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IS THERE VOLATILITY - GROWTH TRADE-OFF? THE CASE OF CROATIA – 1920 TO 2008

In this paper, we study the behaviour of the growth rate of real GDP per capita for Croatia over the period 1920–2008 from a different perspective in that we examine whether there is a common structural break in the growth rate time series. This paper empirically investigates some basic business cycle features, such as volatility, persistence, turning points, and the length of recessions and expansions in the growth rate of real GDP per capita. Conditional volatility is estimated using the Generalised Autoregressive Conditional Heteroscedastic (GARCH) model. Our main findings are that: (1) growth rate per capita experienced some structural breaks during the period covered and break intervals suggest that either one or a combination of events (establishment of new socialist government in 1946, the 1958 new legislation which stimulated industrialisation and the great slump after 1972 due to new inefficiency and management misbehavior) have contributed to the commonality of breaks in the growth rate per capita in Croatia; (2) the empirical results show that there were important events in some of the periods. The two big volatility spikes in 1952 and 1991 of the growth rate, (3) the effects of volatility on the growth rate in Croatia according to Black's hypothesis of positive volatility - growth trade-off are found only in the model estimation with intercept dummy variables which control the volatility of output shock time series.

Keywords: Business Cycles, GARCH-M Model, Per Capita GDP, Growth Rate, Croatia

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1. Introduction

Several seminal papers have sought to document the statistical properties of business cycles which are the key task in modern macroeconomics. Backus and Kehoe (1992) and Hodrick and Prescott (1997) are typical examples of this research line; Barro and Sala-I-Martin (1995) devoted several chapters of their book to studying of the empirical regularities of economic growth. The traditional distinction between the long term relating to economic growth and the short term relating to business cycles is, in the theory of real business cycles, merged. Blanchard and Simon (2001) have examined the contribution of changes in the volatility of components of demand to changes in U.S. real GDP volatility. In this paper, we try to investigate the nature of structural changes that may have taken place over time in Croatia. We place particular emphasis on the study of volatility, persistence and the relationship between growth and volatility.

Growth rates, as well as inflation rates, foreign exchange rates, or returns on stocks, exhibit time-varying volatility. Autoregressive conditional Heteroscedastic (hereafter ARCH) model introduced by Engle (1982) and the extension to generalised ARCH (hereafter GARCH) model by Bollerslev (1986) have been widely used to model volatility of economic and financial time series. Since the ARCH and the GARCH models provide a favorable framework to study time-varying volatility in the time series, they have become a standard tool in econometrics ever since Engle and Bollerslev first reported them. Later in this paper, we concentrate on the growth rate time-varying volatility in Croatia.

As Backus and Kehoe (1992) pointed out, a crucial question in international business cycles is whether countries display similar economic oscillations in time dynamics. This paper contributes to the issue of economic history by showing that Croatian business cycles between 1920 - 2008 had some distinctive features, mainly because of specific shocks in the recent and near past.

Authors such as Black Fisher (1987) in his theory which precedes Kydland and Prescott's contribution to RBC theory (1982), and Caballero (1991) have argued that an increase in volatility should have some impact on growth rates and investment rates. To see the test of this hypothesis, see Caporale, T.; McKiernan, B., p. 765-771, 1998. We investigate whether this holds in the Croatian economy and try to determine if the growth GDP per capita was significantly affected by economic volatility over the long-run period 1920-2008.

This paper evaluates some basic business cycle features, such as volatility, persistence, turning points, and the length of recessions and expansions of the per capita GDP series in Croatia during the 1920-2008.

This paper is organised as follows: In Section 2, the data set presents an analysis of growth rate of GDP per capita in Croatia. In this section we conduct growth rate periodisation without and with structural break assumption. In Section 3 we study the business cycle properties of Croatian per capita GDP, the turning points of recessions and expansions, and try to shed more light on the distinguished phases in Croatia's development according to structural break results. Furthermore in this section we tested the per capita GDP rate series for non-stationary behavior and its volatility and persistence and try to model by the ARMA model the growth rate. In Section 4, the main focus is on the empirical relationship between different concepts of volatility and growth rate. The conditional volatility is estimated in this section using the well-known Generalized Autoregressive Conditional Heteroscedastic (GARCH) model. Finally, Section 5 contains my concluding remarks.

