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CONVERGENCE ACROSS THE BALTIC STATES

BACHELOR THESIS

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Abstract

This study provides a review of convergence in the Baltic States. The empirical part of the paper applies to different tests of convergence, which are usually appearing in connection with the question of convergence in relation to neoclassical growth models. Following Sala-i-Martin, so-called beta-convergence and sigma-convergence tests are conducted for regions of the Baltic States. Time series tests of convergence are considered to examine a convergence among the Baltic States The beta- and sigma-convergence tests indicate that there is a divergence of GDP per capita among the regions of each country. Time series tests of convergence demonstrate that there is no convergence between Latvia and Lithuania or between Latvia and Estonia. However, there is a process of convergence between Estonia and Lithuania.

Kyewords: Convergence; Regional convergence; beta-convergence; sigma-convergence; time series convergence.

Anotācija

Šis darbs satur konverģences apskatu Baltijas valstīs. Darba empīriskajā daļā parādīti dažādi konverģences testi, ko parasti pielieto konverģences pētījumiem attiecībā uz neoklasiskiem augsmes modeļiem. Sekojot Sala-i-Martin, tā saucamie beta-konverģences un sigma-konverģences testi tika pielietoti Baltijas valstu reģioniem. Laika rindu konverģences testi veikti, lai izskatītu konverģenci starp Baltijas valstīm. Beta un sigma-konverģences testi parāda, ka katrā no šīm valstīm pastāv diverģences process reģionos. Šis fakts tika konstatēts, analizējot datus par IKP uz vienu iedzīvotāju. Laika rindu konverģences testi parāda, ka starp Latviju un Lietuvu un starp Latviju un Igauniju nepastāv konverģences, bet starp Lietuvu un Igauniju ir novērots konverģences process.

Atslēgvārdi: Konverģence; Reģionālā konverģence; sigma-konverģence; laika rindu konverģence.

CONTENT

ABBREVIATIONS

GDP – Gross Domestic Product

CPI – Consumer Price Index

HIPC – Harmonized Index of Consumer Prices

EU – European Union

USA – the United States of America

OECD – Organisation for Economic Cooperation and Development

OLS – Ordinary Least Squares

CV – coefficient of variation

DF test - Dickey-Fuller test

ADF test - Augmented Dickey-Fuller test

DW – Durbin-Watson

SC - Schwarz Criterion

LVL – Latvian lats

LTL – Lithuanian litas

EEK – Estonian kroon

INTRODUCTION

Classical economists, such as Adam Smith, David Ricardo, and Thomas Malthus, and, much later, Frank Ramsey, Allyn Young, Frank Knight and Joseph Schumpeter provided many of the basic ingredients that appear in modern theories of economic growth. These ideas include the basic approaches of competitive behavior and equilibrium dynamics, the role of diminishing returns and its relation to the accumulation of physical and human capital, the interplay between income per capita and the growth rate of population, the effects of technological progress in the forms of increased specialization of labor and developments of goods and discoveries of new methods of production, and the role of monopoly power as an incentive for technological advance. (9, p. 9 – 11)

From a chronological viewpoint, the starting point for modern growth theory is the classic article of Ramsey, a work that was several decades ahead of its time. Ramsey's treatment of household optimization over time goes far beyond its application to growth theory; it is hard now to discuss consumption theory, asset pricing or even business-cycle theory without invoking the optimality conditions that Ramsey introduced to economists. Ramsey's intertemporally separable utility function is as widely used today as the Cobb-Douglas production function. The economics profession did not, however, accept or widely use Ramsey's approach until the 1960s. (9, p. 9 – 11)

The next and more important contributions were those of Solow and Swan. The key aspect of the Solow-Swan model is the neoclassical form of production function, a specification that assumes constant returns to scale, diminishing returns to each input, and some positive and smooth elasticity of substitution between the inputs. This production function is combined with a constant saving rate rule to generate an extremely simple general-equilibrium model of the economy. (9, p. 9 – 11)

One of prediction from these models, which has been exploited seriously as an empirical hypothesis recently, is *absolute convergence*. The hypothesis that poor economies tend to grow faster per capita than rich ones – without conditioning on any other characteristics of economies – is referred to absolute convergence. The lower the starting level of real GDP (Gross Domestic Product) per capita, relative to the long-run or steady-state position, the faster is the growth rate. This property arrives from the assumption of diminishing returns to capital; economies that have less capital per worker (relative to their long-run capital per worker) tend to have higher rates of return and higher growth rates. It is more likely to find absolute convergence when testing convergence of regions of the same country which are more *homogeneous*, since they share the same legal system, similar technology, similar educational level, etc. On the contrary, when the economies have different structures, it is assumed that they converge to a different steady state point. In this case convergence is said to be conditional. The *conditional convergence hypothesis* states that if countries possess the same technological possibilities and population growth rates but differ in savings propensities and initial capital-labor ratio, then there should still be convergence to the same growth rate, but just not necessarily at the same capital-labor ratio. (6, p. 12– 13)

It can be noticed that in the Baltic States there is an example of an alternative process. Most part of the population is concentrated in urban areas and fewer people live in rural area showing big differences in density of population of the countries. There are also differences in employment rates between high and less developed regions. Therefore, there is an evidence of fast developing areas (primarily along with the capitals of the countries – e.g., Riga and Riga region) and areas (e.g., Latgale region) that delay their process of catching up with 'leaders-regions'. Differences among regions influence on levels of output and those, in turn, affect income levels. The disparities between initially rich and initially poor regions are becoming more and more evident as well.

Obviously, convergence in the Baltic countries is a continually important research field, giving additional information of development of regions of the countries. An essential argument for regional policy is the insight that a balanced regional development is a prerequisite for social cohesion and an increase of competitiveness of the countries and regions.

In the economic literature devoted to the integration theory, there are two distinct positions relative to the process of the regional growth and catching up hypothesis.

The first one is the thesis of regional divergence, which states that a high development of a country can be in favor of the prosperous regions. The concentration of economic activities in these attractive centers which dispose more developed markets and higher level of industrialization can create additional difficulties for the less developed regions and delay the process of catching up. (7, p. 22 – 40)

The second one is the thesis of the regional convergence stating that higher development will attenuate the initial regional disparities and in the long run the tendency is regional convergence rather than divergence. According to the convergence argument the fact that the USA (United States of America) shows lower regional disparities than the regions of the European Union - is the result of a deeper economic integration, including monetary integration and common currency. (7, p. 22 – 40)

Therefore, it is important to measure the real convergence between regions within the Baltic States in terms of GDP per capita, especially for the later period, when the countries make a strong economic progress.

To take such a measurement a neo-classical approach to convergence based on the simple idea that convergence implies that poor regions grow faster than rich regions in terms of their GDP per capita is used in the work. Accordingly, a strong negative relationship between the growth of GDP per capita and the initial level of GDP is not expected to be found in support of divergence, in a cross-section analysis of different economies.

In this study, the hypothesis of convergence is tested empirically for the countries and for the regions in the Baltic States, using the most recent data available on GDP per capita and CPI (Consumer Price Index).

There does not exist a consensus methodological framework to guide empirical work on testing for regional convergence. Instead, several distinct types of convergence have been suggested in the literature, each implying different test equations. Therefore, three categories of empirical tests were conducted.

The first and dominating type of test studies analyses the cross-section correlation between GDP per capita levels and subsequent growth rates for countries or regions. A negative correlation is taken as evidence of convergence as it implies that – on average – economies with low per capita initial level of GDP are growing faster than those with higher initial GDP per capita. This form of convergence has been termed *ß-convergence* with β - a speed of convergence (divergence).

The second type of test studies investigates whether the cross-section variance of GDP per capita levels tends to decrease over time. This form of convergence has been called σ-*convergence*.

The third type of tests focuses attention on the long-run behavior of differences in GDP per capita across economies. These tests interpret convergence to mean that these differences are transitory in the sense that long-run forecasts of the difference between any pair of economies converge to zero as the forecast horizon grows. Convergence in this sense is called *time series forecast convergence*.

Methodological and theoretical base of the study are foreign working papers, information of scientific books and researches. In order to carry out the study, the following literature and sources were used: published scientific literature in Latvian and English, working papers and publications of the Bank of Latvia and the European Central Bank, accessible information and databases in Internet.

Generally accepted methods of economic science were used – analyzing method, qualitative analyzing methods, different quantitative methods (graphic analysis, correlation and regression analysis).

The structure of the conducted study is the following:

In section 1, an overview of the neo-classical framework of real convergence is made and some recent empirical results are discussed. The section presents description of models that can be applied to detect a convergence. Estimated models should be examined for problems of autocorrelation or heteroscedasticity and therefore, technique of the Runs test, Durbin –Watson d-test and Spearman's test is presented in the section.

In section 2, recent regional data of real GDP are described: Latvia – 1995 – 2005, Lithuania – 1995 – 2005, Estonia – 1996 – 2005. The data were used in the tests of σ- and β-convergence. The tests of σ-convergence are presented for the regional data of the Baltic countries and obtained results are explained in this section.

In section 3, the tests of β-convergence for data for regions of the Baltic countries are run and results of the tests are discussed. It also contains estimation of models for each country along with the examination for problems of autocorrelation and heteroscedasticity in the models.

In section 4, quarterly data of real GDP per capita (1997 – 2007) for the Baltic States are described. The section also contains tests of stationarity of the data obtained. The time series tests of convergence are conducted and the results of the tests are explained in this section.

. The last section of the study contains main findings of the paper and suggestions.

Data analyses were done with help of EViews 5.0.

The paper consists of 73 pages, 10 Tables, 12 Figures and 10 Appendixes.

1 TESTS OF CONVERGENCE AND ESTIMATION OF MODELS

This section presents an overview of the theory of convergence and description of the models that can be applied to detect a convergence. In order to check if estimated models have problems of autocorrelation or heteroscedasticity, technique of tests (the Runs test, Durbin –Watson d test and Spearman's test) is presented below.

1.1 Overview of convergence

There are two concepts of convergence appear in discussion of economic growth across countries or regions. In one view, convergence applies if a poor economy tends to grow faster than a rich one, so that the poor country tends to catch up with the rich one in terms of the level of GDP per capita or product. This property corresponds to the concept of β–convergence (this phenomenon is sometimes described as "regression towards the mean"). The second concept concerns cross-sectional dispersion. In this context dispersion occurs if the dispersion – measured, for example, by the standard deviation of GDP per capita or product across a group of countries or regions - declines over time. We call this process σ-convergence.

The β-convergence of the neo-classical approach is obtained by a regression analysis estimating the growth of GDP per capita of a certain period of time on the initial level of GDP per capita. The regression coefficient β-with a negative sign indicates that regions with a lower initial level of GDP per capita grow more rapidly than regions with a higher initial level of GDP per capita. The general aspect of the estimated equation has the following non linear specification:

$$\frac{1}{T}\log\left(\frac{Y_{it}}{Y_{i0}}\right) = \alpha - \frac{1-e^{-\beta t}}{T}\log(Y_0) + \gamma X_{it} + u_{it} \qquad (1.1.1)$$

where Y_{it} is GDP per capita of region i at time t, Y_{io} is the initial GDP per capita of region i, X_{it} is a set of structural exogenous variables which can influence the growth of GDP per capita, T is the time length in which the growth of GDP per capita is measured, u_{it} is the stochastic error of the equation, α is the constant term which according to the neo-classics is influenced by the rate of technological progress and the steady-state growth rate of GDP per capita, and β is the convergence coefficient which is obtained by a linear estimation. The coefficient β in this specification has a positive sign and reflects the annual rate of convergence or speed of convergence. (6)

The neo-classical theory distinguishes two types of convergence, unconditional and conditional convergence. When it is assumed that all regions (countries) converge to the same terminal point (the steady state point) the convergence is said to be unconditional. In this case, β is obtained without considering in the estimation the set of the structural variables X_{it}, since it is assumed that the economies do not differ significantly in their levels of technology, investment ratio, industrial structure, human capital qualification and other structural factors. In this context, it is more likely to find unconditional convergence when the model is tested for regions of the same country which are more homogeneous, since they share the same legal system, similar technology, similar educational level, etc. On the contrary, when the economies have different structures, it is assumed that they converge to a different steady state point. In this case convergence is said to be conditional and β is obtained by considering in the estimation the set of the conditioning structural factors (X_{it} in Equation (1.1.1)) which are supposed to influence the growth of GDP per capita. (6)

In the neo-classical model, diminishing returns to capital is the explanation why poor regions (countries) grow faster relatively to the rich regions in terms of their per capita income showing β-convergence. Diminishing returns of capital implies that the rate of return is negatively related to the stock of capital per head so that, other things being equal, countries with low amount of capital per head are predicted to grow faster.

Equation (1.1.1) has been estimated in different ways and with different purposes. Barro and Sala – i –Martin have estimated the model to study convergence in per capita personal income across 48 states of the USA during a very long period, 1880-1988, and found evidence of β-convergence which runs at a rate of 2% per year. Similar estimates for the β-coefficient have been found when a different set of data are used referring to the per capita gross state product of the 48 states over the period 1963- 1986. However, the rate of convergence is not stable over time and is shown to be sensitive to the chosen periodicity.

Dewhurst J. H. and Mutis-Gaitan used the same approach to test the convergence of GDP per capita among 63 regions of the EU (European Union) over the period 1981-1991. Estimating the above Equation (1.1.1) (in a more simplified form) they found a conditional convergence across regions in the EU for the whole period at a slow rate of less than 1% per annum. The conditional variables they used include regional population, working-age population, participation rate, regional unemployment rate and the share of employment in agriculture and services. The regions were converging at varying speed heavily dependent on national economic performance. (15)

Armstrong has tested the convergence hypothesis of GDP per capita across 85 regions within the European Union over the period 1950-1992. He finds a slow regional convergence process for the whole period (at about 1% per year) and evidence of a falling convergence rate in the 1970s and 1980s. He finds no evidence to support the existence of separate convergence clubs (between north-south or core peripheral regions) within the EU.

There are many other studies testing the hypothesis of β-convergence across regions in the EU. A common finding of these studies is that there is a significant negative relation between the growth of per capita income and the starting level of per capita income which confirms the neo-classical hypothesis of convergence. However, all studies agree that the process of convergence is very slow or dramatically slow in the EU. A speed of 2% (or less than that) of convergence per year found in most studies since 1950 implies that it will take 50 or more years to eliminate the asymmetries between the regions of the EU, a fact which calls for a more active regional policy in order to accelerate the catching up process of growth between regions. Meanwhile, with regard to σ-convergence the European Commission itself has provided evidence which show the following performance: from the beginning of the 1960s to the middle of the 1970s the per capita income disparities across countries in the EU reduced significantly. Since then and up to the middle of the 1980s the tendency has been reversed and a process of divergence took place. In the second half of the1980s the disparities decreased again but at a slower rate. Finally, this less intensive convergence disappeared in the first half of the 1990s, period in which the disparities across countries remained constant. At the same time, if we consider the disparities across regions the evidence shows that the tendency towards convergence is even lower, especially in the 1980s and 1990s. (15)

Concerning the β-and σ-convergence an interesting question is to know which of the two concepts is preferable.

According to Sala-i-Martin, both concepts are useful since they measure convergence or divergence in a different manner and they give different information. However, he suggests that β-convergence is a more interesting concept since it responds to questions, such as, whether poor economies (countries or regions) are predicted to grow faster than rich ones, how fast the convergence process is, whether the convergence process is conditional or unconditional and whether there is a different convergence process between groups of economies with different structures. All these questions can be answered independently of whether the σ-convergence predicts that the aggregate cross-sectional variance is falling or rising over time. The same author underlines that the relation between the two concepts is accurate only to a certain extent which means that β-convergence is a necessary but not a sufficient condition for σ-convergence. Therefore, in our view the two concepts seem to be complementary and do not replace each other.

