[17] See Beelen, Verspagen (1994), and for the Ricardian technology gap: Cimoli, Soete (1992), Kubielas (2009).

[18] The original four-sector taxonomy by Pavitt is modified by splitting the scale intensive sector into three sectors as in Kubielas (2009).

[19] See the table for industries of the Pavitt's technology sectors in the Appendix.

The research is carried out on the WITS database (*World Integrated Trade Solutions)* of World Bank and UNCTAD. The Balassa indices are computed for each sector and country using trade data at the two digit level of the SITC rev.3 classification. Then individual RCA indices are aggregated into unweighted sector averages for two groups of countries: CEEC and OLD–1. These two groups are selected because they differ mostly in respect of technology gaps. The evolution of RCA indices for particular sectors and selected groups of countries shows clearly sectoral structural changes that enhanced technology gap reduction and convergence in these groups of countries.

Figures 3a to 3f present the results obtained. It is striking that in the old Union the RCA indices in the first four sectors (science-based, specialised suppliers, supplier dominated, technology scale-intensive) almost do not change and fluctuate around zero. The old Union appears to be neutral against the world economy regarding comparative advantages in these four sectors.

Significant changes occur, however, in the same four sectors in the CEEC group. Here we can see a clear convergence and catching up with the old EU by rising RCA's in 1P, 2P, 4P, and a convergence by declining RCA in 3P.

Though the CEEC indicate a negative RCA index in the science-based sector over the whole period, nevertheless the index rises distinctly, especially after the accession, from an initial level of –0,50 to close to zero. A similar trend can be seen in the specialized suppliers sector where the index, still negative but higher than in the science-based sector, grows monotonically up to the crisis when it begins to decline slightly. The most striking is the evolution of comparative advantage of the CEEC in the technology scale intensive sector, where an initially negative index value starts to grow later than in the two preceding sectors (around 2000) but gains momentum after the accession to reach a positive level higher than in the old Union after 2006. This might be an effect of relocation to the CEEC of industries belonging to that sector (in particular automobile industry). Finally, in the most traditional sector (3P), the convergence goes in the opposite direction from a higher level by declining RCA until the crisis when the index stabilizes at still a high value. In this technologically least advanced sector the CEEC group retains the advantage over the old Union during the whole period.

In the mineral resource scale-intensive sector, we note a stable and negative RCA index, with a slight downward trend in the old Union while in the CEEC a fast decline of the index is observed until the accession, followed by a small increase and a stabilization at a negative level, even below that in the old Union. The sector, which enjoyed traditionally a high comparative advantage in the CEEC before the transformation, has lost it after the transformation.

A different picture emerges in the agricultural resource scale-intensive sector. This is the sole sector in which the old Union indicates a continued increase of comparative advantage from initially negative values to positive values of RCA after the year 2000.[20] The CEEC, instead, having enjoyed a comparative advantage in the sector before the transformation, are quickly losing it after the transformation and only after the accession the negative trend is reversed and a complete convergence to the rising RCA in the old Union takes place.

Summing up, we can presume that the closing up of technology gaps and convergence were much supported by positive structural trends, which took place mainly in the CEEC in the following sectors: science-based, specialized suppliers, technology scale-intensive, and agricultural resource scale-intensive. Furthermore, a declining comparative advantages of the CEEC in the traditional sectors (3P and 5Pa) characterized by lower productivity dynamics additionally strengthened the trend to convergence.