2. About the data

In this section, the method of obtaining GDP *per capita* series is explained, as well as a preliminary discussion about some properties in regard of the instantaneous rate of growth that took place.

2.1. The GDP per Capita Series and Growth Rate Periodisation and Structural Breaks

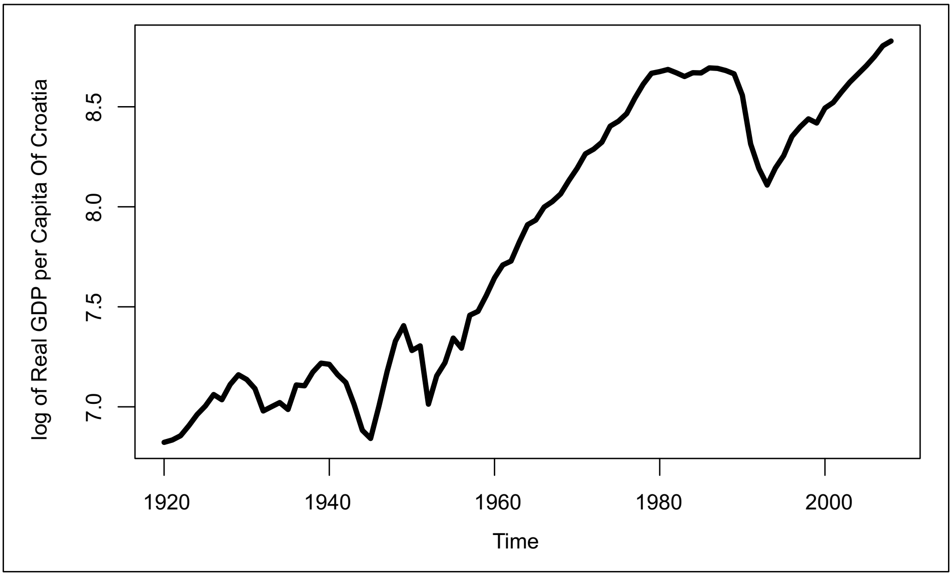
Družić (2004) contains a real GDP *per capita* series of Croatia which is an indicator of living standards (based on USA $ in 1990) from 1920 to 2001 (Table 6.1., pages 228-229, Table 6.3., pages 231-232., respectively). The remaining uncovered data (2002-2008) was obtained from www site: http://www.conference-board.org/economics/database.cfm. Its Total Economy Database Table from June 2009 contained GDP per capita in 1990 US$ (converted at Geary Khamis PPPs) and also data for Croatia. The calculated rate of growth of the latter data for the period between 2002 and 2008 was a key for the extension of Družić's series up to the year 2008. Lucky circumstances are that both series are given in real values from the year 1990. However, such a series extension can be problematic (seemingly, the "grey economy" is not involved in Družić's data, it is not known to us whether it is involved in the second series, etc., then the question of PPPs and the questions of conversion of Družić's data). It is therefore evident that the added series 2002-2008 is approximately the continuation of the upward trend from the early 90's. The structural break of the growth in one of the hypothetical time points after 2001 is absent. This is seen by a simple visual inspection of Table 1.

The transformation of the unique time series 1920-2008 data in natural log form represents the subject matter of our entire empirical analysis. You can find more about the problem of structural break in the next part of this work.

The natural logarithm of the real per capita GDP is plotted below in Figure 1.

Figure 1

LOG OF REAL GDP PER CAPITA OF CROATIA 1920-2008



Source: Author's calculations based on data from Družić (2004), and the Total Economy Database (2009) of annual real GDP per capita growth

The choice of the sub-time intervals on the basis of the aforementioned one-decennial and half-decennial growth rates according to the calculated growth rate in Table 1 is somewhat ad-hoc, and mainly derived from casual observation. When observing sub-periods of accelerated and decelerated growth in such periods, segmentation is difficult to control due to the impact of various exogenous events and it is equally difficult to isolate the more 'structural' forces at work, such as changes in institutions, wars and so on. More specifically, we are interested in structural breaks due to changes in technological and economic regimes. The foundation for estimating breaks in time series regression models was given by Bai (1994) and was extended to multiple breaks by Bai (1997) and Bai & Perron (1998). In this paper, we apply the Bai and Perron (1998) test to see whether there