` Testing for convergence by using the β-methodology can be criticized because only initial and final values of the sample data are used and, therefore, the resultant parameter estimates may be sensitive to the specific values of these observations. This is one of several drawbacks of this methodology, and has recently been critically ommented in a number of studies, Bernard and Durlauf, Greasley and Oxley, Harris and Trainor and in Bernard and Durlauf the relationship between cross-section and time series tests of convergence is analyzed; including the empirical implications. Introducing a new time series test procedure of the Bernard-Durlauf methodology - find evidence of convergence among 22 OECD countries, including convergence towards a group 'leader' exhibiting highest income levels (the USA). (1,3)

1.2 Test of σ-convergence

The σ-convergence measures the dispersion of real GDP per capita or product between regions based on the standard deviation of the cross-section series. When the standard deviation tends to fall over time, such a result indicates that the differences of real GDP per capita between regions in absolute terms decrease with the passage of time, which is an evidence of convergence. On the other hand, divergence implies that the standard deviation of the series in terms of real GDP per capita increases over time. In the case where the standard deviation does not show any clear tendency, but instead, increases or decreases alternatively, we can say that a mixed process of converge and divergence is taking place. (6)

An alternative way of measuring the σ-convergence is to use CV (coefficient of variation), which is obtained by dividing the standard deviation of the series by the mean of the sample. Similarly, a decreasing value of the coefficient of variation over time reflects regional convergence, an increasing value reflects divergence, and a no stable tendency is taken as evidence of both convergence and divergence during the period in consideration. (6)

1.3 Test of β-convergence

In order to measure β-convergence, Equation (1.1.1) can be estimated in a modified form where the growth of GDP per capita is related to its initial level in a linear form of the type:

$$\frac{1}{T}\log\left(\frac{Y_{it}}{Y_{i0}}\right) = \alpha + \beta \log Y_{i0} + u_{it} \tag{1.3.1}$$

The coefficient $\left(\frac{1 - e^{-\beta t}}{T}\right)$ in initial Equation (1.1.1) is an expression that declines with the length of the interval, T, for a given β. That is, if estimate a linear relation between the growth rate of GDP per capita and the the log of initial GDP per capita, then the coefficient is predicted to be smaller the longer the time span over which the growth rate is averaged. The reason is that the growth rate declines as GDP per capita increases. Hence, if compute the growth rate over a longer time span, then it combines more of the smaller future growth rates with the initially larger growth rates. Hence, if interval increases, the effect of the initial position on the average growth rate declines. The coefficient ($\frac{1-e^{-\beta t}}{T}$) approaches 0 as T approaches infinity, and it tends to β as T approaches 0. That is why Equation (1.3.1) can be considered when analyzing β-convergence. In this equation, Y is GDP per capita, i is the individual region of a country, 0 is the base year, t is the final year, T is the length of the time where the growth of GDP per capita is calculated, α is the constant term (autonomous growth) and β measures the rate of convergence or the annual speed of convergence. Equation (1.3.1) is estimated by a least squares method, for the whole period. (9, p.387)

Support for the hypothesis is inferred if $\beta < 0$, with the alternative hypothesis, $\beta >$ 0. In such cases, $\beta < 0$ implies that convergence holds (holds conditionally on some set of exogenous factors, if the exogenous factors are included), and $\beta > 0$ implies that process of divergence takes place.

1.4 Time series test of convergence

There is a description of *Bernard-Durlauf-type time series test* in this part. According to this approach, tests of convergence examine the longrun behaviour of *differences in per capita output across countries.* The main feature of this class of tests is that convergence implies such differences will always be transitory in the sense that long-run forecasts of the *difference between any pair of countries converge to forecast horizon grows.*

The main testing feature of this approach is that output differences between two economies contain a unit-root or time trends if the countries have converged. However, the approach also distinguishes convergence from the tendency to catch-up, where again a strong implication is the absence of a unit root, although significant time-trend effects can exist. In particular, Bernard and Durlauf, utilise the Dickey-Fuller unit root testing procedure as a time-series based test of convergence. Here, convergence implies output innovations in one economy should be transmitted internationally. Utilizing slightly different definitions to Bernard and Durlauf, this can be illustrated via the concepts of *catching-up* and *long-run convergence.* (1)

Definition

Catching-up: Consider two countries i and j, and denote their log per capita real output as Y_i and Y_j. *Catching-up* implies the absence of a unit root in their difference Y_i - Y_j. Non-stationarity in Y_i - Y_j must violate the proposition, although the occurrence of a non-zero time trend in the deterministic process in-itself would not.

Long-run convergence: Consider two countries *i* and *j*, and denote their log per capita real output as Y_i and Y_j. *Long-run convergence* implies the absence of a unit root in their difference Y_i - Y_j and the absence of a time trend in the deterministic process. (1)

Catching-up differs from long-run convergence in that the latter relates to some particular period T equated with long-run equilibrium. In the former case, the existence of a time trend in the stationary Y_i - Y_j series would imply a narrowing of the (log per capita output) gap, or simply that the countries though *catching-up* had *not yet* converged. This catching-up could be oscillatory, but must imply non-divergence of output differences. Conversely, the absence of a time trend in the stationary series implies that catching-up has been completed. (1)

As defined in the foregoing, tests of catching-up and long-run convergence hinge, therefore, on the time-series properties of Y_i - Y_j. The natural route for such tests involves Dickey-Fuller-type tests based on the bi-variate difference in log per capita output between pairs of countries, *i* and *j,* i.e.

$$y_{it} - y_{jt} = \mu + \alpha(y_{i,t-1} - y_{j,t-1}) + \beta t + \sum_{k=1}^{n} \delta_k \Delta(y_{i,t-k} - y_{j,t-k}) + \varepsilon_t \quad (1.4.1)$$

where *y* indicates the logarithm of per capita output. If the difference between the output series contains a unit root, $\alpha = 1$, output per capita in the two economies will diverge. The absence of a unit root, $\alpha<1$, indicates either catching-up, if $\beta \neq 0$, or long-run convergence, if $\beta = 0$.

A testing strategy: testing for convergence within a Bernard-Durlauf-type framework, involves a two-stage process.

Firstly, check for the existence of a unit root in the difference between per capita output in the two countries concerned. The non-rejection of a unit root implies non-stationarity and rejection of the time-series property implications of the convergence hypothesis. Contingent on rejection of the unit root hypothesis is the convergence criteria requirement that significant time-trend effects are absent. Furthermore, strong convergence would imply the insignificance of the constant term.

Testing for catching-up involves the first two stages of testing for convergence, i.e. rejection of a unit root and checks on the significance of the time trend, but becomes an issue only if the time trend is significant. Notice that the concept does not require a zero constant. However, catching-up as a long run property of the model would be inconsistent with a constant, non-time varying, time trend as, asymptotically, a constant time-trend effect would always imply divergence as t $\rightarrow\infty$. Therefore, catching-up characterized by stationary output differences and a constant time trend is relevant only for a particular finite T, and only on the basis that the countries have not already converged. Hence, checking for convergence would always be the first stage, which requires stationary output differences, followed by tests for catching-up. Note, stationary output differences would imply either convergence, catching-up on 'parallelism', i.e. identical growth rates for all time periods.

1.5 Tests used in the study

Spearman's correlation test

Spearman's rank correlation coefficient is

$$r_s = 1 - 6\left[\frac{\sum d_i^2}{n(n^2-1)}\right],$$

where d_i is a differenece in the ranks assigned to two different characteristics of the *i*-th individual or phenomenon and n is a number of individuals or phenomena ranked. The preceding rank correlation coefficient can be used to detect heteroscedasticity as follows:

Assume $Y_i=\beta_0+\beta_1X_i+u_i$.

Step 1. Fit the regression to the data on Y and X and obtain the residuals $\hat{u}_i$

Step 2. Ignoring the sign of $\hat{u}_{i.,}$ that is, taking the absolute value, rank both $|\hat{u}_i|$ and X_i according to an ascending or descending order and compute the Spearman's rank correlation coefficient given previously.

Step 3. The significance of the sample r_i can be tested by the t-test as follows

$$t = \frac{r_s\sqrt{n-2}}{\sqrt{1-r_s{}^2}}$$ with df(degree of freedom)=n-2.

If the computed t-value exceeds the critical t-value, the hypothesis of heteroscedasticity can be accepted; otherwise it can be rejected. If the regression model involves more than one X variable, r_i can be computed between $|\hat{u}_i|$ and each of the X variables separately and can be tested for statistical significance by the test given. (13)

The Runs test

Assume $Y_i=\beta_0+\beta_1X_i+u_i$

Step 1. Fit the regression to the data on Y and X and obtain the residuals $\hat{u}_i$

Step 2. Define run as an uninterrupted sequence of one symbol or attribute of residuals such as "+" or "-". Further define the length of a run as the number of elements in it. Define

n as a total number of observations = $n_1 + n_2$

n_1 as a number of "+" symbols (i.e., + residuals)

n_2 as a number of "-" symbols (i.e., - residuals)

k as a number of runs.

Then under null hypothesis that successive, residuals are independent and alternative hypothesis that residuals have an autocorrelation problem.

Step 3. Obtain critical values (k_{cr1} and k_{cr2}) from tables of critical values of runs in the runs test for the given n_1 and n_2.

Step 4. If k belongs to interval (k_{cr1},k_{cr2}), then null hypothesis cannot be rejected and residuals are independent; if k is out of the interval (k_{cr1},k_{cr2}), then null hypothesis can be rejected and residuals have a problem of autocorrelation. (13)

Durbin –Watson d test

The mechanics of the Durbin-Watson test are as follows:

Step 1. Run OLS regression and obtain the residuals.

Step 2. Compute d.

Step 3. For the given sample size and given number of explanatory variables, find out the critical d_L and d_U values.

Step 4. Now follow the decision rules in given Table 1.5.1. (12, p. 423)

Table 1.5.1

Durbin-Watson d test: Decision rules

Null hypothesis	Decision	If
No positive autocorrelation	Reject	$0 < d < d_L$
No positive autocorrelation	No decision	$d_L \le d \le d_U$
No negative autocorrelation	Reject	$4 - d_L < d < 4$
No negative autocorrelation	No decision	$4 - d_U \le d \le 4 - d_L$
No autocorrelation, positive or negative	Do not reject	$d_U < d < 4 - d_U$

Source: Durbin-Watson d test: Decision rules (12, p. 423)

The unit root test of stationarity

In order to introduce this test, the following model is considered:

$$Y_t = Y_{t-1} + u_t \qquad (1.5.1)$$

where u_t is the stochastic error term that follows the classical assumptions, namely, it has zero mean, constant variance and is non-autocorrelated. Such an error term is also known as a white noise error term. Equation (1.5.1) is a first-order or AR(1), regression in that we regress the value of *Y* at time t on its value at time *(t-1)*. Now if the coefficient of Y_{t-1} is in fact equals to 1, we face what is known as the unit root problem, i.e., a nonstationarity situation. Therefore, if we run the regression

$$Y_t = \rho Y_{t-1} + u_t \tag{1.5.2}$$

And actually find that ρ=1, then we say that the stochastic variable Y_t has a unit root. In (time series) econometrics, a time series that has a unit root is known as a random walk (time series). And a random walk is an example of a non-stationary time series. For example, asset prices, such as stock prices, follow a random walk, that is, they are non-stationary. Equation (1.5.2) is often expressed in an alternative form as

$$\Delta Y_t = (\rho\text{-}1)Y_{t-1} + u_t = \delta Y_{t-1} + u_t \tag{1.5.3}$$

where $\delta=(\rho-1)$ and where Δ, as we know, is the first-difference operator and $\Delta Y_t = (Y_t - Y_{t-1})$. Now the null hypothesis is that $\delta=0$.

If δ is in fact 0, we can write (1.5.3) as

$$\Delta Y_t = (Y_t - Y_{t-1}) = u_t \tag{1.5.4}$$

What says is that the first differences of a random walk time series are stationary time series because by assumption u_t is purely random. (12, p. 718 – 720)

Now it time series is differenced once and the differenced time series is stationary, we say that the original (random walk) series is integrated of order 1, denoted by I(1). Similarly, if the original series has to be differenced twice (i.e., take first difference of the first difference) before it becomes stationary, the original time series is integrated of order 2, or I(2). In general, if a time series has to be differenced d times, it is integrate of order d or I(d). Thus, any time we have an integrated time series of order 1 or greater, we have a non-stationary time series. By convention, if d=0, the resulting I(0) process represents a stationary time series. We will use the terms a stationary process and an I(0) process as synonymous. (12, p. 718 – 720)

To find out if a time series Y_t (e.g., GDP) is non-stationary, run the regression (1.5.2) and find out if $\hat{\rho}$ is statistically equal to 1 or, equivalently, estimate (1.5.3) and find out if $\hat{\delta}$ = 0on the basis of, say, the t statistic. Under the null hypothesis that ρ=1, the conventionally computed t statistic is known as the τ (tau) statistic, whose critical values have been tabulated by Dickey and Fuller on the basis of Monte Carlo simulations. In the literature the tau test is known as the Dickey-Fuller (DF) test, in honor of its discoverers. If the null hypothesis that ρ=1 is rejected (i.e., the time series is stationary), we can use usual Student's t test. (12, p. 718 – 720)

If the computed absolute value of the τ statistic exceeds the DF or MacKinnon DF absolute critical τ values, then we do not reject the hypothesis that the given time series is stationary. If, on the other hand, it is less than the critical value, the time series is non-stationary. If the regression is run in the form of (1.5.3) the estimated τ (tau) statistic usually has a negative sign. Therefore, a large negative τ value is generally an indication of stationarity. (12, p. 718 – 720)

For the theoretical and practical reasons, the Dickey-Fuller test is applied to regressions run in the following forms:

$$\Delta Y_t = \delta Y_{t-1} + u_t \tag{1.5.6}$$

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + u_t \tag{1.5.7}$$

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + u_t \tag{1.5.8}$$

where t is the time or trend variable. In each case the null hypothesis is that δ=0, that is, there is a unit root. The difference between (1.5.8) and the other two regressions lies in the inclusion of the constant (intercept) and the trend term. If the error term u_t is autocorrelated, one modifies as follows:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + \varepsilon_t \tag{1.5.9}$$

where, for example, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, etc., that is, one uses lagged difference terms. The number of lagged difference terms to include is often determined empirically, the idea being to include enough terms so that the error term in (1.5.9) is serially independent. The null hypothesis is still that δ=0 or ρ=1, that is a unit root exists in *Y* (i.e., *Y* is non-stationary). When the DF test is applied to models like (1.5.9), it is called augmented Dickey-Fuller (ADF) test. The ADF test statistic has the same asymptotic distribution as the DF statistic, so the same critical values can be used. (12, p. 718 – 720)

Schwarz Criterion

Schwarz Criterion (SC) value was designed to help in the selection of the better of two alternate models. The lower value is better. It is important that these comparisons are made using the same weighting scheme.

$$SC = N \ln(WSS) + M \ln(N) ,$$

where *N* is the number if data points, *M* is the number of adjustable parameters, and *WSS* is the weighted sum of squared residuals. (3)

2 ANALYSIS OF σ-CONVERGENCE

In this section, the tests of σ-convergence are presented for the data of the Baltic countries. The data used in the tests of σ- and β-convergence is described below**.**

2.1 Latvian regional data description

In order to estimate the models for regional convergence for districts of Latvia, recent annual data of GDP per capita and CPI provided by Central Statistical Bureau of Latvia (data base) have been explored; real GDP per capita data are computed and displayed in the Table 2.1.1.

Table 2.1.1

Real GDP per capita[1] of Latvian districts in 1995 – 2005 (per capita, LVL)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Aizkraukle district	776	762	761	717	887	820	1013	1177	993	1119	1320
Aluksne district	661	655	534	610	628	649	658	728	802	816	1001
Balvu district	511	511	537	515	545	530	556	663	685	843	819
Bauska district	844	813	704	703	739	798	790	777	950	894	1130
Cesis district	699	694	763	742	772	860	908	949	1095	1172	1420
Daugavpils district	748	742	900	661	618	718	706	582	575	537	642
Dobele district	869	843	745	673	711	753	819	962	1017	1009	1244
Gulbene district	619	640	699	722	631	681	831	900	916	897	1018
Jelgava district	511	474	536	513	558	613	563	647	872	742	1032
Jekabpils district	610	592	632	613	705	799	840	861	1105	935	1188
Kraslava district	464	456	523	533	510	521	561	590	627	700	688
Kuldiga district	584	594	659	652	675	738	734	838	954	921	1038
Liepaja district	592	582	527	524	556	629	677	734	836	896	867
Limbazi district	800	811	859	728	809	813	814	852	954	920	1085
Ludzas district	492	488	538	524	528	560	590	625	666	723	778
Madona district	585	582	659	640	614	644	713	745	971	1133	1099
Ogre district	749	734	655	707	705	776	863	952	903	983	1189
Preili district	456	452	528	486	493	561	637	716	771	897	1092
Rezekne district	410	393	355	330	328	371	398	426	531	551	565
Riga district	1003	1014	1004	1106	1081	1200	1282	1401	1576	1740	2266
Saldus district	877	883	871	928	826	897	1446	1534	1202	1623	1461
Talsi district	684	707	745	853	797	864	888	1032	1036	1006	1299
Tukums district	804	812	822	772	720	768	849	919	973	899	1302
Valka district	824	793	795	775	812	770	762	1017	1204	1322	1466
Valmiera district	698	719	889	888	979	1013	1068	1286	1322	1496	1705
Ventspils district	650	612	433	509	510	573	994	1013	753	1408	1158

[1] Real GDP per capita data were computed for every year as ratio of GDP per capita of a district at current prices and Consumer Price Index of the country (base 1995=1.0) in appropriate year and initial data is in Appendix 1.