Figure 3a. Average RCA 1P

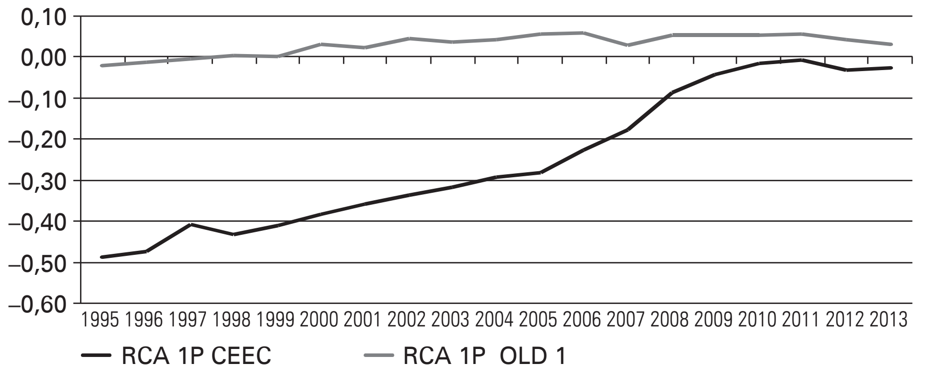
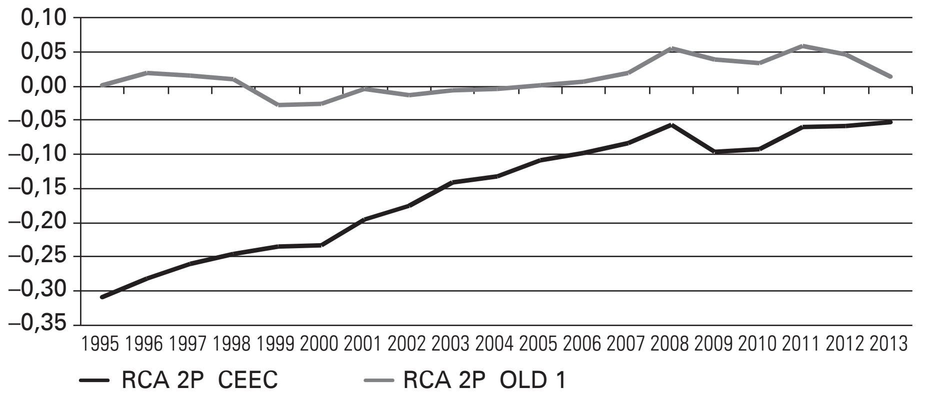


Figure 3b. Average RCA 2P



[20] It is by some authors regarded as an effect of the common agricultural Policy of the EU (Fagerberg, 2002a).

