Economic growth and convergence in the world economies: an econometric analysis

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This paper investigates, whether convergence or divergence can be observed among world economies between 1992 and 2008. The catching-up process is calculated for GDP per capita, as this indicator is a relative good quantitative proxy for economic growth. However, the factors behind economic growth were not analysed, only the existence and rate of (actual and expected) catching-up.

Both econometric and purely statistical methods have been applied and I have also created an indicator called omega to analyse the convergence process by a new approach. Convergence can be confirmed by all of the indicators: economies are converging to their own level of steady-states but only very slow catching-up can be measured for low income economies (and also for developed countries). Long-run catching-up process is also expected to take place but this primary applies for middle income countries, which mainly confirms the existence of club convergence.

Keywords: Conditional convergence, club convergence, economic growth

1. Introduction

Economic growth and convergence is one of the most discussed fields in economics as the long-run growth basically determines the welfare of countries. Actually, it is assumed that countries with lower GDP per capita tend to grow faster, than the richer ones. This process is called catching-up. This is of great importance as convergence assumes long-run common (or group-specific / own) steady-state levels.

Developing countries might be able to converge towards high income countries, as they can e.g. adopt new technologies of high income countries. These flows might lead to higher rate of economic growth exceeding the growth rate of developed countries. However, the convergence process of lower income countries is not guaranteed. There are many factors leading to divergence: e.g. high level of debts and net lending.

The analysis of economic growth is widely applied in the literature: both the determinants of economic growth and the rate of convergence are measured in vari-

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ous ways by many researchers. In this paper only the rate of convergence is analysed.

On the basis of economic, statistical and econometric models several studies found empirical evidence of convergence among countries. However, mostly conditional convergence can be confirmed. This means that economies are converging but the steady-state is not common, countries are converging towards different steady-states. Therefore, convergence can be measured when control variables (which determine the steady state) are also integrated into the models (e.g. investment/depreciation rate).

Convergence is especially found among homogenous groups of countries (e.g. EU regions, US States, Australian States, Japanese prefectures, Canadian provinces), while generally divergence can be measured among heterogeneous economies and among world economies on the whole.

A catching-up rate of 2% can be estimated very often in various country groups and countries, which might be interpreted as a general rate of convergence. However, this rate might also be defined as a 'statistical artifact' (Johnson et al. 2004).

In this paper an indicator is also presented (which is based on cluster analysis) to analyse convergence by a new approach. In growth econometrics cluster analysis is primarily applied for determining convergence clubs. Researchers (Hobijn – Franses 2000, Corrado et al. 2004) identified groups of converging countries or pattern of differences among world economies. However, in this paper an indicator is primarily applied to calculate convergence.

In the following sections different approaches of convergence are presented. Both econometric and purely statistical methods are calculated: new and some modified classical approaches are also applied.

2. Methodology

Table 1 shows the main economic indicators of the world economies:

Table 1. Economic outlook (2000-2007)

Country group	Year	GDP (current billion USD)	GDP deflator (annual, %)	Agriculture, (% of GDP)	Industry, (% of GDP)	Services, (% of GDP)	Exports (goods, services; % of GDP)	GCF (% of GDP)	FDI net inflows (current billion USD)
World	2000	31 969	5	4	29	67	25	22	1 519
	2005	45 179	5	3	28	69	27	22	1 117
	2006	48 863	6	3	28	69	28	22	1 457
	2007	54 584	5	N/A	N/A	N/A	N/A	N/A	2 139
OECD	2000	24 727	2	2	28	70	22	22	1 273
	2005	33 506	2	2	26	73	23	21	771
	2006	35 223	2	1	26	73	24	21	993
	2007	38 278	2	N/A	N/A	N/A	N/A	N/A	1 515
Middle income	2000	5 660	7	11	36	54	27	24	155
	2005	9 413	5	10	37	53	33	27	270
	2006	11 103	7	9	38	53	33	28	342
	2007	13 490	6	9	37	53	33	29	495
Low income	2000	371	6	30	24	45	28	20	6
	2005	602	9	27	28	45	31	23	12
	2006	701	9	26	29	45	32	24	21
	2007	801	7	25	30	46	32	25	32

Source: Data of World Bank 2009

Substantial differences can be observed among the country groups. The GDP growth is fast, especially in low income countries but they account for only 1.5% of the world GDP in 2007 (although they represent 20% of the population). As the inflation rate is higher in these economies, the difference of deflated GDPs (constant prices) is more substantial.