The GDP per capita at current prices (for 26 districts of Latvia) and CPI (Consumer Price Index with base of 1995 year) data were taken from the databases of Central Statistical Bureau of Latvia over the period 1995 – 2005. GDP per capita data at current prices are thereafter converted to real GDP per capita via CPI deflator for the sample. There are 4 districts (Preili, Kraslava, Ludza and Rezekne districts) that show the level of real GDP per capita below LVL 500 a year at the beginning of the period. There is one absolute leader of the level of real GDP per capita – Riga district with the level of more than LVL 1000 a year. All other districts have the level of real GDP per capita between LVL 500 and LVL 900 a year in 1995. All the districts (except Valmieras district which shows constant growth) have rises and falls in their real GDP per capita during the period. Almost all of the districts had a decrease in real GDP per capita during 1999 – 2000. The districts that had less real GDP per capita at the beginning of the period are among the districts that have less real GDP per capita in the end of the period. In 2005 there are 6 outsiders that did not reach the level of real GDP per capita of LVL 1000 - Preili, Kraslava, Ludza, Rezekne, Daugavpils and Liepaja districts. Still the leader is Riga district with the value of real GDP per capita of more than LVL 2200, the second place takes Valmiera district with the value of real GDP per capita of more than LVL 1700 and all other districts have real GDP per capita between LVL 1000 and LVL 1500 a year. A clearer view of the growth of disparities among the districts of Latvia is shown in Appendix 2.

2.2 Lithuanian regional data description

In order to estimate a model for regional convergence for the counties of Lithuania, recent data provided by Central Statistical Bureau of Lithuania (data base) has been explored. GDP per capita at current prices (for 10 counties of Lithuania) and CPI (with base of 2005 year) data were taken over the period 1995 – 2005. GDP per capita data at current prices are thereafter converted to real GDP per capita via CPI deflator for the sample. Data of real GDP per capita are displayed in the Table 2.2.1.

Table 2.2.1

Real GDP per capita[1] of Lithuanian counties in 1995 – 2005 (per capita, LTL thousand)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Alytus county	8.24	9.17	9.87	11.12	11.09	11.14	11.43	11.95	12.43	13.09	14.29
Kaunas county	9.04	10.11	12.04	13.14	12.78	13.01	13.98	14.53	16.50	17.66	20.01
Klaipeda county	10.50	11.76	13.13	14.41	14.26	15.30	15.71	16.69	18.27	19.08	21.78
Marijampole county	7.71	8.70	10.31	10.49	9.08	9.89	9.59	10.30	11.80	12.08	13.31
Panevezys county	9.57	10.82	11.93	12.71	11.62	12.28	12.65	13.39	14.31	15.93	16.95
Siauliai county	8.64	9.88	10.31	10.70	10.46	10.51	10.51	11.44	12.95	14.31	15.38
Taurage county	6.25	7.17	7.16	7.84	7.92	8.33	8.67	8.96	9.29	9.74	10.35
Telsiai county	8.24	9.17	9.98	11.44	11.19	11.66	12.35	12.88	14.52	16.44	17.94
Utena county	9.57	10.46	10.85	12.08	12.04	11.45	11.84	12.78	14.62	15.53	17.15
Vilnius county	11.17	12.58	15.19	17.06	17.21	18.11	19.39	22.15	24.64	26.49	29.77

Source: own calculations, initial data presented in Appendix 3

In 1995 there is only one county where real GDP per capita is below LTL 7,000 a year – Taurage county, for all other counties real GDP per capita is between LTL 7,000 and LTL 11,500 a year. There is no sound difference in the level of real GDP per capita between counties at the beginning of the period. In 1998 there is one absolute leader among the counties – Vilnius county, reaching the level of real GDP per capita more than LTL 17,000 a year. There is a constant growth from the beginning of the period till 1998 and a decrease in 1998 – 1999 in the level of real GDP per capita for all the counties of Lithuania. After 1999 all the counties have a permanent increase in their levels of real GDP per capita till the end of the period. In 2005 there is still the same outsider – Taurage country, which level of real GDP per capita is less then LTL 11,000 a year and one particular leader – Vilnius county, which has the level of real GDP per capita more than LTL 29,000 a year. All other counties reached the level of real GDP per capita in between LTL 13,000 and LTL 22,000 in 2005. A clearer view of the growth of disparities among the counties of Lithuania is shown in Appendix 4.

[1] Real GDP per capita data were computed for every year as ratio of GDP per capita of a county at current prices and Consumer Price Index of the country (base 2005=1.0) in appropriate year and initial data is in Appendix 3.

2.3 Estonian regional data description

In order to estimate a model for regional convergence for counties of Estonia, recent data provided by Central Statistical Bureau of Estonia (data base) have been explored. GDP per capita at current prices and CPI (with base of 1995 year) data were taken from databases of Central Statistical Bureau of Estonia for its 15 counties over the period 1996 – 2005. GDP per capita data at current prices are thereafter converted to real GDP per capita via CPI deflator for the sample. Data of real GDP per capita are displayed in the Table 2.3.1.

Table 2.3.1

Real GDP per capita[1] of Estonian counties in 1996 – 2005 (per capita, EEK thousand)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Harju county	45.26	52.27	55.29	57.86	64.98	70.18	76.81	86.41	94.48	103.87
Hiiu county	29.18	32.13	34.12	36.03	36.56	36.30	38.96	40.09	43.46	47.26
Ida-Viru county	25.52	27.51	26.92	27.37	29.46	30.59	32.76	36.01	36.91	45.80
Jogeva county	19.01	20.49	21.02	20.40	22.36	23.30	24.74	25.73	27.67	30.58
Jarva county	24.16	28.36	29.48	30.94	32.73	33.98	36.00	38.91	40.91	41.15
Laane county	27.06	29.19	30.43	29.31	30.52	31.71	33.88	34.95	38.67	42.76
Laane-Viru county	25.54	26.81	27.98	29.98	32.74	34.35	38.54	39.87	41.64	46.77
Polva county	21.96	23.07	22.09	23.23	25.56	27.15	26.88	28.99	28.84	32.31
Parnu county	26.96	30.30	32.72	32.63	36.20	39.79	41.70	43.49	45.61	53.59
Rapla county	24.02	25.13	26.76	27.12	29.69	30.52	31.78	35.02	35.27	37.80
Saare county	23.83	25.28	26.40	27.28	29.80	32.97	34.94	37.01	39.30	45.83
Tartu county	26.86	29.03	30.62	31.50	33.76	38.27	41.84	48.47	51.44	62.41
Valga county	19.83	20.54	22.44	23.65	25.31	25.28	28.50	31.40	31.14	35.71
Viljandi county	23.24	24.52	25.09	26.12	28.01	29.86	32.47	34.94	36.50	40.22
Voru county	20.27	22.87	23.42	24.80	26.92	27.52	30.18	32.66	33.16	36.41

Source: own calculations, initial data presented in Appendix 5

[1] Real GDP per capita data were computed for every year as ratio of GDP per capita of a county at current prices and Consumer Price Index of the country (base 1995=1.0) in appropriate year and initial data is in Appendix 5.

In 1996 there is only one leader – Harju county, which had more than EEK 45,000 of real GDP per capita a year. All other counties have their levels of real GDP per capita in between EEK 19,000 and EEK 29,500 of real GDP per capita a year. All the counties do not have any noticeable decrease in their level of real GDP per capita in 1996 - 2005. During the period Harju county has been developed faster than the others and has reached a level of real GDP per capita of more than EEK 100,000 a year in 2006. The second place of level of real GDP per capita (more than EEK 60,000) took Tartu county. All other counties reached level of real GDP per capita in between EEK 30,000 and EEK 47,500 in 2005. A clearer view of the growth of disparities among the counties of Estonia is shown in Appendix 6.

The obtained data of real GDP per capita are used to perform tests of σ – and β-convergence and further in this study, for "GDP per capita" one should understand "real GDP per capita".

2.4 Estimating of σ-convergence across Latvian districts

As the first attempt, σ-convergence has been discovered based on the coefficient of variation of GDP per capita and the results are exposed in Table 2.4.1. Coefficients of variation were computed as ratio of standard deviation of GDP per capita among districts of Latvia and mean for every year in 1995 – 2005.

Table 2.4.1

Coefficient of variation of GDP per capita for 26 districts of Latvia, over the period 1995-2005

Coefficient of Variation	0.225	0.23	0.236	0.244	0.242	0.235
Years	1995	1996	1997	1998	1999	2000
Coefficient of Variation	0.282	0.294	0.253	0.301	0.308	
Years	2001	2002	2003	2004	2005	

Source: own calculations, initial data presented in Appendix 1

There is an evidence of σ-convergence in two distinct periods: the period 1998-2000 with a lower fall in the coefficient of variation of GDP per capita and the period 2002-2003 with a higher fall in the disparities of GDP per capita across districts. On the other hand, one can say that there is a divergence in GDP per capita for the years 1995 – 1998, 2000 – 2002 and a new divergence since 2003. Since there is the evidence of convergence and divergence, a mixed process of convergence and divergence took place. For the whole period 1995 – 2005 the figures show that the coefficient of variation of GDP per capita across districts increased in absolute terms, which means a divergence among the Latvian districts.

Figure 2.4.1 gives a clear view of the tendency of the σ-convergence and divergence, where the coefficient of variation of the cross-district GDP per capita is plotted over the whole period 1995 – 2005 for 26 districts of Latvia.

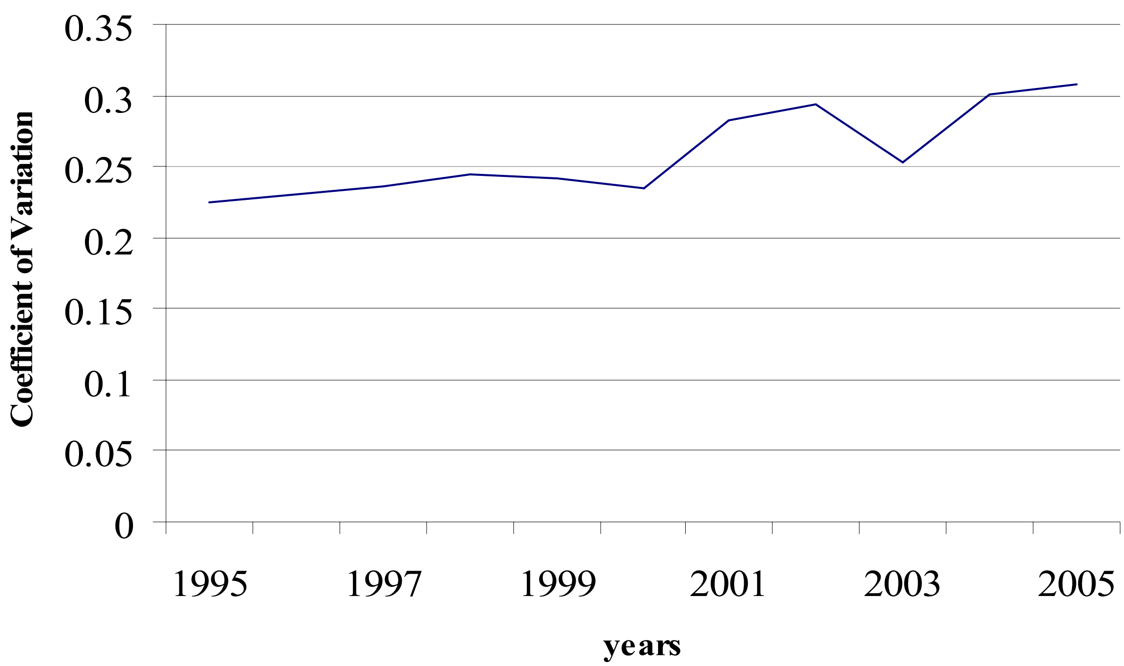

Figure 2.4.1 **Coefficient of variation of GDP per capita for 26 districts of Latvia, over the period 1995-2005**

Source: Table 2.4.1

2.5 Estimating of σ-convergence across Lithuanian counties

σ-convergence has been discovered based on the coefficient of variation of GDP per capita and the results are exposed in Table 2.5.1. Coefficients of variation were computed as a ratio of standard deviation of GDP per capita among the counties of Lithuania and mean for every year in 1995 – 2005.

Table 2.5.1

Coefficient of variation of GDP per capita for 10 counties of Lithuania, over the period 1995-2005

Coefficient of Variation	0.16	0.16	0.20	0.21	0.22	0.23
Years	1995	1996	1997	1998	1999	2000
Coefficient of Variation	0.25	0.28	0.28	0.29	0.30	
Years	2001	2002	2003	2004	2005	

Source: own calculations, initial data presented in Appendix 3

There is an evidence of σ-convergence for only the first year of the period. Since 1996 till 2006 the coefficient of variation was growing showing an increase in the disparities of the GDP per capita across the counties. For the whole period 1995 – 2005 the figures show that the coefficient of variation of GDP per capita across the counties increased in absolute terms, which means a strong divergence among the counties of Lithuania.

Figure 2.5.1 gives a clear view of the tendency of the σ-divergence, where the coefficient of variation of the cross-county GDP per capita is plotted over the whole period 1995-2005 for 10 counties of Lithuania.

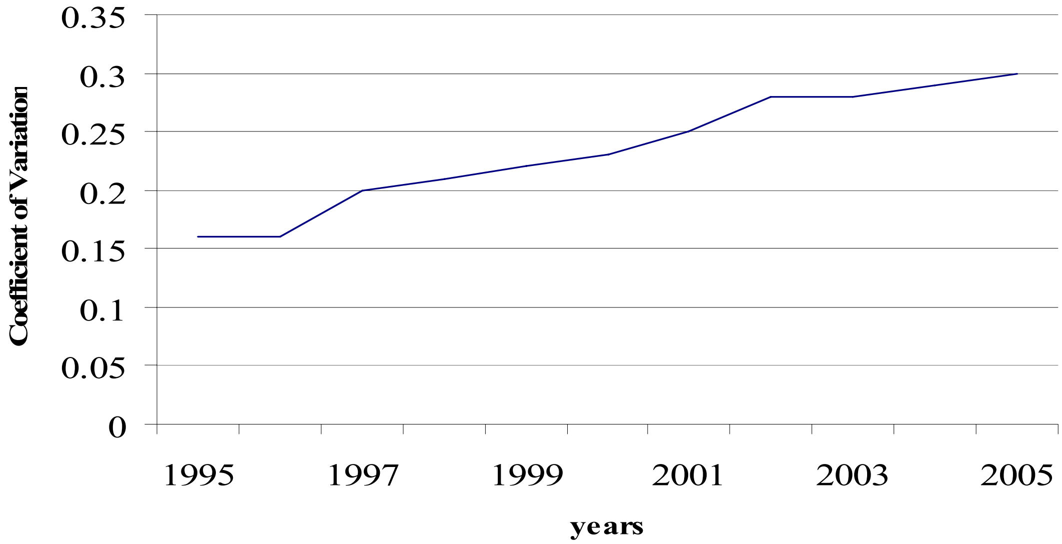

Figure 2.5.1 **Coefficient of variation of GDP per capita for 10 counties of Lithuania, over the period 1995-2005**

Source: Table 2.5.1

2.6 Estimating of σ-convergence across Estonian counties

σ-convergence has been discovered based on the coefficient of variation and the results are exposed in Table 2.6.1. Coefficients of variation were computed as a ratio of standard deviation and mean of GDP per capita among the counties of Estonia for every year in 1996 – 2005.