Figure 3c. Average RCA 3P

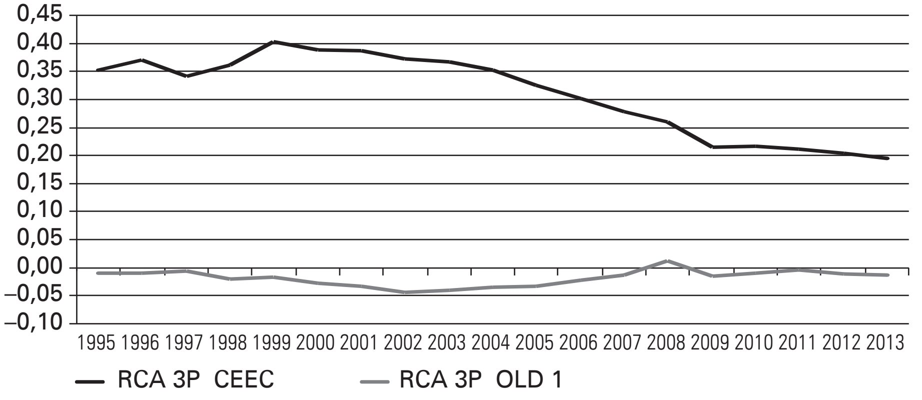


Figure 3d. Average RCA 4P

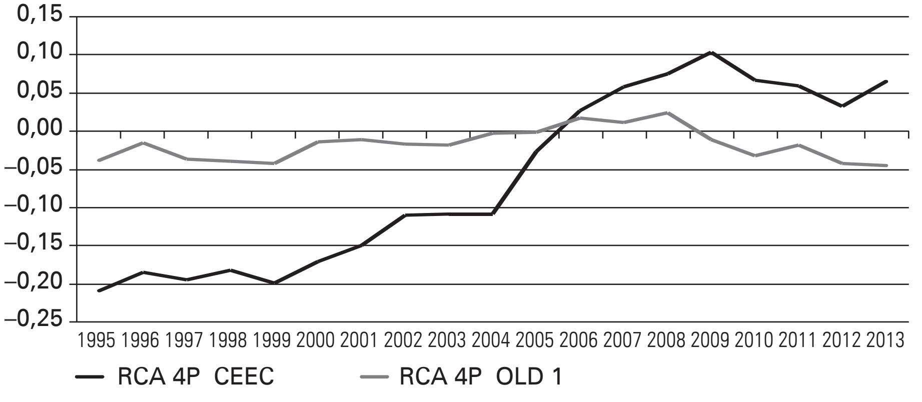


Figure 3e. Average RCA 5P(a)

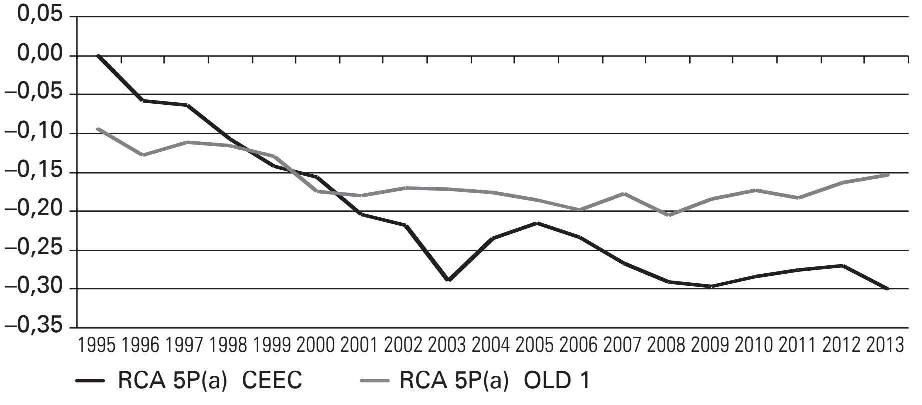
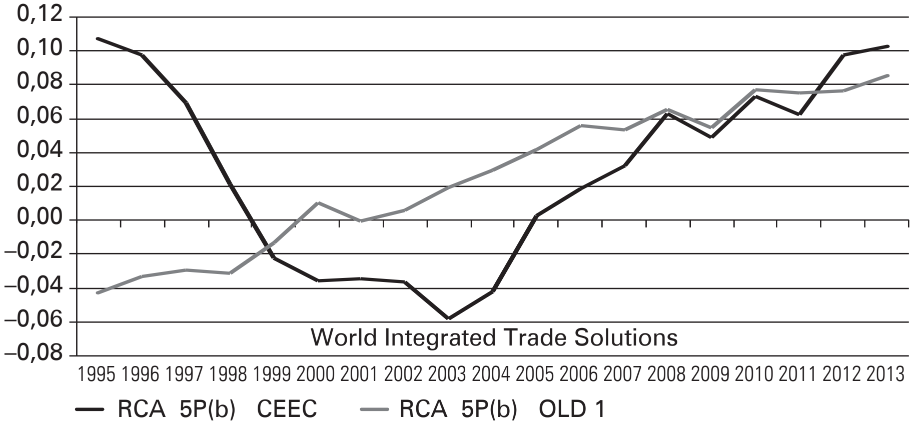


Figure 3f. Average RCA 5P(b)



Source: Own calculations based on WITS database (*World Integrated Trade Solutions)*.

SUMMARY AND CONCLUSIONS

In the study a Schumpeterian perspective was adopted to capture the interaction between economic fluctuations and growth dynamics. In this approach, these two processes are linked by innovations that are not evenly distributed over time and space, causing technology gaps between countries. However, less developed countries have the chance to catch up through imitation and diffusion of innovative technologies, and thus to reduce the technology gap. In this context a question arises as to how cyclical fluctuations affect innovation in the technology frontier area and diffusion in catching up countries. But this relation is reciprocal as the technology gap has an impact on the economy's susceptibility to cyclical fluctuations. The outcome of the feedback is determined by innovation mechanisms working on both sides of the technology gap. In the analysis, we attempted to highlight the interrelationships between economic fluctuations, technology gaps and innovation mechanisms.