Table 1

INSTANTANEOUS REAL GDP PER CAPITA GROWTH RATE IN %

Instantaneous growth rate					
1920- 1930	3.63	**1920-1925**	3.83	**1965-1970**	4.93
1930-1940	1.6	**1925-1930**	2.94	**1970-1975**	4.64
1940-1950	2.17	**1930-1935**	-2.68	**1975-1980**	5.46
1950-1960	4.44	**1935-1940**	4.35	**1980-1985**	-0.28
1960-1970	5.4	**1940-1945**	-7.97	**1985-1990**	-1,88
1970-1980	5.0	**1945-1950**	10.2	**1990-1995**	-0.55
1980-1990	-0.5	**1950-1955**	0.56	**1995-2000**	4.08
1990-2000	1.43	**1955-1960**	6.61	**2000-2005**	4.37
2000-2008	4.37	**1960-1965**	6.12	**2005-2008**	4.25
1920-2008			2.47		

Source: Ibidem

Note: The time series segmentation according to ad-hoc judgment, as in Smits, J.P., de Jong, H., van Ark, B. (1999)

are any statistically significant breaks in the log of GDP per capita time series and it is this methodology that is repeated here and displayed in Table 2.

Technically speaking, because we are concerned with assessing deviations from stability in our linear regression modeling of instantaneous growth rate obtained as simple or ad hoc periodisation *via* different time trend coefficients, it is reasonable to assume that there are some breakpoints in the data generating process of our basic time series, where the time trend coefficients (e.g. instantaneous growth rate) shift from one stable regression relationship to a different one (Zeileis et al., 2003). Thus there are a various number of time segments in which the trend regression coefficients are constant; so we opted for a better first choice periodisation according to Table 2.

We tested our series on the log of real GDP per capita for structural breaks. The Bai and Perron test selects the most likely dates. In Figure 2 and Table 3, three possible break dates are presented according to the minimum Schwarz's Bayesian Criterion (BIC) (see Table 3) and thus result in the optimal 4-segment partition of the entire time series.

The first date (1946) corresponds to a period in which, for the first time, the new revolutionary government really governed under the communist leadership during the entire fiscal year after the liberation of Croatia from the Pavelić's quisling creation, the first wave of nationalization, due to the "Nationalisation of Privately Owned Economic Companies Act" (1946), started. For this reason, we can state that, in this year, Croatia experienced the first serious institutional turning point in its own economic life; the second one corresponds (1959) to the moment when it adopted a set of laws on the nationalisation of building land, the "Nationalisation of Rented Buildings and Building Land Act" (1958), thus the second wave of nationalisation of private property occurred, which sets the preconditions for an efficient relocation of social resources and a vigorous industrial modernisation that mainly ends with the third break date (1972) and which begins a series of missed investments as a consequence of the previous successful socialist managers. It needs to be said that the procedure for dating the described events is the product of economic intuition. The described events could divert the economic history towards acceleration and diminution of the growth velocity log of GDP per capita during the identified years.

Our tests reveal a clear structural break in the series around 1946. In the log of GDP per capita series we find a low regression coefficient of 0.51% for the period 1920-1946, which means that the estimated coefficient remained stable over a period of 25 years, which also marks a period of political upheaval and considerable changes in institutional regimes (including the devastating World War II). After the Second World War the instantaneous growth rate was raised to a higher level (1.95) during the second period 1947-1959. The growth was relatively raised just under four times, however the trend of long-term growth is inadequate (that is to say higher than 1%). The year 1972 also appears to be a breaking point in the long-term development of the log of GDP per capita, showing a stable instantaneous growth rate of 5.39 per cent from 1960 to 1972 and only 0.2% instantaneous growth rate per capita thereafter until 2008.[1]

[1] As far as GDP per capita growth is concerned, the differences for the years before and after 1972 are really striking. Before 1972 the coefficient is 2.34 and after the break 0.1, indicating two clearly different regimes of efficiency for the last almost half century. It seems that the stimulation of the social consumption in the 60's (that is to say the so-called social consumption) could stimulate the growth of the GDP in the 60's. In the documents of the ruling Communist Party it was promoted the idea of intercession for an intensified social consumption but a series of missed investments, the rise in the level of debt of the country, and finally the most important thing the removal of the socialist leading cadres after the Croatian Spring have given another directions to the events in a short time.