Table 2.6.1

Coefficient of variation of GDP per capita for 15 counties of Estonia, over the period 1996-2005

Coefficient of Variation	0.243	0.273	0.285	0.292	0.306	0.322
Years	1996	1997	1998	1999	2000	2001
Coefficient of Variation	0.333	0.357	0.382	0.380		
Years	2002	2003	2004	2005		

Source: own calculations, initial data presented in Appendix 5

There is an evidence of σ-convergence for only the last year of the period. Since 1996 till 2004 the coefficient of variation was growing showing an increase in the disparities of the GDP per capita across the counties. For the whole period 1996 – 2005 the figures show that the coefficient of variation of GDP per capita across the increased counties in absolute terms which means a strong divergence among the counties of Estonia.

Figure 2.6.1 gives a clear view of the tendency of the σ-divergence, where the coefficient of variation of the cross-county GDP per capita is plotted over the whole period for 15 counties of Estonia, over the period 1996-2005.

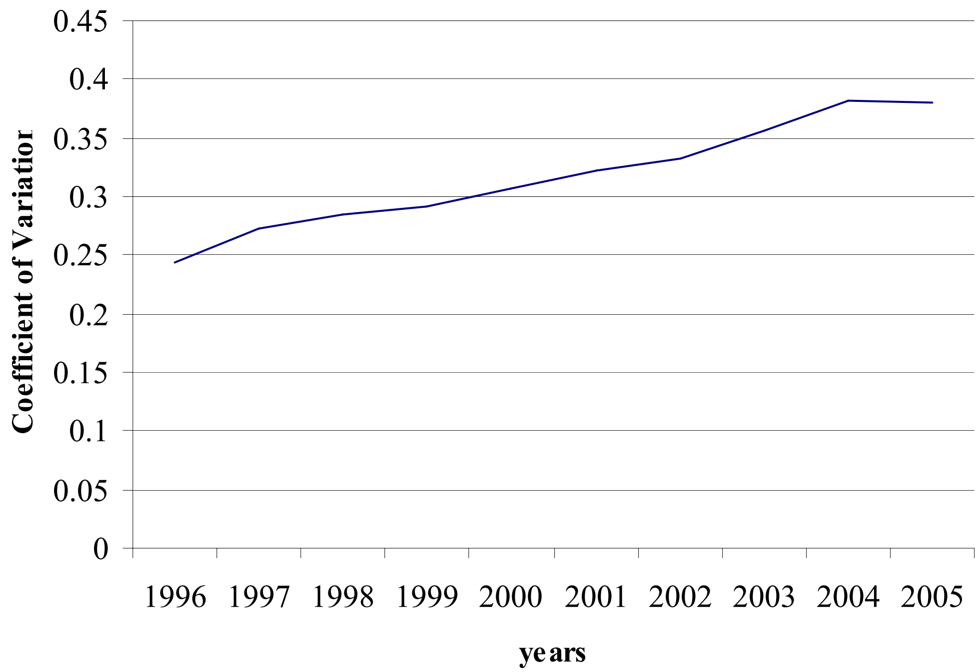

Figure 2.6.1 **Coefficient of variation of GDP per capita for 15 counties of Estonia, over the period 1996-2005**

Source: Table 2.6.1

3 ANALYSIS OF β-CONVERGENCE

This section provides results of the tests of β-convergence for data for regions of the Baltic countries. It also contains estimation of models for each country along with the examination for problems of autocorrelation and heteroscedasticity.

3.1 Estimating of β-convergence across Latvian districts

A more formal approach to detect the convergence or divergence process over time is to plot annualized growth rates against initial levels of GDP per capita. This is done for the whole period 1995 – 2005 (Figure 3.1.1).

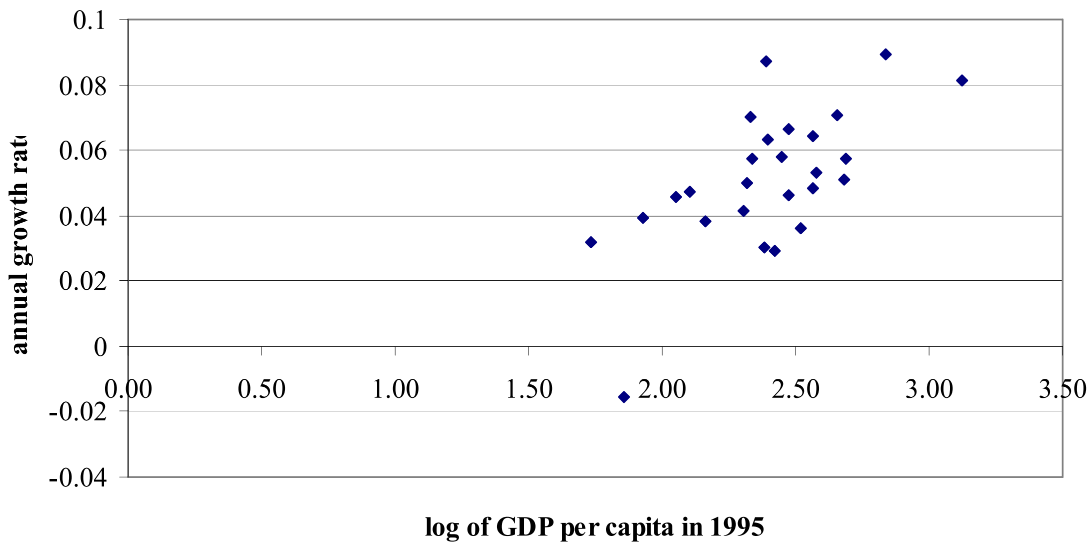

Figure 3.1.1 **Correlation diagram of the log of GDP per capita in 1995 and annual growth rate of GDP per capita**

Source: own calculations, data presented in Appendix 7

In each case the vertical axis measures the annual growth rate $\frac{1}{T}\log(\frac{Y_{it}}{Y_{io}})$, (where Y_{it} and Y_{i0} are GDP per capita of an individual district i in the last year of the period and the initial year of the period respectively, and T is the length – 10 years considered) and the horizontal axis measures the log of the base-year GDP per capita of the respective districts. The most obvious feature of the Figure 3.1.1 is the positive relation between annual growth rates and initial levels of GDP per capita, which rejects the idea of cross-district convergence of the neo-classical type suggesting that poor districts grow faster in their GDP per capita than wealthy ones.

To measure β-convergence, Equation (1.3.1) was estimated by the least squares method, for the whole period 1995 – 2005. The estimated results are presented below with a summary of the most important statistics (t-ratio in brackets):

Model 3.1.1[1]

$$\frac{1}{10}\log\left(\frac{Y_{2005}}{Y_{1995}}\right) = -0.059 + 0.046\log(Y_{1995}) \qquad R^2=0.422$$

$$(-2.21)\quad (4.18) \qquad\qquad DW=1.86$$

A linear regression analysis for the model (statistically significant at 5% significance level), estimating the annualized growth of GDP per capita on the initial level of GDP gives a positive β-coefficient showing an annual divergence rate of 4.6% for the whole period. The regression results reject the convergence hypothesis (the null hypothesis - there is a significant negative ratio between the growth of GDP per capita and the starting level of GDP per capita; and alternative hypothesis - there is a significant not negative ratio between the growth of GDP per capita and the starting level of GDP per capita) with β-coefficient being positive and statistically significant (at 5% significance level). The autonomous growth (statistically significant at 5% significance level) is negative, and expressed through constant term is 5.9%.

Examination of residuals

The examination of the residuals is a good visual diagnostics to detect autocorrelation or heteroscedasticity. For the estimated model values of the residuals were plotted against independent variables - initial levels of GDP per capita in 1995.

[1] Model is estimated with the help of EViews 5.0 and initial data is in Appendix 7

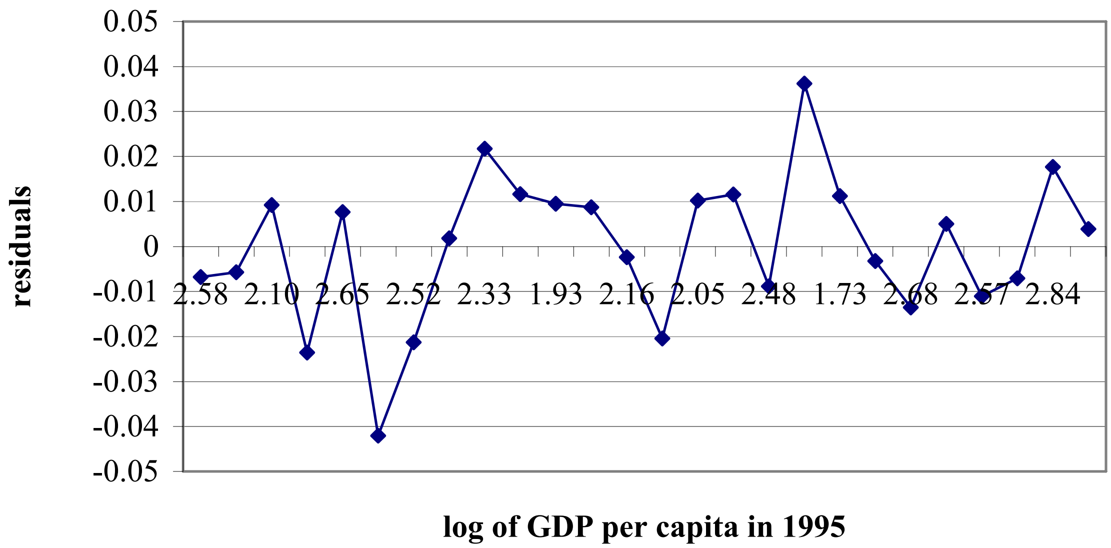

Figure 3.1.2 **Residuals of the estimated Model 3.1.1 proportional to log of GDP per capita in 1995**

Source: own calculations, initial data presented in Appendix 7

From the Figure 3.1.2 it can be seen that the residuals from the regression appear to be distributed on both sides of the horizontal axis (zero mean). There is a quick check of residuals that indicates that the residuals show little evidence of autocorrelation. Figure 3.1.2 indicates that one of the observations deviates from the general trend in the data. This point may be an outlier, which causes a problem of heteroscedasticity.

Although the coefficient of determination is 0.422, which means that the model explains 42.2% of annual growth rate of GDP per capita, considering the period of 10 years, it highlights a divergence across the districts of Latvia. One of the observations can be an outlier, so it was decided to check the model for the outlier adding a dummy variable for the suspicious observation. Finally, the results (showing process of divergence) are consistent with the σ-divergence where it was found a raise in the coefficient of variation and therefore a divergence.

Examination for the outlier

It can be seen that one of the points in Figure 3.1.2 is the outlier. This value regards to Daugavpils district. In order to estimate the speed of divergence of Daugavpils district in comparison with the others, it was decided to create a model with a dummy variable D_i, where D_i=1 for Daugavpils district and D_i=0 for the others. The estimated model is presented below with a summary of the most important statistics (t-ratio in brackets):

Model 3.1.2[1]

$$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}}) = -0.029 + 0.034\log(Y_{1995}) - 0.027D\log(Y_{1995}) \quad R^2=0.605$$

$$(-1.18) \quad (3.44) \qquad\qquad (-3.27) \qquad\qquad DW=2.223$$

A linear regression analysis for the model (statistically significant at 5% significance level), estimating the annualized growth of GDP per capita in relation to the initial level of GDP gives a positive β-coefficient showing an annual divergence rate of 3.4% for the whole period. The regression results reject the convergence hypothesis (the null hypothesis - there is a significant negative relation between the growth of GDP per capita and the starting level of GDP per capita; and alternative hypothesis - there is a significant not negative relation between the growth of GDP per capita and the starting level of GDP per capita) with β-coefficient being positive and statistically significant (at 5% significance level). The autonomous growth (statistically insignificant at 5% significance level) is negative, and expressed through constant term is 2.9%. The coefficient of dummy variable (statistically significant at 5% significance level) shows, that the speed of divergence statistically differs from that of all Latvia and 2.7% lower, estimating the results for Daugavpils district.

Examination of residuals

The examination of the residuals is a good visual diagnostics to detect autocorrelation or heteroscedasticity. For the estimated model values of the residuals were plotted against independent variable - initial levels of GDP per capita in 1995.

[1] Model is estimated with the help of EViews 5.0 and initial data is in Appendix 7

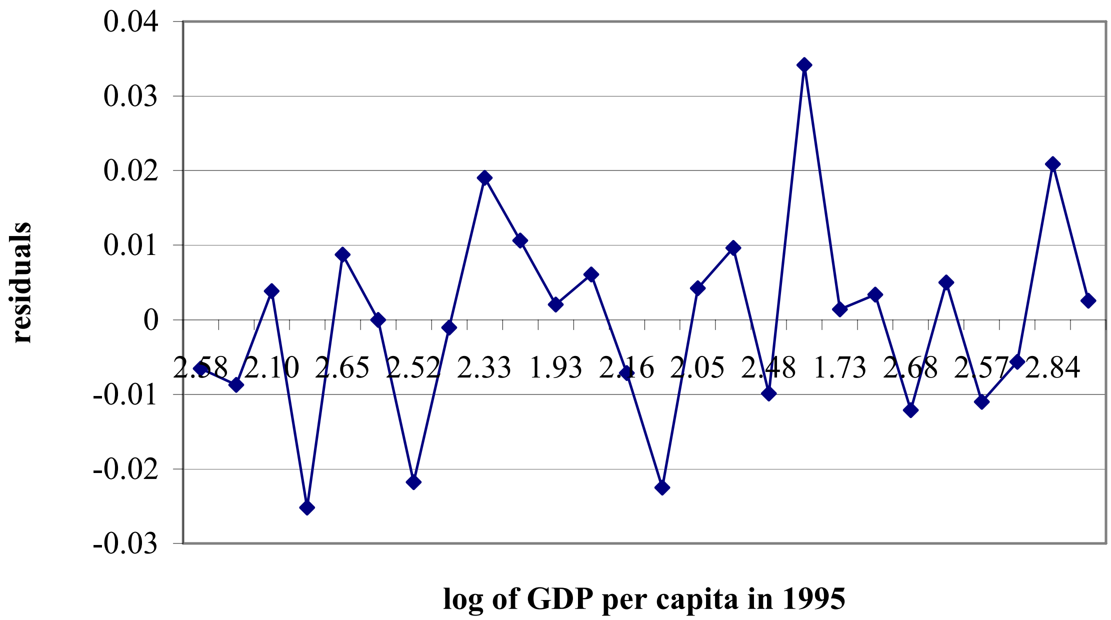

Figure 3.1.3 **Residuals of the estimated Model 3.1.2 proportional to log of initial level of GDP per capita**

Source: own calculations, initial data presented in Appendix 7

From the Figure 3.1.3 it can be seen that the residual errors from the regression appear to be distributed on both sides of the horizontal axis (zero mean). There is a quick check of residuals that indicates that the residuals show little evidence of autocorrelation, therefore has been performed Durbin-Watson d-test to examine the model for autocorrelation. The vertical spread of the points is not uniform with the increase in the factor of GDP per capita in 1995, indicating a suspicion for heteroscedasticity. As a consequence Spearman's rank correlation test of heteroscedasticity has been run and the results are provided below.

Durbin-Watson d-test

The present model was tested for existing of autocorrelation using Durbin-Watson d-test for autocorrelation. The upper (d_U) and lower (d_L) critical values of the d-statistic at 0.05 level of significance from the table of the D-W statistic were found for the given sample size (26 districts) and the number of explanatory variables (log of initial level of GDP per capita and dummy variable). The upper (d_U) and lower (d_L) critical values of the d statistic are 1.55 and 1.22 respectively. In order to test for autocorrelation the decision rule of Durbin-Watson d-test ($d_U \leq d \leq 4 - d_U$) that rejects both positive and negative autocorrelation was used. Since $1.55 \leq 2.22 \leq 4 - 1.55$, the former decision rule is hold and there is no problem of autocorrelation.

Spearman's rank correlation test

According to the test, if the computed t-value exceeds the critical t-value, hypothesis of heteroscedasticity might be accepted the (a null hypothesis – residuals have a homoscedasticity, an alternative hypothesis – residuals have a heteroscedasticity); otherwise it might be rejected. The critical t-value was obtained from the tables of percentage points of the t-distribution and for 26 observations (degree of freedom is 24) it equals 2.064 (at 5% significance level). Since the computed t-value (2.033) is less than the critical t-value, then it is concluded that the hypothesis of heteroscedasticity is rejected and there is no problem of heteroscedasticity in the estimated model.