It was found that, firstly, technology gaps were the largest in the new accession countries of the EU, where we also found the fastest rate of gap reduction over the analyzed period. The trends applied to all the gap measures used (GDP p.c., GERD p.c., EPO p.c.), though gap sizes were the largest and reduction thereof was the fastest when measured by patenting (EPO p.c.). *This confirms the Gerschenkron's hypothesis of backwardness' advantage.*

Secondly, a significant positive correlation was found between the size of technology gap and growth rate fluctuations of GDP and TFP. This means that the larger the technology gap the more is the economy exposed to fluctuations of the growth rates of GDP and TFP. However, this relation could not be confirmed in the case of TFP during the last crisis, when mainly strong demand effects of technology gap were observed while TFP changes are related rather to supply exogenous factors. Generally, it can then be ascertained that *technology gap enhances cyclical fluctuations*.

The analysis of the innovation mechanisms on both sides of the technology gap revealed that demand factors and technology gap effect are more significant for GDP growth in diffusion countries than for countries at the technology frontier, where innovation mechanism is dominated by supply factors. It is not surprising, then, that diffusion countries are more exposed to declining GDP growth in downturns. This follows from the fact that *the innovation mechanism in the advanced countries is more supply oriented while in the less advanced countries it is more demand oriented.*

But it appears that even in times of economic expansion the cumulated demand effect can be disadvantageous to catching up countries. Though a pure Kaldor effect accelerates diffusion and reduces technology gap, *a cumulated demand effect, that determines comparative advantage of the advanced countries in trade, turns out to their advantage and impedes technology gap reduction in the expansion of world market.* Thus, a principal factor of gap reduction in the less developed countries is the size of the gap (Gerschenkron's effect), unlike in the most advanced countries. In all cases a positive and statistically significant impact of economic growth rate on gap reductions was found. *Gaps decrease in boom and rise or decrease less in slump.*

As the descriptive statistics show, the strongest gap reductions took place in times of prosperity before and just after the accession while the crisis brought about an end to this trend. In absolute terms the biggest reduction effect was seen in the CEEC after the accession. In another panel regression analysis we have isolated this effect for the accession countries but have found that in relative terms the accession did not contribute to gap reduction more in the accession countries but rather less than in the rest of the panel. *It seems that the accession also contributed to the reduction of the gaps in the old Europe due to market enlargement.* By the same method the crisis effect was explored and *a negative influence of the crisis on gap reduction was evidently confirmed*.

The technology gap dynamics is mirrored in GDP convergence processes both to the sample average and to the technology frontier. *A clear trend to convergence can be observed only in the prosperity years while in the downturn of 1999–2000 and during the last crisis we can see a slowdown in convergence or even a divergence.* As the convergence to the average of the sample and to the technology frontier are identical we are not yet anticipating a burst of a new innovation wave leading to a flight of the technology frontier.

It seems that the advantage of advanced countries resulted from their small technology gap, which made them more resistant to economic fluctuations as exogenous supply factors of their innovation mechanism proved less sensitive, and in economic expansion they gained from a cumulated demand effect. The catching up countries relied more on the demand factor of Kaldor effect which in the slowdown abated the technology gap effect, their main factor reducing the gap.

The processes of gap reduction and convergence were accompanied by structural changes in output and trade, which have been analyzed on the base of comparative advantages in trade of the old EU and the accession countries using the Pavitt's taxonomy of industries.

While in the old EU the comparative advantages in four sectors (science-based, specialized suppliers, technology scale-intensive, supplier dominated) did not change and stayed around zero, the most spectacular changes leading to convergence took place in those sectors in the accession countries. In the first three most advanced sectors a strong convergence trend upwards to the old EU level was seen in the CEEC, even exceeding that level in the technology scale-intensive sector. In the traditional supplier dominated sector, instead, the accession countries lost comparative advantage and approached the old EU level by a downward convergence trend. A similar trend took place in the other traditional sector, the mineral resource scale-intensive sector, where the RCA of the CEEC decreased even below the old EU level. Finally, in the agricultural resource scale-intensive sector the CEEC group quickly lost their initial comparative advantages and only after the accession the negative trend was reversed and a complete convergence to the rising RCA in the old Union took place.