It is also important to note that agriculture contributes to the GDP in the highest way in low income countries (the rate is ca. 15-20 times higher compared to OECD countries) but the gross valued added of industry accounts for approximately the same rate of contribution (in relative terms) in all country groups. There is also empirical evidence that the more developed the countries are the more substantial gross value added of services is obtained.

As for the income side of GDP (gross capital formation and export), the differences among country groups are not significant compared to the production ap-

proach. Substantial growth rates can also be observed. The same holds true to FDI inflows, which can be interpreted as an effect of globalisation.

The growth rate of GDP per capita is a good proxy for economic growth, hence the analysis is based on this indicator. Data on PPS GDP per capita (and population) are available from IMF for 171[2] countries for the period from 1992 to 2008.

As there are not any other longer time series available in the database (or some data are missing) convergence is only measured by GDP per capita. Therefore, the factors having a significant impact on economic growth cannot be observed by this approach, only the speed and existence of convergence/divergence (which is also the purpose of this paper). At the same time, aggregated factors can be explained by classifications, dummy and constant variables, so the (average or aggregated) effects of omitted variables are also measured. Hence, the measurement of convergence is expanded for appropriate calculation.

As there are different definitions of convergence (e.g. converging to a rate or level of economy/economies, diminishing disparities), multiple methods have been applied. These indicators of convergence (especially the sigma and the beta) are basically based on theories of economic growth: on endogenous and exogenous models (Sorensen et al. 2005). However, as substantial differences exist among these theories, mostly non-theoretical (statistical) models were applied.

3. Data analysis

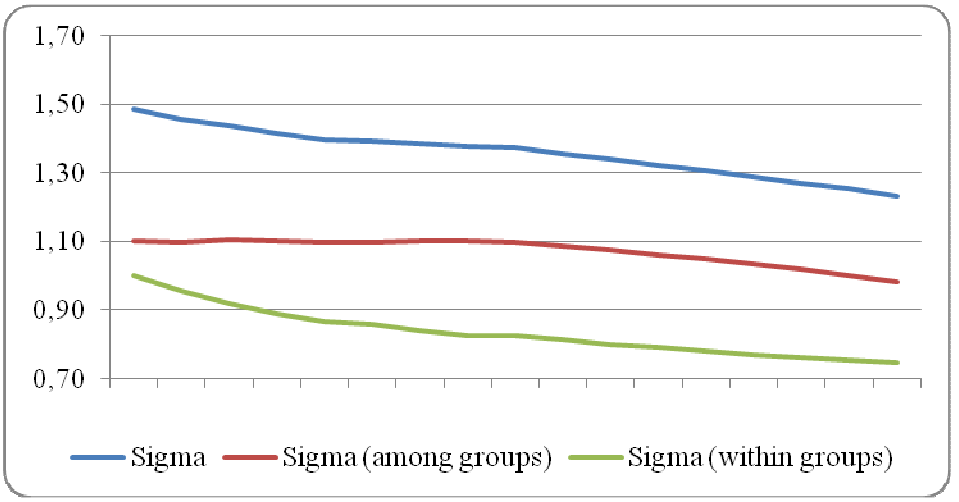
In the following five approaches of convergence are presented:

3.1. Sigma convergence

Chart 1 illustrates the standard deviation of GDP per capita of the world economies (in logarithmic form), which is called sigma (Sala-i Martin 1996b):

[2] Time series data of 11 countries were very short and were not taken into account: Afghanistan, Rep. of.; Bosnia and Herzegovina; Estonia; Georgia; Iraq; Liberia; Montenegro; Serbia; Slovak Republic; Timor-Leste, Dem. Rep. of; Zimbabwe.