Although the explanatory power of the model is relatively better than that of the previous one (R^2=0.605, the model explains 60.5% of variations of annual growth rates) and there is no problem of heteroscedasticity and autocorrelation in the model. Considering the period of 10 years, it highlights a divergence across the districts of Latvia and the difference in the speed of divergence is 2.7% less estimating the results for Daugavpils district.

3.2 The differences in speed of divergence within the regions of Latvia

In order to discover the differences in speed of divergence between each of 5 regions (Riga and Pieriga region, Kurzeme region, Vidzeme region, Latgale region and Zemgale region) and the whole Latvia, on the basis of Equation (1.1.1) 5 models were estimated.[1] The following dummy variables were used:

in the 1st model R_i=1 for Riga and Pieriga region and R_i=0 for the others,
in the 2nd model K_i=1 for Kurzeme region and K_i=0 for the others,
in the 3rd model V_i=1 for Vidzeme region and V_i=0 for the others,
in the 4th model L_i=1 for Latgale region and L_i=0 for the others,
in the 5th model Z_i=1 for Zemgale region and Z_i=0 for the others.

[1] Models are estimated with the help of Eviews 5.0 and initial data is in Appendix 7

The estimated 5 models are presented below with a summary of the most important statistics (t-ratio in brackets):

Model 3.2.1

$$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}}) = -0.072 + 0.05\log(Y_{1995}) - 0.005R\log(Y_{1995}) \qquad R^2=0.472$$

(-2.63) (4.53) (-1.49) DW=1.58

Model 3.2.2

$$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}}) = -0.059 + 0.046\log(Y_{1995}) + 0.00005K\log(Y_{1995}) \qquad R^2=0.422$$

(-2.16) (4.08) (0.01) DW=1.86

Model 3.2.3

$$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}}) = -0.054 + 0.043\log(Y_{1995}) + 0.003V\log(Y_{1995}) \qquad R^2=0.437$$

(-1.98) (3.77) (0.8) DW=1.77

Model 3.2.4

$$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}}) = -0.1 + 0.06\log(Y_{1995}) + 0.008L\log(Y_{1995}) \qquad R^2=0.483$$

(-2.79) (4.33) (1.65) DW=1.69

Model 3.2.5

$$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}}) = -0.06 + 0.047\log(Y_{1995}) - 0.002Z\log(Y_{1995}) \qquad R^2=0.43$$

(-2.21) (4.17) (-0.59) DW=1.84

The linear regression analyses for 5 models (statistically significant at 5% significance level), estimating the annualized growth of GDP per capita in relation to the initial level of GDP give a positive β-coefficient showing a divergence. But the coefficients with dummy variables are statistically insignificant at 5% significance level in all 5 estimated models.

Since the coefficients with dummy variables are not statistically significant, it means that the difference in speed of divergence between the whole Latvia and its 5 regions is not statistically significant. Therefore, one can make a conclusion that there is no difference of structural factors influencing on speed of convergence among regions and model of absolute convergence can be applied considering the regions of Latvia.

3.3 Estimating of β-convergence across Lithuanian counties

A more formal approach to detect the convergence or divergence process over time is to plot annualized growth rates against initial levels of GDP per capita. This is done for the whole period 1995 – 2005 (Figure 3.3.1).

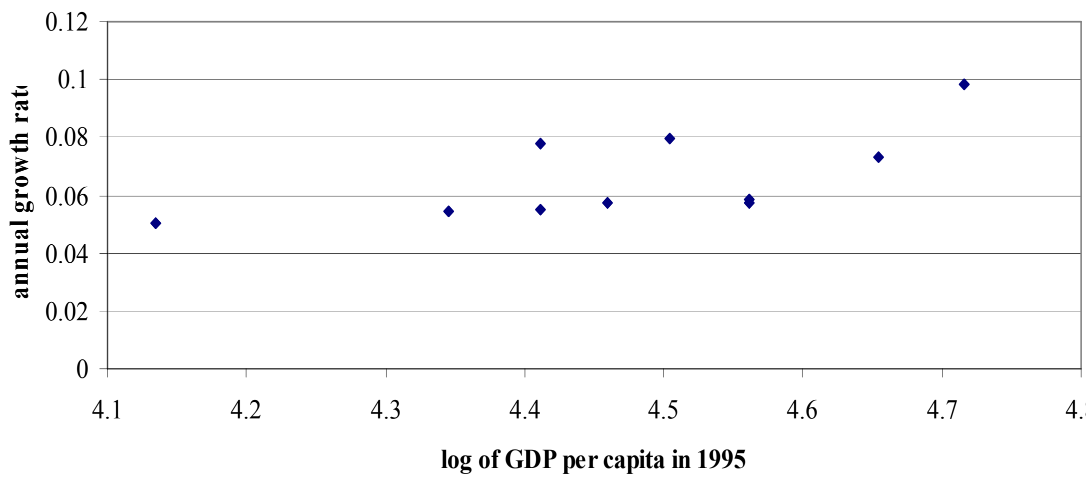

Figure 3.3.1 **Correlation diagram of the log of GDP per capita in 1995 and annual growth rate of GDP per capita**

Source: own calculations, data presented in Appendix 8

In each case the vertical axis measures the (annualized) growth rate $\frac{1}{T}\log(\frac{Y_{it}}{Y_{io}})$, (where Y_{it} and Y_{i0} are the GDP per capita of the individual county i in the last year of the period and the initial year of the period respectively, and T is the length of the period considered – 10 years) and the horizontal axis measures the log of the base-year GDP per capita of the respective counties. The most obvious feature of the Figure 3.3.1 is the positive relation between annual growth rates and initial levels of GDP per capita, which reject the idea of cross-region convergence of the neo-classical type suggesting that poor regions grow faster in their GDP per capita than wealthy ones.

To take a measure of β-convergence, Equation (1.3.1) was estimated by the least squares method, for the whole period 1995 – 2005. The estimated results are presented below with a summary of the most important statistics (t-ratio in brackets):

Model 3.3.1[1]

$$\frac{1}{10}\log\left(\frac{Y_{2005}}{Y_{1995}}\right) = -0.20 + 0.06\log(Y_{1995}) \qquad R^2=0.423$$

$$(-1.82)\ (2.42) \qquad DW=2.27$$

A linear regression analysis for the model (statistically significant at 5% significance level), estimating the annualized growth of GDP per capita on the initial level of GDP per capita gives a positive β-coefficient showing an annual divergence rate of 6% for the whole period. The regression results reject the convergence hypothesis (the null hypothesis - there is a significant negative relation between the growth of GDP per capita and the starting level of GDP per capita; and alternative hypothesis - there is a significant not negative ratio between the growth of GDP per capita and the starting level of GDP per capita) with β-coefficient being positive and statistically significant (at 5% significance level). The autonomous growth (statistically insignificant at 5% significance level) is negative, and expressed through constant term is 20%.

Examination of residuals

The examination of the residuals is a good visual diagnostic to detect autocorrelation or heteroscedasticity. For the estimated model values of the residuals were plotted against independent variable - initial levels of GDP per capita in 1995.

[1] Model is estimated with the help of EViews 5.0 and initial data presented in Appendix 8

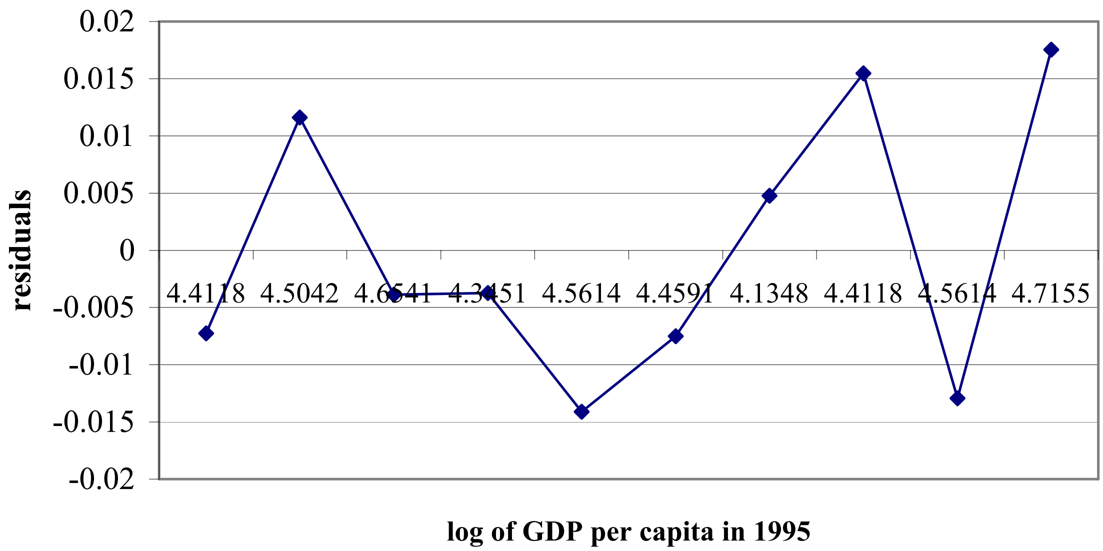

Figure 3.3.2 **Residuals of the estimated Model 3.3.1 proportional to log of initial level of GDP per capita**

Source: own calculations, initial data presented in Appendix 8

The Figure 3.3.2 represents that residuals are distributed on both sides of the horizontal axis (mean zero). Still there is a quick check of residuals that could indicate that the residuals show a little evidence of autocorrelation. So it was decided to carry out Durbin-Watson d-test to inspect for autocorrelation. The points spread vertically wider and wider with the increase in the factor of GDP per capita in 1995, indicating a suspicion for heteroscedasticity. Therefore, Spearman's rank correlation test of heteroscedasticity has been run and the results are displayed below.

Durbin-Watson d-test

The present model was tested for existing of autocorrelation using Durbin-Watson d-test for autocorrelation. The upper (d_U) and lower (d_L) critical values of the d-statistic at 0.05 level of significance from the tables of the D-W statistic were found for the given sample size (10 counties) and the number of explanatory variables (log of initial level of GDP). The upper (d_U) and lower (d_L) critical values of the d statistic are 1.32 and 0.88 respectively. In order to test for autocorrelation the decision rule of Durbin-Watson d-test ($d_U \leq d \leq 4 - d_U$) that rejects both positive and negative autocorrelation was used. Since

1.32 < 2.27 < 4 –1.32, the former decision rule holds, there is no problem of autocorrelation.

Spearman's rank correlation test

According to the test, if the computed t-value exceeds the critical t-value, the hypothesis of heteroscedasticity might be accepted (a null hypothesis – residuals have a homoscedasticity, an alternative hypothesis – residuals have a heteroscedasticity); otherwise it might be rejected. The critical t-value was obtained from the tables of percentage points of the t-distribution and for 10 observations (degree of freedom is 8) it equals 2.31 (at 5% significance level). Since the computed t-value (1.7) is less than the critical t-value, then it is concluded that the hypothesis of heteroscedasticity is rejected and there is no problem of heteroscedasticity in the estimated model.

Although the coefficient of determination is 0.423, which means that the model explains 42.3% of variation of annual growth rate of GDP per capita, there is no problem of heteroscedasticity and autocorrelation in the model; considering the period of 10 years, it highlights a divergence across the counties of Lithuania. Finally, the results are consistent with the σ-divergence where it was found a raise in the coefficient of variation of GDP per capita.

3.4 Estimating of β-convergence across Estonian counties

A more formal approach to detect the convergence or divergence process over time is to plot annualized growth rates against initial levels of GDP per capita. This is done for the whole period 1996 – 2005 (Figure 3.4.1).

In each case the vertical axis measures the (annualized) growth rate $\frac{1}{T}\log(\frac{Y_{it}}{Y_{io}})$, (where Y_{it} and Y_{i0} are GDP per capita of an individual region *i* in the last year and the initial year respectively, and *T* is the length of the period considered – 9 years) and the horizontal axis measures the log of the base-year GDP per capita of the respective counties.

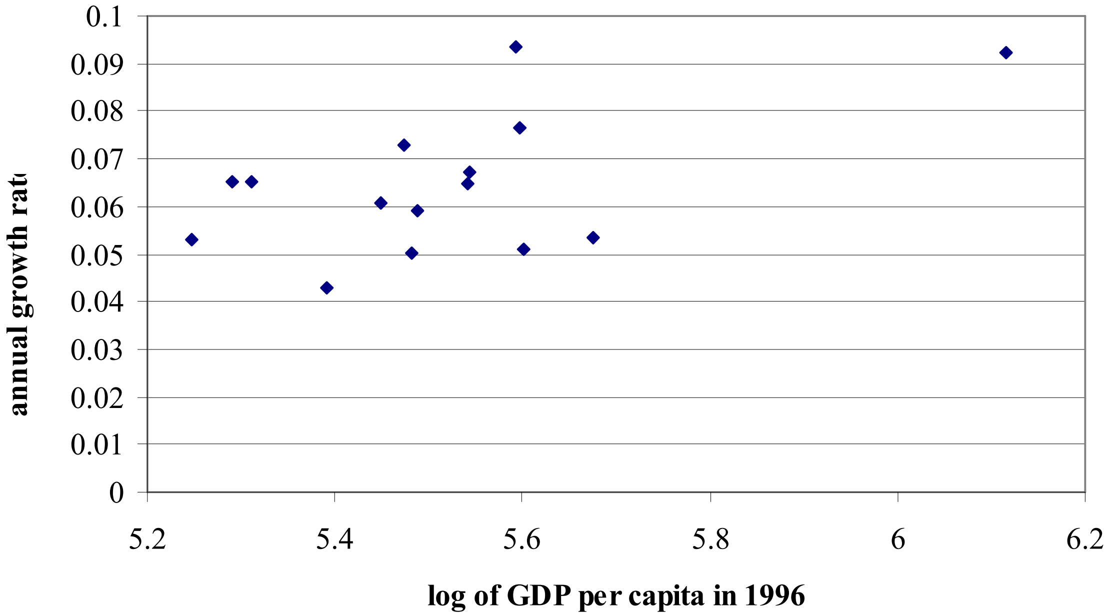

Figure 3.4.1 **Correlation diagram of the log of GDP per capita in 1996 and annual growth rate of GDP per capita**

Source: own calculations, data presented in Appendix 9

The most obvious feature of the Figure 3.4.1 is the positive ratio between annual growth rates and initial levels of GDP per capita, which reject the idea of cross-region convergence of the neo-classical type suggesting that poor counties grow faster in their GDP per capita than the wealthy ones.

To measure β-convergence, Equation (1.3.1) was estimated by the least squares method, for the whole period 1996 – 2005. The estimated results are presented below with a summary of the most important statistics (t-ratio in brackets):

Model 3.4.1[1]

$$\frac{1}{9}\log\left(\frac{Y_{2005}}{Y_{1996}}\right) = -0.15 + 0.039\log(Y_{1996}) \qquad R^2=0.30$$

(-1.65) (2.36) DW=1.896

[1] Model is estimated with help of EViews 5.0 and initial data are in Appendix 9.

A linear regression analysis for the model (statistically significant at 5% significance level), estimating the annualized growth of GDP per capita on the initial level of GDP gives a positive β-coefficient showing an annual divergence rate of 3.9% for the whole period. The regression results reject the convergence hypothesis (the null hypothesis - there is a significant negative ratio between the growth of GDP per capita and the starting level of GDP per capita; and alternative hypothesis - there is a significant not negative ratio between the growth of GDP per capita and the starting level of GDP per capita) with β-coefficient being positive and statistically significant (at 5% significance level). The autonomous growth (statistically insignificant at 5% significance level) is negative, and expressed through constant term is 15%.

Examination of residuals

The examination of the residuals is a good visual diagnostic to detect autocorrelation or heteroscedasticity. For the estimated model values of the residuals were plotted against independent variable - initial levels of GDP per capita in 1996.