The above described structural changes clearly correspond to the results of the analysis of technology gap reduction and convergence. Like in the case of technology gap reduction, structural changes in the catching up countries were the main factor driving convergence. And, similarly, the accession and crisis effects were visible.

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DATA SOURCES

EUROSTAT: GDP annual growth rates, GDP p.c. (EURO PPP), GERD p.c. (EURO 2005 prices), EPO p.c.,GFCF/GDP.
GGDC DATABASE: The Conference Board Total Economy Database – TFP.
WITS (World Integrated Trade Solutions) Word Bank/UNCTAD: export data SITC rev.3.
WTO (World Trade Organization): growth in the volume of world merchandise exports.

APPENDIX: TECHNOLOGY CLASSIFICATION OF INDUSTRIES BY PAVITT'S TAXONOMY

Pavitt	SITC rev.3	
1P	54 75 76 792	Medicinal and pharmaceutical products Office machines and computers Telecommunication and RTV equipment Aircraft/spacecraft
2P	71 72 77 87 88	Power-generating machinery and equipment Machinery specialized for particular industries Electrical machinery, apparatus and appliances Scientific and controlling instruments Photographic apparatus, equipment and optical goods

3P	84 85 82 61 63 65 69	Apparel and clothing Footwear Furniture Leather Cork/wood Textile articles Metal manufactures
4P	78 791 793	Road vehicles Railway/trams Ships
5P(a)	25 23 27 28 32 33 34 51 52 53 55 56 57 58 59	Pulp Crude/synthetic rubber Crude fertilizer/mineral Metal ores Coal/coke Petroleum Gas Organic chemicals Inorganic chemicals Dyeing/tanning/colors Cosmetic Manufactured fertilizers Plastics in primary form Plastics in non-primary form Chemicals nes
5P(b)	0 1	Food Beverages/tobacco

Source: Own elaboration based on Pavitt (1984).

LUKA TECHNOLOGICZNA A KRYZYS GOSPODARCZY W NOWEJ I STAREJ EUROPIE

STRESZCZENIE

Celem artykułu jest badanie współzależności między wahaniami koniunktury gospodarczej, dynamiką luki technologicznej a konwergencją ekonomiczną w Unii Europejskiej. Przyjmujemy, że te procesy są powiązane poprzez mechanizmy innowacyjne, których działanie na rynkach krajów na granicy technologicznej różni się od tych, które funkcjonują w krajach doganiających. W pierwszym przypadku badanie potwierdza podażowy charakter tego mechanizmu, podczas gdy w drugim – popytowy. Prowadzi to do odmiennego przebiegu procesów dostosowawczych w różnych fazach cyklu koniunkturalnego w tych dwóch grupach krajów. Został przebadany wpływ luki technologicznej na fluktuacje gospodarcze (kryzys) oraz wpływ fluktuacji gospodarczych na redukcję luki technologicznej i konwergencję. Uzyskane wyniki znajdują wyjaśnienie w świetle interakcji różnych mechanizmów innowacyjnych na granicy technologicznej i w krajach doganiających. Najważniejszym czynnikiem redukcji luki w krajach mniej rozwiniętych okazał się sam rozmiar luki (efekt Gerschenkrona). Konwergencja w kategoriach PKB per capita w Unii Europejskiej następowała głównie przez redukcję luki technologicznej w krajach mniej rozwiniętych, gdzie również miały miejsce największe zmiany strukturalne w produkcji i handlu. Kryzys spowolnił proces konwergencji, a akcesja nowych krajów go przyspieszyła.

Słowa kluczowe: luka technologiczna, wzrost gospodarczy, kryzys, akcesja, konwergencja, innowacje i dyfuzje, Unia Europejska.
JEL Classification: F15, F43, F44, O33, O47, O52