Chart 1. Sigma convergence (1992-2008)



Source: own calculations based on data of IMF 2009

The indicator slightly differs from the classic one, as I wanted to modify the sigma in order to take certain factors into account. First, the log values are weighted by the number of population (as these differences are significant among world economies) and second, the sigma is divided into two groups: sigma among and within country groups (which are also weighted) in order to analyse the standard deviation in detail. For calculating the partial standard deviations three groups have been chosen: OECD (members of Organisation for Economic Co-operation and Development), LDC (members of least developed countries defined by the United Nations) and ROW (members of rest of the world countries – non-OECD and non-LDC)[3].

As you can see, *convergence* can be observed: the sigma shows a negative trend, i.e. inequalities were diminishing – approximately at a yearly rate of 1.4 percentage points – among world economies from 1992 to 2008. However, in 1992 the difference between sigma among and within country groups was not significant compared to 2008. This means that disparities among countries of the same group are diminishing quite fast, but disparities among country groups are diminishing at a much smaller rate.

Both tendencies can be accepted, as the convergence of world economies might be rather *conditional*: there are significant differences between countries and group of countries but the convergence might principally apply for countries of simi-

[3] As the time series are not long and there are not any significant changes between the base and the current year, the groups have been determined on the basis of the current year only.

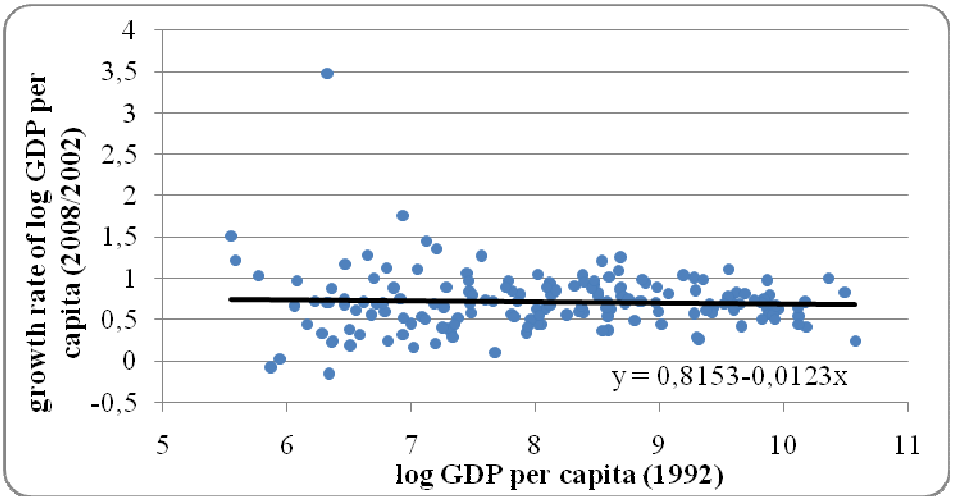
lar level, i.e. countries are converging to their own (group-) level of steady state. In such a way, there is also sign of *club convergence* as economies are not converging towards common, but towards separate steady sates, which may be the same for economies belonging to the same group.

On the basis of sigma I also calculated the number of expected years essential for significant *catching-up*, which is based on ARIMA models[4] (Maddala 2004) of the standard deviations. It can be assumed that natural inequalities will exist in the future as well, hence the comparison of deviations is of greater importance. On the basis of the models, the sigma within and among country groups will be equal in approximately 25-30 years and the total sigma is expected to be under 0.9 till then. Both tendencies are good signs of catching-up, hence strong convergence process is expected to take place, especially in the long-run. However, as past tendencies are actually extrapolated by the models (so long-run effects like trend shifts are not taken into account), the forecasts have to be accepted carefully.

3.2. Beta convergence

Chart 2 shows the log regression of GDP per capita and growth rate called beta (Sala-i Martin 1996a) among world economies:

Chart 2. Beta convergence (1992-2008)



Source: own calculations based on data of IMF 2009

[4] For the sigma among country groups an AR(1) (with constant and trend), for the (total) sigma an ARMA (p=1, q=1; with constant and trend) and for the sigma within country groups a double exponential smoothing model was applied. The (total) sigma and the sigma among country groups are stationary but the sigma within country groups is integrated of order one. No regression errors are detected in the residuals.