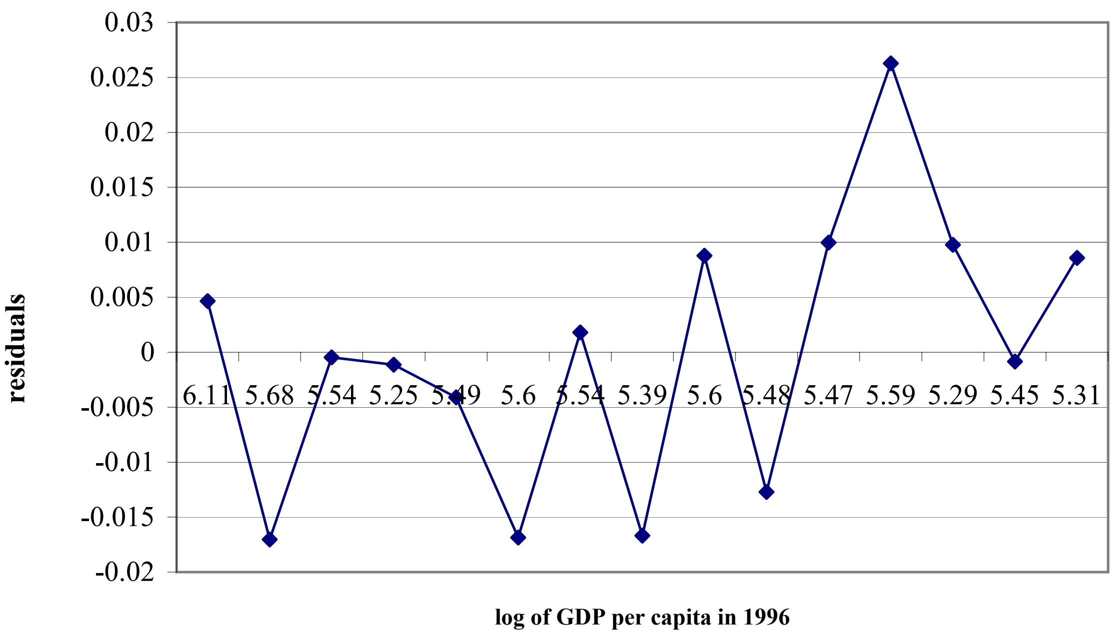

Figure 3.4.2 **Residuals of the estimated Model 3.4.1 proportional to log of initial level of GDP per capita**

Source: own calculations, initial data presented in Appendix 9

From the Figure 3.4.2 it can be seen that the residuals from the regression appear to be distributed on both sides of the horizontal axis (zero mean). There is a quick check of residuals that indicates that the residuals show little evidence of autocorrelation. The Figure 4.4.2 indicates that one of the observations deviates from the general trend in the data. This point may be the outlier which causes a problem of heteroscedasticity..

Although the coefficient of determination is 0.30, which means that the model explains 30% of variation of annual growth of GDP per capita, considering period of 9 years, it highlights a divergence across the counties of Estonia. One of the observations can be an outlier, so it was decided to check the model for the outlier adding a dummy variable for the suspicious observation. Finally, the results are consistent with the σ-divergence where divergence was found in a raise in the coefficient of variation of GDP per capita.

Examination for the outlier

It can be seen that one of the points in the Figure 3.4.2 is the outlier. This value regards to Tartu county. In order to estimate the speed of divergence of Tartu county in comparison with the others, it was decided to create a model with a dummy variable T_i, where T_i=1 for Tartu county and T_i=0 for the others. The estimated model is presented below with a summary of the most important statistics (t-ratio in brackets):

Model 3.4.2[1]

$$\frac{1}{9}\log(\frac{Y_{2005}}{Y_{1996}}) = -0.132 + 0.035\log(Y_{1996}) + 0.005T\log(Y_{1996}) \qquad R^2=0.55$$

(-1.73) (2.56) (2.58) DW=2.8

A linear regression analysis for the model (statistically significant at 5% significance level), estimating the annualized growth of GDP per capita in relation to the initial level of GDP gives a positive β-coefficient showing an annual divergence rate of 3.5% for the whole period. The regression results reject the convergence hypothesis (the null hypothesis - there is a significant negative relation between the growth of GDP per

[1] Model is estimated with help of EViews 5.0 and initial data is in Appendix 9.

capita and the starting level of GDP per capita; and alternative hypothesis - there is a significant not negative ratio between the growth of GDP per capita and the starting level of GDP per capita) with β-coefficient being positive and statistically significant (at 5% significance level). The autonomous growth (statistically insignificant at 5% significance level) that is negative and expressed through constant term is 2.9%. The coefficient of dummy variable (statistically significant at 5% significance level) shows that the speed of divergence is statistically differs from that of all Estonia and 0.5% greater, estimating the results for Tartu county.

Examination of residuals

The examination of the residuals is a good visual diagnostic to detect autocorrelation or heteroscedasticity. For the estimated model values of the residuals were plotted against independent variable - initial levels of GDP per capita in 1996.

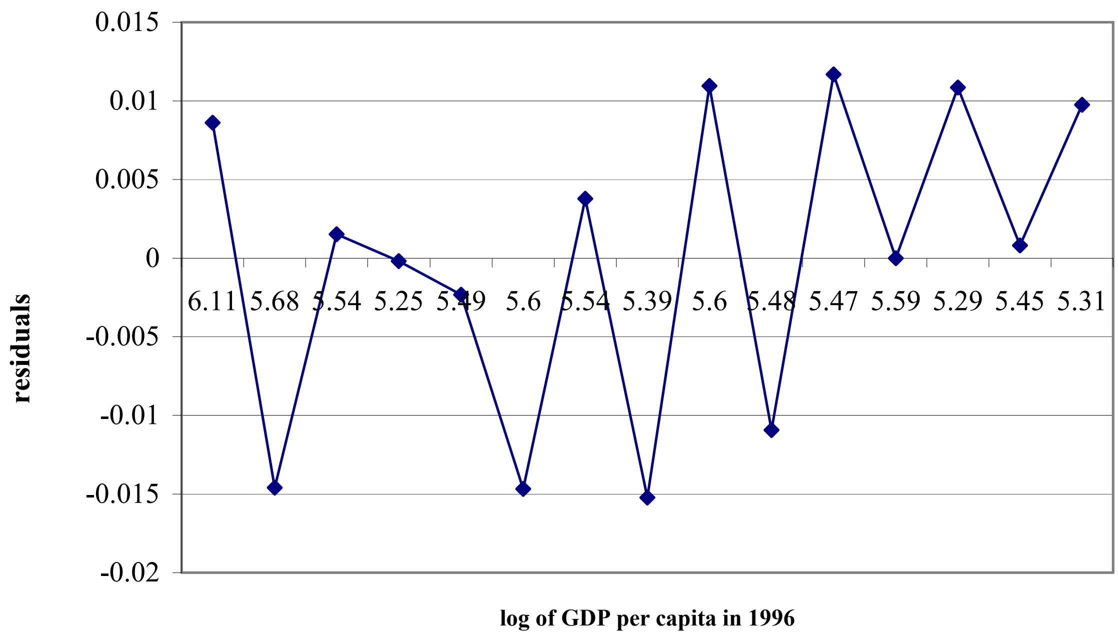

Figure 3.4.3 **Residuals of the estimated Model 3.4.2 proportional to log of initial level of GDP per capita**

Source: own calculations, initial data presented in Appendix 9

From the Figure 3.4.3 it can be seen that the residuals from the regression appear to be distributed on the both sides of the horizontal axis (zero mean). There is a quick check of residuals that indicates that the residuals show evidence of autocorrelation, therefore Durbin-Watson d-test was carried out to examine the model for autocorrelation.

Durbin-Watson d-test

The present model was tested for existence of autocorrelation using Durbin-Watson d-test for autocorrelation. The upper (d_U) and lower (d_L) critical values of the d-statistic at 5% level of significance from the table of the D-W statistic were found for the given sample size (15 counties) and the number of explanatory variables (log of initial level of GDP per capita and dummy variable). The upper (d_U) and lower (d_L) critical values of the d-statistic are 1.543 and 0.946 respectively. Obtained d-statistic from the model is 2.8. In order to test for autocorrelation must be used the decision rule of Durbin-Watson d-test ($4 - d_U \leq d \leq 4 - d_L$) that indicates on 'zone of indecision' and it cannot be concluded if a autocorrelation problem exists in the model. Therefore, the Runs test is used to examine the model for a problem of autocorrelation.

The Runs test

The Runs test was carried out for the estimated Model 3.4.2. The residuals were obtained from the estimated model and the number of runs (k=9) was calculated. The number of positive values of residuals is 9 (N_1=9) and number of negative values of residuals is 6 (N_2=6). The critical values derived from the table of critical values of runs in the Runs test (N_1=9, N_2=6) are 4 and 13 at 5% level of significance. Since the value of the number of runs belongs to the interval of the critical values ($4 < 9 < 13$), the null hypothesis (a null hypothesis – residuals are distributed randomly, an alternative hypothesis – residuals have an autocorrelation problem) cannot be rejected and it is concluded that residuals are distributed randomly and there is no problem of autocorrelation.

Spearman's rank correlation test

According to the test, if the computed t-value exceeds the critical t-value, it might be accepted the hypothesis of heteroscedasticity (a null hypothesis – residuals have a homoscedasticity, an alternative hypothesis – residuals have a heteroscedasticity); otherwise it might be rejected. The critical t-value was obtained from tables of percentage points of the t-distribution and for 15 observations (degree of freedom is 13) it equals 2.16 (at 5% significance level). Since the computed t-value (1.103) is less than the critical t-value, then it is concluded that the hypothesis of heteroscedasticity is rejected and there is no problem of heteroscedasticity in the estimated model.

Although the coefficient of determination is 0.55, which means that the model explains 55% of variation of annual growth of GDP per capita, there is no problem of heteroscedasticity and autocorrelation in the model. Considering period of 9 years, it highlights a divergence across the counties of Estonia and difference in the speed of divergence is bigger for 0.5% estimating the results for Tartu county.

4 ANALYSIS OF TIME SERIES CONVERGENCE

This section presents results of the analyses of time series tests of convergence across the Baltic countries. Quarterly data from Eurostat has been obtained to conduct the study.

4.1 Description of time series data

To do time series tests of convergence across the Baltic States (Latvia, Lithuania and Estonia) the quarterly data for GDP per capita at current prices and monthly HIPC (Harmonized Index of Consumer Prices) are derived from the Eurostat database over the period of 1996 – 2007.

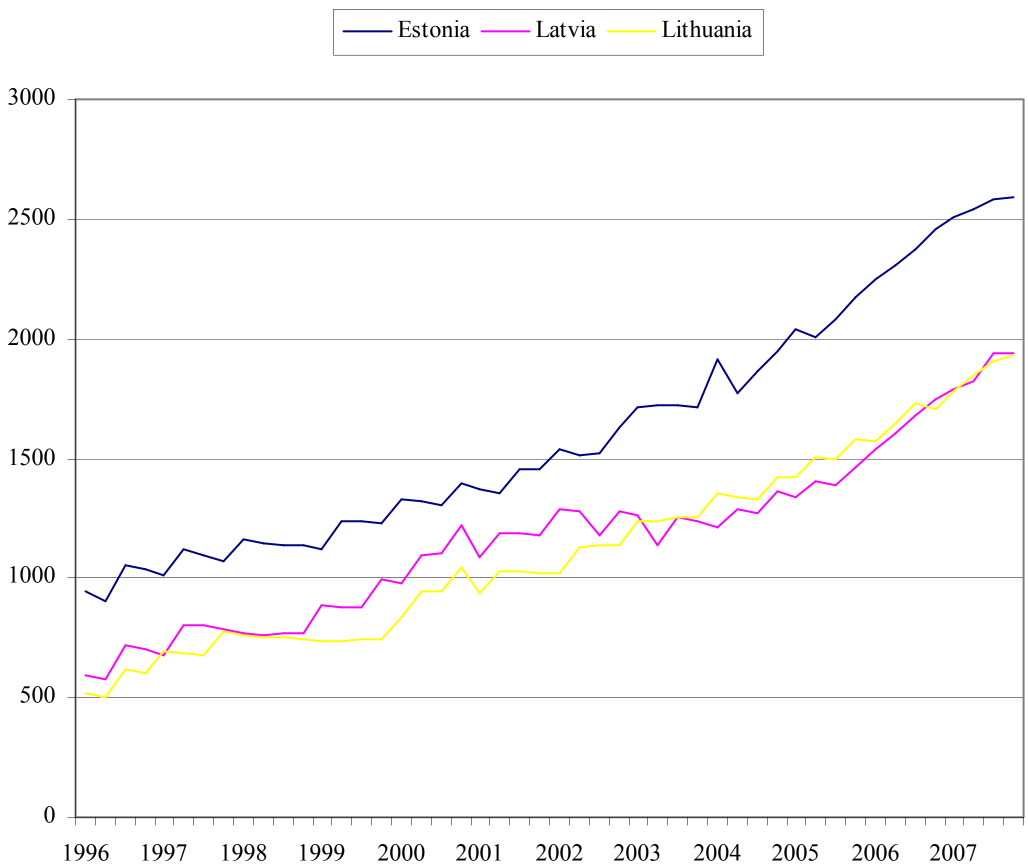

Figure 4.1.1 **Real GDP per capita[1] in the Baltic States over period 1997 – 2007 (per capita, EUR)**

Source: own calculations, initial data presented in Appendix 10

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[1] Real GDP per capita data were computed for every quarter as ratio of GDP per capita of a country at current prices and Harmonized Index of Consumer Prices of the country (base 2005=1.0) in appropriate year and initial data is in Appendix 10

The data for GDP per capita at current prices are thereafter converted to real GDP per capita via HIPC deflator. In Figure 4.1.1, graphs show tendency of growth of real GDP per capita over the time period 1996 – 2007 for Latvia, Lithuania and Estonia.

The quarterly data of real GDP per capita for each country is plotted against the time. At the beginning of the period the Baltic States have the level of real GDP per capita in between EUR 500 and EUR 1,000. Despite insignificant falls in their GDP per capita, the countries have constant growth. In 1996 Lithuania had the least level real GDP per capita, and Estonia had the greatest level of real GDP per capita among the countries. In 2003 Lithuania reached the level of real GDP per capita of Latvia and until 2006 Lithuania had the second place among the countries. Since 2006 Latvia and Lithuania were showing a little difference in their real GDP per capita. Figure 4.1.1 reveals that Estonia had the highest real GDP per capita level in the whole sample period. Latvia and Lithuania seem to catch up with Estonian level of real GDP per capita and therefore the empirical part of the study also includes a formal convergence test of the data shown in Figure 4.1.1.

The obtained data of real GDP per capita is used for time series tests of convergence and further in this study, for "GDP per capita" one should understand "real GDP per capita".

4.2 Tests of stationarity of the time series

In order to apply for time series tests of convergence, it is necessary to check for stationarity the time series of GDP per capita of Estonia, Latvia and Lithuania over period 1996 – 2007. Economic time series variables like GDP per capita variables are usually found to be non-stationary in levels and consequently, the Dickey-Fuller tests are performed for all GDP per capita in order to investigate for stochastic a trend - which is an import part of time series tests of convergence. The DF/ADF-tests whether GDP per capita is integrated, I(n), or stationary, I(0), are done with a time trend for GDP per capita of all three countries (Estonia, Latvia and Lithuania) where the inclusion of a deterministic trend will give power to an alternative hypothesis of trend-stationarity. The results are reported in the Table 4.2.1.

Table 4.2.1

DF/ADF-test statistics and critical values of unit root test

	DF-test statistic (intercept)	ADF-test statistic (intercept/trend)
Estonia	0.856332	-1.878005
Latvia	0.213556	-2.038599
Lithuania	0.637817	-2.146391
	Critical Value	**Critical Value**
	-2.9241	-3.5066

Source: own calculations, initial data presented in Appendix 10

The DF/ADF-test statistics has been derived from the unit root test. The tests also include a deterministic trend to allow for an alternative hypothesis of trend stationarity and the critical values for the two cases reported in the Table 4.2.1 at the 5% level of significance, according to MacKinnon (1991).

The hypotheses of stationarity (a null hypothesis – time series is non-stationary, an alternative hypothesis – time series is stationary) of the GDP per capita time series of all three countries were tested. In all the tests the DF/ADF-test statistic values derived from in the unit root test are greater than critical values. Then the null hypothesis is not rejected and conclusions from the Table 4.2.1 are in all cases similar for the countries – time series of GDP per capita are non-stationary and it means that they are integrated. Now it will be tried to check if the time series are integrated of order 1 – also when allowing for a deterministic time trend in the data. The DF/ADF-tests whether GDP per capita is integrated of order 1, I(1), are done with the first difference of GDP per capita of all three countries (Estonia, Latvia and Lithuania). The results are reported in the Table 4.2.1.