Table 2

INSTANTANEOUS REAL GDP PER CAPITA GROWTH RATE IN % WITH STRUCTURAL BREAKS

	Instantaneous growth rate
1920- 1946	0.51
1947-1959	1.95
1960-1972	5.39
1973-2008	0.2

Source: Ibidem

Note: The time series segmentation according to structural break dates

Table 3

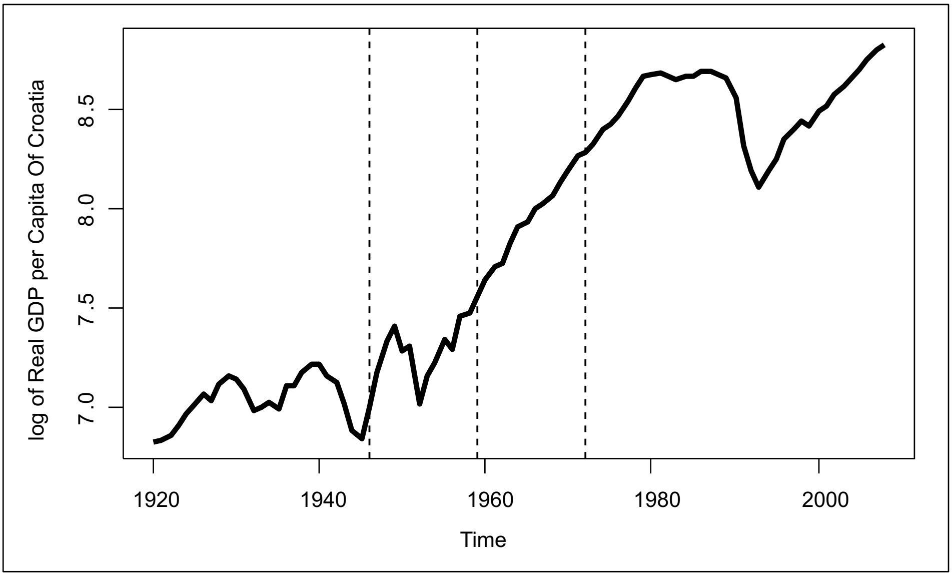
THE BREAK DATES IN THE LOG OF REAL GDP PER CAPITA GROWTH IN CROATIA ACCORDING TO BAI AND PERRON (1998) TEST FOR STRUCTURAL BREAK

Calculated break dates
m = 1 1962
m = 2 1956 1969
m = 3 1946 1959 1972
m = 4 1947 1960 1973 1990
m = 5 1934 1947 1960 1973 1990
Fit
m 0 1 2 3 4 5
RSS 41.505 5.392 2.876 2.338 2.205 2.162
BIC 193.658 21.006 -25.918 **-35.415** -31.650 -24.417
Break dates of minimum BIC segmentation corresponding to break dates
1946 1959 1972
Confidence intervals for break dates of optimal *4*-segment partition
2.5 % breakpoints 97.5 %
1 1943 **1946** 1948
2 1957 **1959** 1960
3 1970 **1972** 1974

Source: Calculated by author

Figure 2

BREAK DATES OF LOG OF REAL GDP PER CAPITA GROWTH



Source: Ibidem

Note: The dashed vertical lines mark three break dates in growth level constancy and occur in 1946, 1959 and 1972, respectively

3. Cyclical properties of log of per capita GDP

To extract the cyclical component of the log of per capita GDP series, we detrend the natural logarithm of that series with the well-known Hodrick-Prescott (HP) filter. Following a standard procedure of the related literature (Favero, C.A., p. 54, 2001), we adopt the value of 100 for the smoothing parameter λ, and for annual data.