Where:

- y = growth rate of log GDP per capita
- x = log GDP per capita.

Convergence can be observed again as the rise of regression curve is negative, i.e. countries with lower GDP per capita tend to grow faster than the richer ones.

Though no autocorrelation and ARCH-effect are detected and the residuals are following normal distribution, the error term is heteroskedastic and one outlier – Equatorial Guinea – may also generate distortions (Ramanathan 2003). In addition, although several low income countries generated fast economic growth, the convergence is far from perfect as the high income countries were growing relative fast, too.

Therefore, the convergence might be rather *conditional* again, so other variables have to be applied for estimating the regression. As there are not any long times series of macroeconomic variables available in the IMF database (or values are missing), dummies are used for classifying the countries into groups mentioned previously.

The secondary calculations showed convergence again and no regression errors are detected:

$$y = 1.12 - 0.07 \cdot x + 0.25 \cdot dum1 + 0.17 \cdot dum2 \quad (1)$$

Where:

- y = growth rate of log GDP per capita
- x = log GDP per capita
- dum1 and dum2 = dummy variables for country groups.

All variables are significant but the outlier should be included for improving the results. The calculation assumes significant club convergence, an almost 7% catch-up rate among economies – exceeding substantially the growth rate confirmed by common empirical results and neoclassical models (2%). At the same time, the regression should be interpreted carefully as the adjusted R^2 is very low (below 5%). Still, there are signs of *club convergence* again.

On the basis of beta the *catching-up* process can be determined. It will take probably more than 100 years for the lowest income country to catch up with highest income country. However, there are very strong assumptions for both high and low income countries and the regression is biased, so the catching-up can only be interpreted as auxiliary indicator and other methods of convergence analysis should be applied.

3.3. Panel modelling

The analysis of inequalities is widely applied in the literature (mostly by panel data), and the modified sigma presented previously is a good proxy for inequalities in my opinion. Therefore, the sigma calculated within countries (which might be of the

greatest importance) have to be divided by the average GDP per capita of the groups and regressed with log GDP per capita:

$$V_{q_w,t} = c + \log(X_{ij,t}) + \varepsilon \tag{2}$$

$$V_{\sigma_{w,t}} = \frac{\sqrt{\sum_{j=1}^{n}\sum_{i=1}^{n_j} f_{ij,t} \cdot \left(\log X_{ij,t} - \log \overline{X_{j,t}}\right)^2}}{\log \overline{X_{j,t}}} \tag{3}$$

Where:

- c: constant variable
- ε: error term
- f: number of population
- x: GDP per capita
- i: country (1, 2… 171)
- j: group (LDC, OECD, ROW)

At the same time, the cross-sectional beta analysis is static, as only the base and the current period are compared. Therefore, panel data have to be applied in order to acquire new information. On the basis of different unit root tests (Levin, Lin, Chu; Breitung; Im, Pesaran, Shin; Fisher ADF and PP; Hadri) there is no presence of unit root in either of the variables.

I applied fixed and random effect models with different weights. The fixed effect model (fixed cross-sections and fixed period dummies) with cross-sectional weights explained the highest variation of inequalities (adjusted $R^2 = 98.1\%$):

$$\sigma_w = -0.27 + 0.04 \cdot x + a_i + b_t + \varepsilon_{it} \Rightarrow E(\varepsilon_i \varepsilon_i' \mid X_i^*) = \sigma^2 I_T \tag{4}$$

Where:

- σ_w: sigma within countries
- x: log GDP per capita
- a_i: cross-sectional fixed effects
- b_t: period fixed effects
- ε_{it}: error term
- i: country (1, 2… 171)
- t: time factor (1992, 1993, ... 2008)