The DF/ADF-test statistics has been derived from the unit root test. The tests also include a deterministic trend to allow for an alternative hypothesis of trend stationarity and the critical values for the two cases reported in the Table 4.2.2 at the 5% level of significance, according to MacKinnon (1991).

Table 4.2.2

DF/ADF-test statistics and critical values of unit root test

	DF-test statistic (intercept)	**ADF-test statistic (intercept/trend)**
Estonia	-10.42239	-10.87501
Latvia	-10.49637	-10.57539
Lithuania	-10.80604	-11.04435
	Critical Value	**Critical Value**
	-2.9256	-3.5088

Source: calculations done with help of Eviews 5.0, initial data presented in Appendix 10

The hypotheses of stationarity (a null hypothesis – time series is non-stationary, an alternative hypothesis – time series is stationary) of the 1st differences of GDP per capita time series of all three countries were tested. In all the tests the DF/ADF-test statistic values derived from in the unit root test are greater than critical values. Then the null hypotheses are rejected and the conclusions from the Table 4.2.2 are in all cases similar for the countries – time series of the 1st differences of GDP per capita are stationary.

The conclusions from the Table 4.2.1 and the Table 4.2.2 are in all cases similar for Estonia, Lithuania and Latvia. The time series of GDP per capita are not stationary and time series of the 1st differences of GDP per capita are stationary. So the time series are integrated of order 1, and it is possible to apply to estimation of time series tests of convergence among the countries.

4.3 Time series tests of convergence among the Baltic States[1]

In order to examine a convergence of Bernard-Durlauf approach, the time series of differences of GDP per capita between two countries are tested. The problem is to test if GDP per capita difference between two economies contains a unit-root. The ADF tests are performed for three pairs of countries (Latvia- Estonia, Estonia-Lithuania and Latvia-Lithuania); the results are reported in the Table 4.3.1:

[1] in this part “GDP per capita” should be treated as “logarithm of real GDP per capita”

Table 4.3.1

ADF-test statistics, critical values, lag lengths, slopes of trends and their p-values of unit root test

	Slope	p-value	Lag length	ADF-test statistic	Critical Value
Latvia/Estonia	0.00046	0.4855	1	-2.1074	-3.5107
Estonia/Lithuania	-0.00225	0.0084	0	-4.4465	-3.5085
Latvia/Lithuania	-0.00110	0.2701	3	-2.0024	-3.5155

Source: estimations done with help of Eviews 5.0 and initial data presented in Appendix 10

The ADF-test statistics has been derived from the unit root test. The tests include a deterministic trend. Slopes of trends and their p-values are represented in the Table 4.3.1. The critical values for the tests are reported in the Table 4.3.1 at the 5% level of significance, according to MacKinnon (1991). The lag length was selected according to Schwarz criterion that varies the lag length from 0 to 9.

Time series test of convergence between Latvia and Estonia

The hypothesis of stationarity (a null hypothesis – time series is nonstationary, an alternative hypothesis – time series is stationary) of the GDP per capita time series of difference between Estonia and Latvia was tested. In the tests the ADF-test statistic value derived from in the unit root test is greater than the critical value. Then the null hypothesis is not rejected and it is concluded that GDP per capita time series of difference between Estonia and Latvia is not stationary. Since the time series is not stationary, it is concluded that there is no convergence between Estonia and Latvia.

Time series test of convergence between Estonia and Lithuania

The obtained results of unit root test of GDP per capita time series difference between Estonia and Lithuania show that the difference does not contain a unit root, therefore the hypothesis of non-stationarity (a null hypothesis – time series is nonstationary, an alternative hypothesis – time series is stationary) is rejected (for the tests the ADF-test statistic value derived from in the unit root test is smaller than critical values) and time series is stationary. Since the time series is stationary, it is concluded that there is a convergence between Estonia and Lithuania. The slope (-0.00225) of trend in the estimated model for two countries Estonia and Lithuania is statistically significant at 5% significance level. Significance of trend indicates on catching-up process between the countries.

Time series test of convergence between Latvia and Lithuania

The hypothesis of stationarity (a null hypothesis – time series is nonstationary, an alternative hypothesis – time series is stationary) of GDP per capita time series of difference between Lithuania and Latvia was tested. In the tests the ADF-test statistic value derived from in the unit root test is greater than the critical value. Then the null hypothesis is not rejected and it is concluded that GDP per capita time series of difference between Lithuania and Latvia is not stationary. Since the time series is not stationary, it is concluded that there is no convergence between Lithuania and Latvia.

CONCLUSIONS AND SUGGESTIONS

The conducted study has lead to the following conclusions:

1. There are two positions relative to the process of sequence growth: convergence and divergence.
2. Absolute convergence can be used to estimate convergence among regions, and conditional convergence should be applied to estimate convergence among countries.
3. Various types of convergence exist along with corresponding tests to verify them. (β-convergence, σ-convergence and time series tests of convergence).
4. All regions of the Baltic States revealed growth in their GDP per capita over the observed period: Latvia in 1995 – 2005, Lithuania in 1995 – 2005, and Estonia in 1996 – 2005.
5. Rich regions showed faster growth than poor regions in all the Baltic countries
6. For the Baltic States, differences of GDP per capita between the poorest region and the richest region are much greater at the end of the period than at the beginning of the period.
7. Each country has a 'leader-region' that had the highest level of GDP per capita at the beginning of the period and still has the greatest level of GDP per capita at the end of the period observed.
8. Estonia has the highest level of GDP per capita among the Baltic States in 1996 – 2007.
9. Tests of σ-convergence showed that there is a mixed process of convergence and divergence among Latvian districts, process of divergence among Lithuanian counties and process of divergence among Estonian counties.
10. Tests of β-convergence prove the fact that there is a process of divergence among the regions of each country in the Baltic States.
11. The annual speed of divergence in estimated models for Latvia – 3.4%, for Estonia – 3.5% and for Lithuania – 6%.[1]

[1] For Latvia an Estonia Model 3.1.2 and Model 3.4.2 with dummy variables are considered

12. Testing Latvian regions for β-convergence, it was concluded, that there is no difference of structural factors influencing on speed of convergence among regions of Latvia.
13. Estimated models have neither problem of autocorrelation, nor of heteroscedasticity. However, it should be taken into account that the number of observation is not great because of definite number of administrative territories in the countries (districts, counties, regions).
14. Time series of real GDP per capita of Latvia, Lithuania and Estonia appeared to be integrated of order 1 for the period of observation (1996 – 2007).
15. Time series tests of convergence demonstrate that there is no convergence between Latvia and Lithuania or between Latvia and Estonia. However, there is a process of convergence between Estonia and Lithuania.

In order to reduce divergence the following suggestions can be considered:

1. Investment in human capital. The evidence supports the view that investment in human capital, such as, education and training tends to increase productivity and growth rate, as well.
2. Investment in infrastructure. It increases both the return on private investment and job creation. This, in turn, leads to growth of output and raise of growth rates.
3. Subsidies or tax incentives for private investments. It would encourage faster development of regions.
4. Support regions through EU structural funds according to EU regional policy.
5. Support by either tax reduction or subsidies (or other type of benefits) successful and profitable businesses in the regions.
6. To develop a special state program to subsidize quality life and re-locations in the regions.
7. To coordinate better supplies and improved product marketing in order to encourage growth of trade in the regions. Improvement in communication could help a faster development of the regions.
8. Reduce unnecessary local regulations in order to help and support small regional businesses.

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Appendix 1

GDP per capita and CPI, Latvia, 1995 - 2005

GDP per capita at current prices of Latvian districts in 1995 – 2005 (per capita, LVL)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Aizkraukle district	776	896	971	957	1212	1151	1457	1724	1497	1792	2257
Aluksne district	661	770	681	815	858	910	946	1066	1210	1307	1711
Balvu district	511	601	685	688	745	744	799	971	1033	1350	1401
Bauska district	844	956	898	938	1009	1120	1136	1138	1433	1432	1932
Cesis district	699	816	973	991	1054	1206	1305	1390	1652	1878	2429
Daugavpils district	748	873	1149	883	844	1008	1015	853	867	861	1098
Dobele district	869	991	951	899	971	1057	1178	1409	1534	1616	2128
Gulbene district	619	753	892	964	862	955	1195	1319	1381	1437	1741
Jelgava district	511	558	684	685	762	860	810	948	1315	1189	1765
Jekabpils district	610	696	806	818	963	1121	1208	1262	1666	1498	2032
Kraslava district	464	536	667	711	696	731	806	865	945	1122	1177
Kuldiga district	584	698	841	871	922	1035	1056	1227	1438	1475	1775
Liepaja district	592	684	673	699	760	883	973	1076	1261	1435	1483
Limbazi district	800	954	1096	972	1105	1140	1170	1248	1438	1474	1855
Ludzas district	492	574	686	700	721	786	849	915	1004	1158	1330
Madona district	585	685	841	855	839	904	1025	1092	1464	1815	1879
Ogre district	749	863	836	944	963	1089	1241	1395	1362	1575	2033
Preili district	456	531	674	649	673	787	916	1049	1162	1437	1868
Rezekne district	410	462	453	440	448	521	573	624	801	883	966
Riga district	1003	1193	1281	1477	1477	1684	1844	2053	2376	2787	3875
Saldus district	877	1038	1111	1239	1128	1258	2079	2247	1812	2600	2498
Talsi district	684	832	951	1139	1089	1212	1277	1512	1563	1612	2221
Tukums district	804	955	1049	1030	984	1077	1221	1347	1468	1440	2226
Valka district	824	932	1014	1034	1109	1080	1096	1490	1816	2118	2507
Valmiera district	698	845	1134	1185	1337	1421	1536	1884	1993	2396	2915
Ventspils district	650	720	553	679	696	804	1429	1484	1135	2256	1980

Source: Central Statistical Bureau of Latvia, database

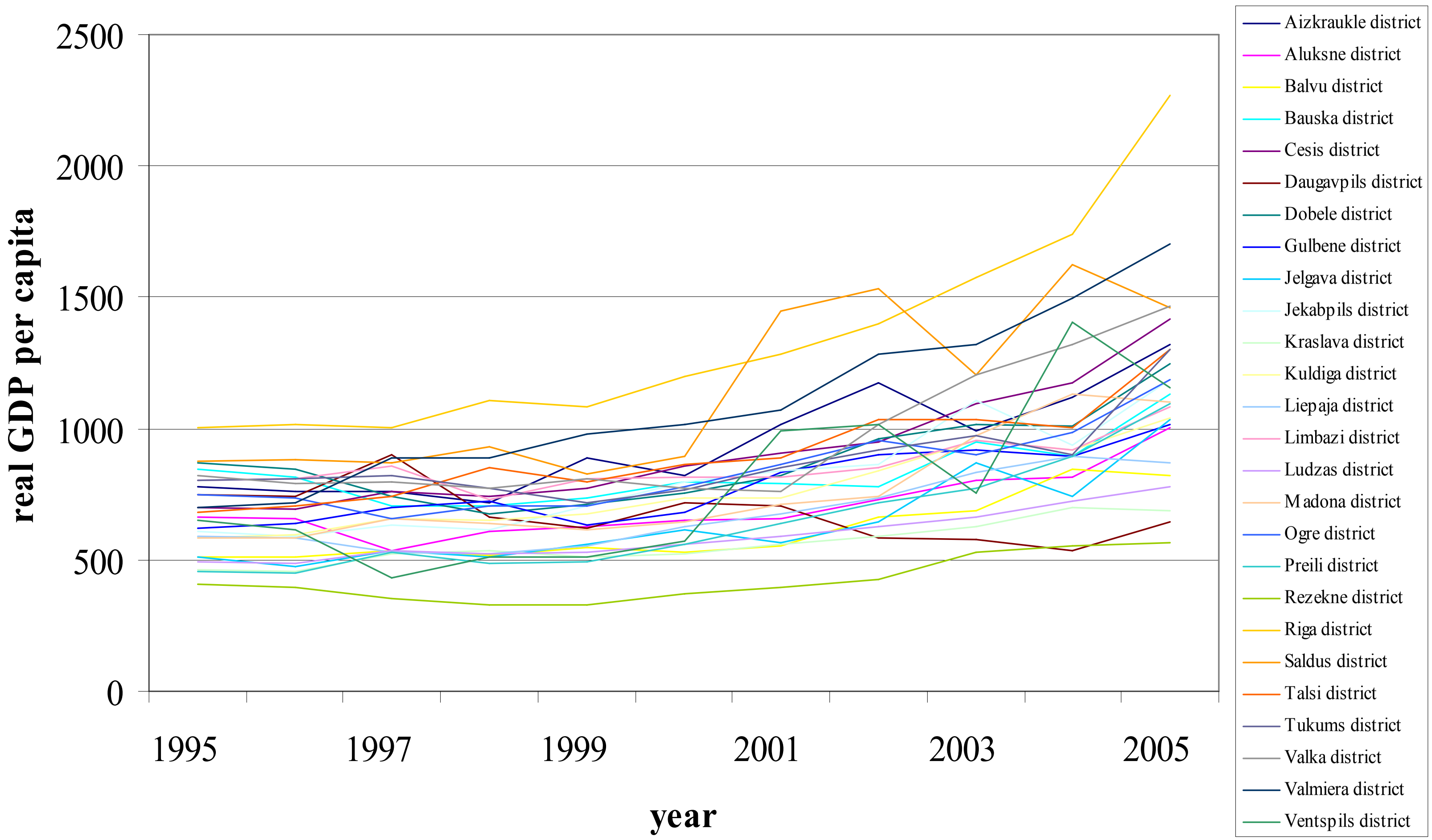
Consumer Price Indexes in Latvia, 1995 - 2005

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CPI	100	117.6	127.6	133.5	136.6	140.3	143.8	146.5	150.8	160.2	171

Source: Central Statistical Bureau of Latvia, database

Appendix 2

Real GDP per capita of Latvian districts in 1995 – 2005



Real GDP per capita of Latvian districts in 1995 – 2005 (per capita, LVL)

Source: own calculations, initial data presented in Appendix 1

Appendix 3

GDP per capita and CPI, Lithuania, 1995 – 2005

GDP per capita of Lithuanian counties in 1995 – 2005 (per capita, LTL thousand)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Alytus county	6.2	7.8	9.1	10.5	10.5	10.7	11.2	11.6	11.9	12.9	14.3
Kaunas county	6.8	8.6	11.1	12.4	12.1	12.5	13.7	14.1	15.8	17.4	20.0
Klaipeda county	7.9	10	12.1	13.6	13.5	14.7	15.4	16.2	17.5	18.8	21. 8
Marijampole county	5.8	7.4	9.5	9.9	8.6	9.5	9.4	10	11.3	11.9	13.3
Panevezys county	7.2	9.2	11	12	11	11.8	12.4	13	13.7	15.7	17.0
Siauliai county	6.5	8.4	9.5	10.1	9.9	10.1	10.3	11.1	12.4	14.1	15.4
Taurage county	4.7	6.1	6.6	7.4	7.5	8	8.5	8.7	8.9	9.6	10.4
Telsiai county	6.2	7.8	9.2	10.8	10.6	11.2	12.1	12.5	13.9	16.2	18.0
Utena county	7.2	8.9	10	11.4	11.4	11	11.6	12.4	14	15.3	17.2
Vilnius county	8.4	10.7	14	16.1	16.3	17.4	19	21.5	23.6	26.1	29.8