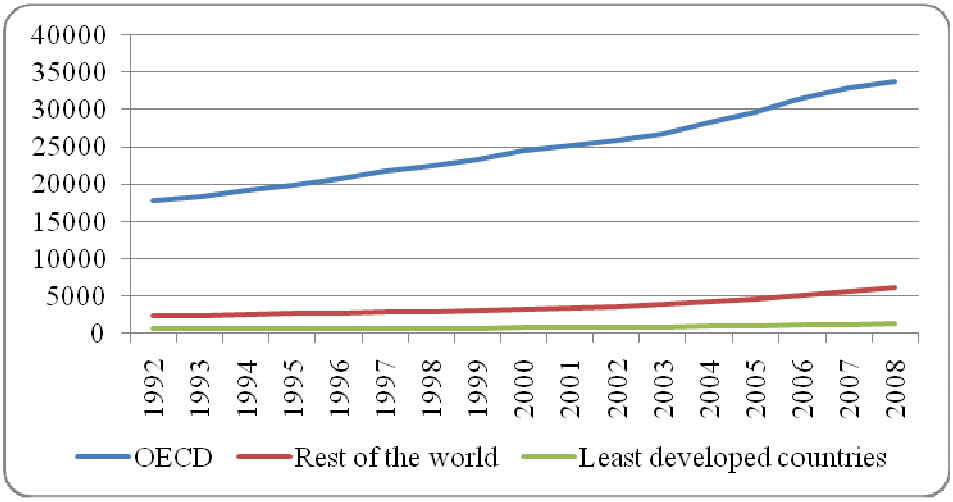
The fixed cross-sectional and periodic effects are tested by F statistics (Kőrösi et al. 1989) and are both significant. However, disparities among countries are much substantial in the whole time interval.

Although the GDP per capita is significant, it represents only 5.2% of the variation (adjusted R^2), i.e. the level of GDP per capita substantially influences the inequalities of economies but other (mostly cross-sectional) effects have a much significant role.

3.4. Cointegration

Chart 3 demonstrates the average log GDP per capita of the country groups:

Chart 3. Average GDP per capita (1992-2008)



Source: own calculations based on data of IMF 2009

Substantial differences can be seen between the countries, and the richer the countries are the faster they tend to grow.

However, some kind of link can be observed between LDC and ROW countries, which may be confirmed by testing the stochastic processes. By different type of unit root tests[5] (DF-GLS, KPSS, PP, ADF, ERS, NG-Perron) all three series are accepted as being integrated of order one, i.e. by differencing the series once stationarity can be achieved. But the linear combination of the series may be stationary, i.e. the series may be cointegrated (Maddala – Kim 1999).

After regressing each of the series by these variables the error terms (unit root, autocorrelation) showed sign of cointegration between the LDC and ROW series. To analyse the processes in the detail, error correction models were applied and cointegration was tested by the Johansen procedure. Cointegration can really be accepted between LDC and ROW series at a 10% significance level and the error correction

[5] Tests of higher power and higher significance levels (e.g. 10-20%) were primarily applied for robust estimation (Maddala – Kim 1999).

model underlines the diminishing disparities between countries. Therefore, long-run relationship between the average GDP per capita of least developed and rest the world countries exist, however, no relationship exist between OECD countries and ROW or LDC.

The expected catching-up process can also be extrapolated on the basis of ARIMA[6] models. There is no sign of convergence between LDC and ROW or LDC and OECD. But *convergence can be found between OECD and ROW*: for ROW countries it will take approximately 35-40 years to catch up with OECD economies on the basis of the models. Hence, inequalities are expected to diminish among high and middle income countries but there is little hope for the low income countries.

On Chart 3, we can see signs of divergence between ROW and LDC in the recent years, which also leads to convergence between ROW and OECD. So it can be assumed that cointegration cannot really be accepted, or more precisely: the cointegration between ROW and OECD will probably be accepted (but not between ROW or LDC) in the future. However, there is not any evidence for this approach but the high significance level of cointegration may also confirm this hypothesis.

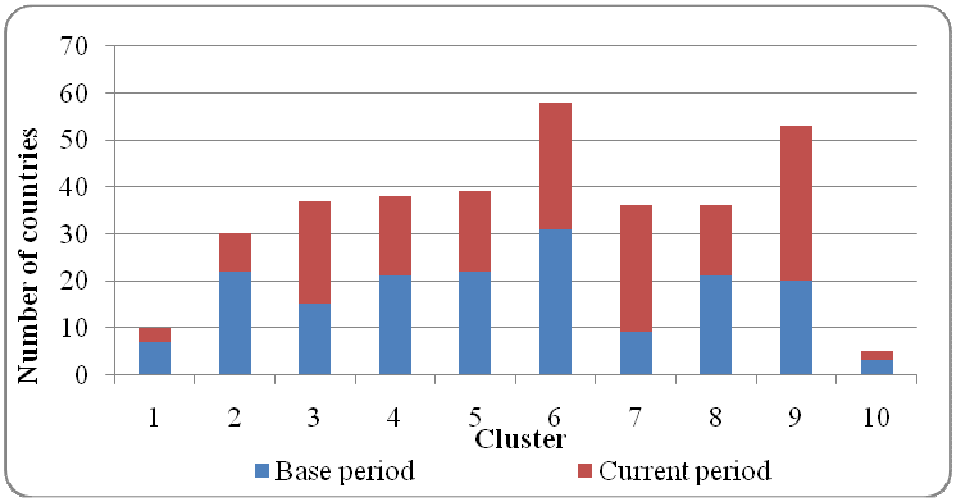
3.5. Omega approach

In the following, a different approach is applied: on the basis of clusters an indicator is presented to calculate convergence. As this type of analysis substantially differs from those presented previously, new information could be acquired by this approach. In such a way, we can take significant changes into account – which might be of great importance, as the other approaches presented previously are based on actual data.

At first, I clustered the GDP per capita of the countries in the base (2002) and in the current period (2008). Chart 4 demonstrates the results of clustering:

[6] For the OECD countries two MA variables (with constant and trend), for the LDC one MA variable (with constant and trend), and for the ROW countries two MA variables (with constant, trend and trend squared) have been applied. All three variables were also differenced once to achieve stationarity. No regression errors are detected in the residuals.

Chart 4. Omega approach (1992-2008)



Source: own calculations based on data of IMF 2009

As you can see, substantial differences can be observed between the base and the current period. Many countries originally clustered into groups of lower income, now probably joined higher income groups. However, we cannot be certain, as we do not know on the basis of this chart, what kind of process each country followed. Therefore, neither the existence, nor the rate of convergence or divergence can be measured by the chart or by the common indicators of descriptive statistics. Therefore, I created an indicator called omega to compare the base and the current period:

$$\omega = \frac{\sum_{j=1}^{n}\sum_{i=1}^{n_J} \alpha \cdot (K_{C\,ji} - K_{B\,ji}) \cdot \left[\left(\frac{f_{jiB} \cdot x_{jiB} + f_{jiC} \cdot x_{jiC}}{f_{jiB} + f_{jiC}}\right) - \left(\frac{f_B \cdot \bar{x}_B + f_C \cdot \bar{x}_C}{f_B + f_C}\right)\right]}{\left|\sum_{j=1}^{n}\sum_{i=1}^{n}\left[\left(\frac{f_{jiB} \cdot x_{jiB} + f_{jiC} \cdot x_{jiC}}{f_{jiB} + f_{jiC}}\right) - \left(\frac{f_B \cdot \bar{x}_B + f_C \cdot \bar{x}_C}{f_B + f_C}\right)\right]\right|} \Big/ \alpha \qquad (5)$$

Restrictions:

- Optimal number of clusters
- $$\left(\frac{f_{jiB} \cdot x_{jiB} + f_{jiC} \cdot x_{jiC}}{f_{jiB} + f_{jiC}}\right) \neq \left(\frac{f_B \cdot \bar{x}_B + f_C \cdot \bar{x}_C}{f_B + f_C}\right) \qquad (6)$$
- If: $(K_{C\,ji} - K_{B\,ji}) = 0$ (7)

Than:

$$\left| \sum_{j=1}^{n} \sum_{i=1}^{n} \left[\left(\frac{f_{jiB} \cdot x_{jiB} + f_{jiC} \cdot x_{jiC}}{f_{jiB} + f_{jiC}} \right) - \left(\frac{f_B \cdot \overline{x}_B + f_C \cdot \overline{x}_C}{f_B + f_C} \right) \right] \right| = 0 \quad (8)$$

Where:

- K: cluster
- C: current period (2008)
- B: base period (1992)
- f: number of population
- x: GDP per capita
- i: country (1, 2, … 171)
- j: group (LDC, OECD, ROW)
- α: other weights (no other weights have been applied in this analysis).