Source: Central Statistical Bureau of Lithuania, database

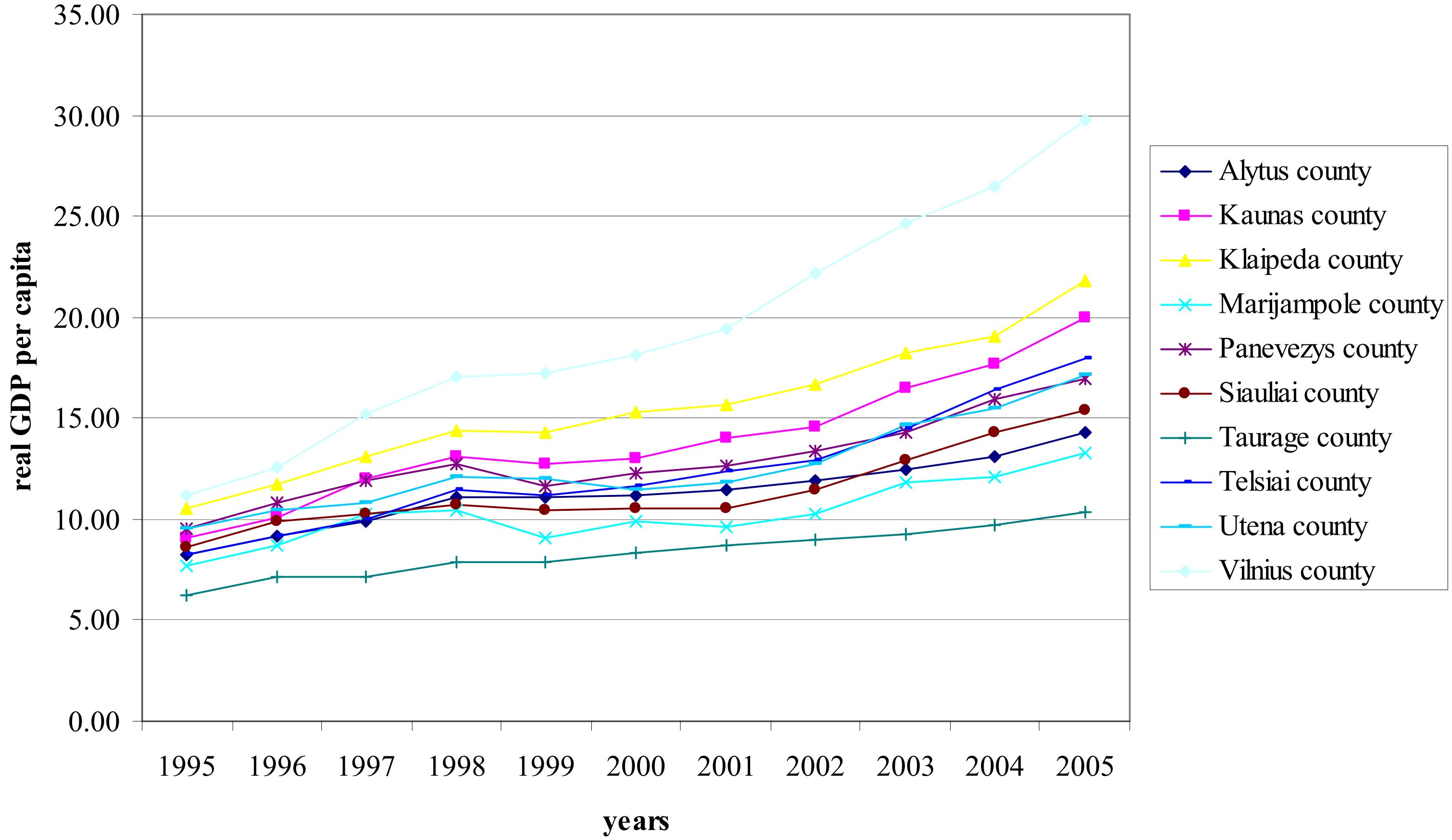
Consumer Price Indexes in Lithuania, 1995 - 2005

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CPI	75.22	85.06	92.17	94.39	94.69	96.06	98.01	97.05	95.76	98.54	100.00

Source: Central Statistical Bureau of Lithuania, database

Appendix 4

Real GDP per capita of Lithuanian counties in 1995 – 2005



Real GDP per capita of Lithuanian counties in 1995 – 2005 (per capita, LTL thousand)

Source: own calculations, initial data presented in Appendix 3

Appendix 5

GDP per capita and CPI, Estonia, 1996 – 2005

.

GDP per capita of Estonian counties in 1996 – 2005 (per capita, EEK)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Harju county	55709.4	71554.5	81883.9	88522.9	103396	118146	133958	152665	171937	196762
Hiiu county	35917.6	43979.2	50530.7	55120.5	58175	61110.5	67948.6	70830.5	79085.9	89523.7
Ida-Viru county	31421.2	37662.3	39876.5	41871.8	46873.5	51499.4	57131.4	63620.7	67165.4	86763.4
Jogeva county	23399.5	28047.9	31136.5	31215.6	35581.9	39222.5	43150.9	45462.4	50349.9	57936.2
Jarva county	29738.3	38817.1	43661.9	47334.7	52083.2	57207.4	62784.6	68746.3	74452.4	77950.5
Laane county	33311.5	39956.7	45068.2	44836.9	48559.1	53376.1	59097.2	61751	70370.6	80999.3
Laane-Viru county	31435.8	36699.8	41440	45873.1	52099.4	57836.1	67222.3	70432.5	75783.6	88602.5
Polva county	27035.1	31575.4	32723.9	35535	40668.3	45701.7	46879.7	51215.7	52483.8	61212.9
Parnu county	33189.8	41481.1	48456.1	49917.8	57596.7	66990.3	72731.1	76838.7	82992.4	101527
Rapla county	29573.1	34405.2	39636.1	41490	47250.4	51382.4	55428.9	61869.3	64184.1	71615
Saare county	29328.6	34598.5	39103.7	41737.4	47420.3	55498.1	60940.3	65395	71519.2	86827.4
Tartu county	33061.1	39733.2	45346	48202.5	53711.1	64427	72974.3	85632.5	93608.5	118223
Valga county	24411.3	28114.2	33230.4	36189	40269.9	42562.7	49699.8	55483.1	56671.6	67655.1
Viljandi county	28609.7	33561.6	37156.6	39957.2	44561.9	50265.6	56635.3	61736.5	66426	76186.1
Voru county	24955.1	31308.3	34688.6	37944.2	42831.7	46322	52628.2	57699	60336.5	68965.6

Source: Central Statistical Bureau of Estonia, database

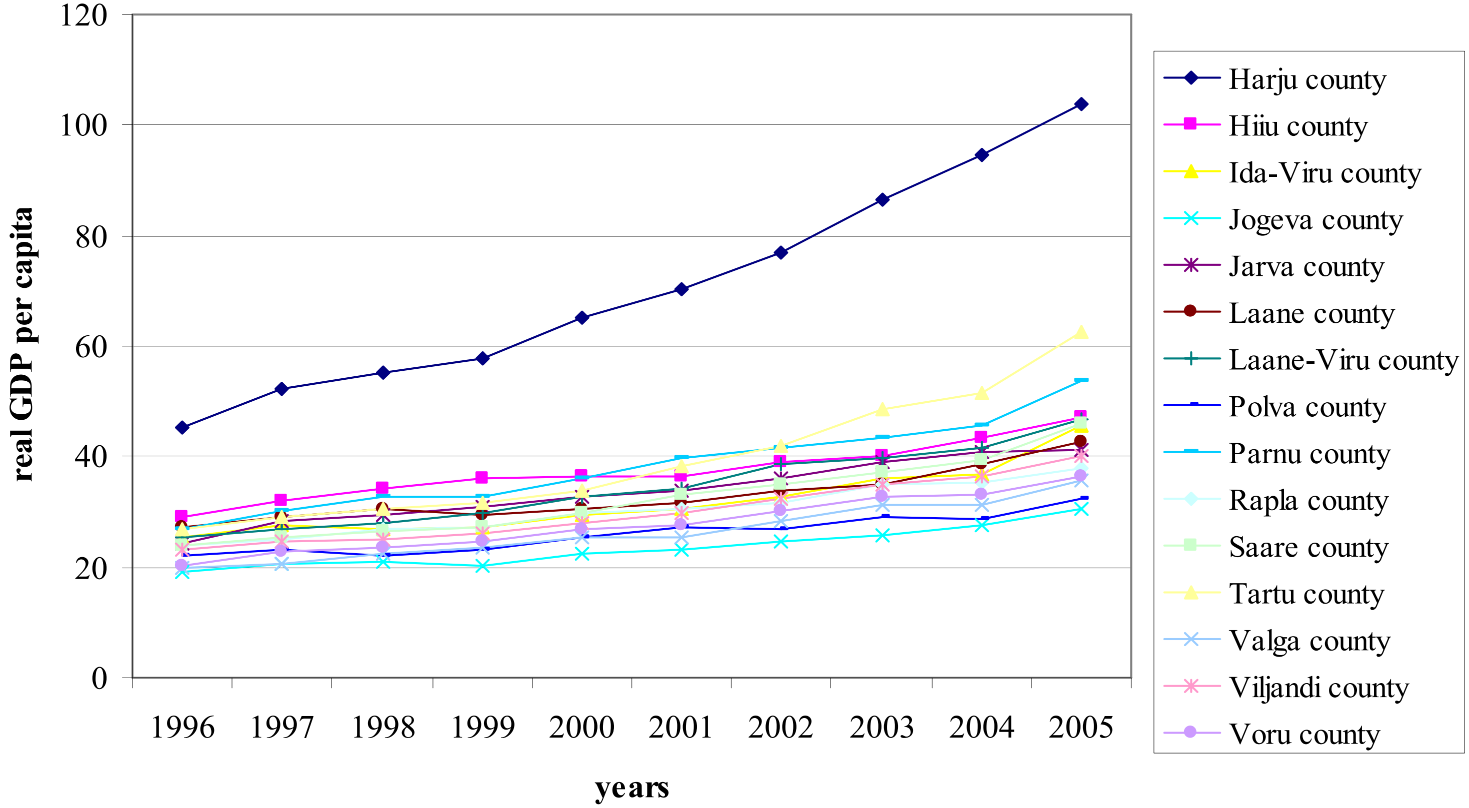
Consumer Price Indexes in Estonia, 1996 - 2005

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CPI	123.1	136.9	148.1	153.0	159.1	168.3	174.4	176.7	182.0	189.4

Source: Central Statistical Bureau of Estonia, database

Appendix 6

Real GDP per capita of Estonian counties in 1996 – 2005



Real GDP per capita of Estonian counties in 1996 – 2005 (per capita, EEK thousand)

Source: own calculations, initial data presented in Appendix 5

Appendix 7

Log of GDP per capita in 1995 and annual growth rate of GDP per capita for Latvian districts, 1995 – 2005

	$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}})$	$\log(Y_{1995})$
Aizkraukle district	0.0531	2.5801
Aluksne district	0.0415	2.3032
Balvu district	0.0472	2.1033
Bauska district	0.0292	2.4246
Cesis district	0.0709	2.6536
Daugavpils district	-0.0153	1.8596
Dobele district	0.0359	2.5213
Gulbene district	0.0498	2.3206
Jelgava district	0.0703	2.3342
Jekabpils district	0.0667	2.4751
Kraslava district	0.0394	1.9291
Kuldiga district	0.0575	2.3399
Liepaja district	0.0382	2.1602
Limbazi district	0.0305	2.3840
Ludzas district	0.0458	2.0513
Madona district	0.0630	2.3968
Ogre district	0.0462	2.4756
Preili district	0.0874	2.3910
Rezekne district	0.0321	1.7315
Riga district	0.0815	3.1206
Saldus district	0.0510	2.6816
Talsi district	0.0641	2.5640
Tukums district	0.0482	2.5663
Valka district	0.0576	2.6852
Valmiera district	0.0893	2.8360
Ventspils district	0.0577	2.4492

Source: own calculations, initial data in Appendix 1

Appendix 8

Log of GDP per capita in 1995 and annual growth rate of GDP per capita for Lithuanian counties, 1995 – 2005

	$\frac{1}{10}\log(\frac{Y_{2005}}{Y_{1995}})$	$\log(Y_{1995})$
Alytus county	0.05505	4.41182
Kaunas county	0.07946	4.50420
Klaipeda county	0.07297	4.65414
Marijampole county	0.05458	4.34513
Panevezys county	0.05718	4.56136
Siauliai county	0.05764	4.45908
Taurage county	0.05047	4.13484
Telsiai county	0.07778	4.41182
Utena county	0.05833	4.56136
Vilnius county	0.09805	4.71551

Source: own calculations, initial data in Appendix 2

Appendix 9

Log of GDP per capita in 1996 and annual growth rate of GDP per capita for Estonian counties, 1995 – 2005

	$\frac{1}{9}\log(\frac{Y_{2005}}{Y_{1996}})$	$\log(Y_{1996})$
Harju county	0.0923	6.1149
Hiiu county	0.0536	5.6760
Ida-Viru county	0.0650	5.5422
Jogeva county	0.0528	5.2475
Jarva county	0.0592	5.4872
Laane county	0.0508	5.6007
Laane-Viru county	0.0672	5.5427
Polva county	0.0429	5.3919
Parnu county	0.0763	5.5970
Rapla county	0.0504	5.4816
Saare county	0.0727	5.4733
Tartu county	0.0937	5.5931
Valga county	0.0654	5.2898
Viljandi county	0.0609	5.4485
Voru county	0.0651	5.3118

Source: own calculations, initial data in Appendix 3

Appendix 10

GDP per capita and HICP[1] of Latvia, Lithuania and Estonia, 1996 - 2007

Data on per capita GDP and HICP[2]

	per capita GDP, EUR			HICP		
	Estonia	Latvia	Lithuania	Estonia	Latvia	Lithuania
1996q01	600	400	400	63.53	67.03	76.67
1996q02	600	400	400	66.37	68.99	79.98
1996q03	700	500	500	66.59	69.85	80.91
1996q04	700	500	500	67.38	71.35	83.05
1997q01	700	500	600	69.07	73.62	86.68
1997q02	800	600	600	71.67	74.75	87.43
1997q03	800	600	600	73.01	75.03	88.90
1997q04	800	600	700	74.59	76.18	90.53
1998q01	900	600	700	77.21	77.63	92.37
1998q02	900	600	700	78.46	78.49	93.20
1998q03	900	600	700	79.01	78.01	93.09
1998q04	900	600	700	79.01	78.30	93.92
1999q01	900	700	700	80.17	79.36	94.88
1999q02	1000	700	700	80.88	79.69	94.67
1999q03	1000	700	700	80.90	79.46	94.27
1999q04	1000	800	700	81.45	80.57	94.21
2000q01	1100	800	800	82.61	81.91	95.74
2000q02	1100	900	900	83.28	82.14	95.53
2000q03	1100	900	900	84.44	81.44	95.20
2000q04	1200	1000	1000	85.81	82.00	95.64
2001q01	1200	900	900	87.37	82.86	95.98
2001q02	1200	1000	1000	88.73	84.15	97.13
2001q03	1300	1000	1000	89.34	84.15	97.24
2001q04	1300	1000	1000	89.60	84.61	97.69
2002q01	1400	1100	1000	91.19	85.60	98.44
2002q02	1400	1100	1100	92.44	85.79	97.61
2002q03	1400	1000	1100	91.92	84.98	96.52
2002q04	1500	1100	1100	92.25	85.95	96.81

[1] Harmonized Index of Consumer Prices
[2] Quarterly HICP were computed as average for 4 months

2003q01	1600	1100	1200	93.30	87.24	96.89
2003q02	1600	1000	1200	93.15	88.26	96.97
2003q03	1600	1100	1200	93.08	87.91	95.66
2003q04	1600	1100	1200	93.37	88.97	95.64
2004q01	1800	1100	1300	93.89	91.03	95.82
2004q02	1700	1200	1300	96.11	93.34	97.45
2004q03	1800	1200	1300	96.71	94.40	97.90
2004q04	1900	1300	1400	97.48	95.42	98.46
2005q01	2000	1300	1400	98.14	97.18	98.78
2005q02	2000	1400	1500	99.54	99.60	99.74
2005q03	2100	1400	1500	100.91	100.69	100.09
2005q04	2200	1500	1600	101.41	102.54	101.38
2006q01	2300	1600	1600	102.46	104.02	102.08
2006q02	2400	1700	1700	103.97	106.08	103.33
2006q03	2500	1800	1800	105.36	107.28	104.09
2006q04	2600	1900	1800	105.98	108.91	105.64
2007q01	2700	2000	1900	107.67	111.93	106.56
2007q02	2800	2100	2000	110.05	115.10	108.47
2007q03	2900	2300	2100	112.46	118.45	110.27
2007q04	3000	2400	2200	115.78	123.79	114.02

Source: own calculations, initial data are from Eurostat database, seasonally adjusted data