The indicator has been applied, as the less developed the countries are and the higher the rate of economic growth is (measured by the weighted deviation from the average), the more significant the convergence will be. The omega equals to zero, when the economy is clustered into the same group in the base and in the current period. That is essential in my opinion, as I wanted to take only significant changes into account – this idea is behind the indicator.

Table 2 shows the final results of calculations:

Table 2. Omega convergence (1992-2008)

Country group	**ω**	**V_ω** [7]
LDC	-0.98	1.27
ROW	-1.72	1.33
OECD	1.03	2.22
Total	-0.78	-

Source: own calculations based on data of IMF 2009

There is *convergence* among world economies, also within group of countries: while the convergence is *strong among ROW* countries (-1.72), among LDC and OECD countries only low convergence can be measured (-0.98 and 1.03 respectively). For OECD countries divergence is measured, as the (high income) economies either joined higher income clusters or remained in the same cluster for the current period.

Therefore, we can assume that countries with a GDP per capita significantly differing from the average tend to converge lower and leaving a country group may also be quite difficult.

[7] = Omega/total

4. Conclusions

The analysis of convergence is of great importance in economics, as the economic growth basically determines the welfare of countries. Therefore, it is important to see, whether a catching-up process among world economies exist or not.

This paper presented different types of analysis in order to measure the existence and rate of divergence or convergence among world economies. As the database covers only GDP per capita data, the factors behind the economic growth and convergence / divergence cannot be tested. However, the purpose of this paper is to determine the existence and rate of convergence / divergence, hence other variables are only needed to avoid distortions – but factors like constants, dummies ad clusters can be applied to avoid biased estimations.

Though some methods may be biased (especially the beta analysis), each model can be accepted. All of the analysis showed convergence among countries, which basically confirms the neoclassical approach, hence the main assumptions and conclusions of the growth model may apply for world economies. However, endogenous growth models cannot be rejected, either. As the convergence process is far from perfect and not only the level of GDP per capita determines the economic growth (confirmed by the beta and panel analysis), factors like research and development determined in the endogenous models probably influence long-run economic growth, too.

At the same time, the convergence might be rather conditional (which is also confirmed by neoclassical models). Therefore, the convergence process can be measured basically among countries, which are almost at the same income level, or more precisely: countries are converging to their own steady states. However, as for the low income countries, only very slow convergence can be measured. Therefore, club convergence can also be accepted – but absolute convergence can surely be rejected on the basis of these models. This means that middle income countries are especially converging towards each other (i.e. 'poorer' economies are catching up) but they are also converging towards high income economies.

The significant convergence of middle income countries can be interpreted by different ways. The OECD and LDC groups are primary economic categories but these are also influenced by other factors (e.g. political). It is also obvious that middle income economies follow other trends than LDC and OECD countries: they are more similar as they are actually determined by common, similar economic (e.g. GDP growth, inflation rate), political (e.g. democracy) and social factors (e.g. employment rate).

The variation among LDCs and OECD countries is higher as more differences exist among them – also within both groups. So it is very difficult for them to converge: lower income countries of LDCs cannot converge as they probably do not have significant economic driving forces, while higher income countries of OECD countries are hardly to be caught up as they have existing core driving forces

(mostly economic and political) significantly differing from the average and they will have / acquire such factors in the future, as well.

The catching-up process of economies was also forecasted in three ways. Long-run catching-up is expected to take place, at least 30 years are needed for significant convergence. But this primary applies for middle income countries, which mainly confirms the existence of club and conditional convergence.

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