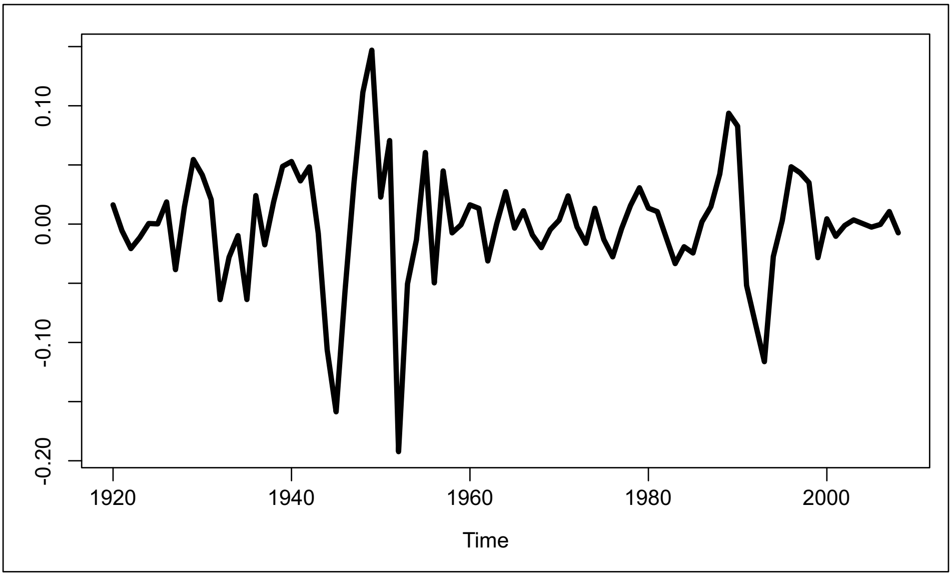
3.1. Cycles of the growth per capita output

Figure 3 presents the time path of the cyclical component of the natural log of Croatian per capita real GDP.[2]

[2] Due to non-stationary of GDP per capita in the long run we must filter the data, but in this section we are interested in cycle component of GDP which is in core stationary.

Figure 3

CYCLICAL COMPONENT OF THE NATURAL LOG
OF REAL GDP PER CAPITA



Source: Ibidem

Next we study evolution across the cyclical phases (i.e., expansion and recession).

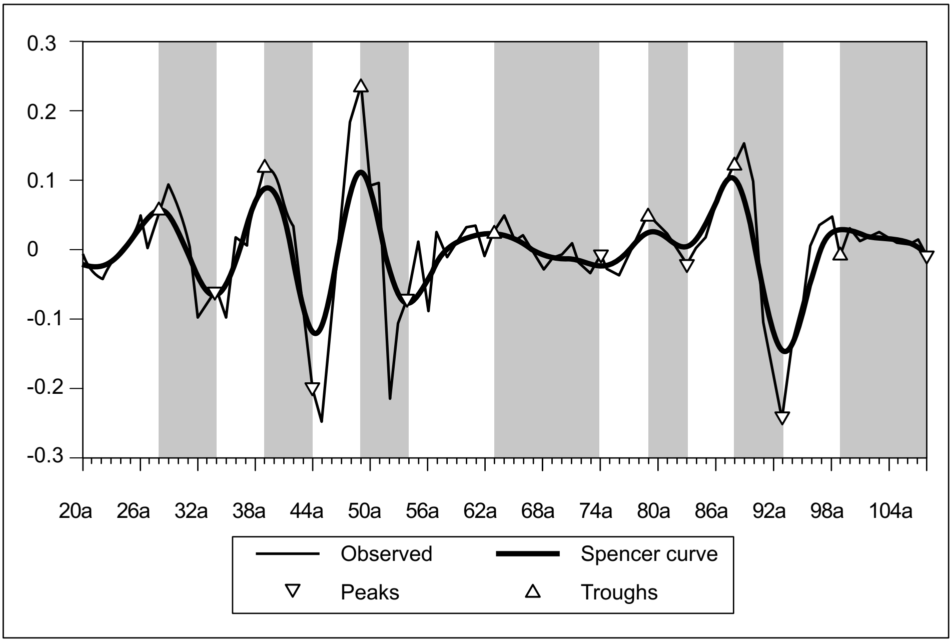
3.2. Dating Recessions, Expansions and Turning Points

We now turn to the problem of dating recessions, expansions and turning points. We follow Canova (1994) and Harding and Pagan (2002) and adopt very simple dating rules.

Let y_t^C denote the cyclical component of natural log per capita GDP. We say that an *expansion* takes place at year *t* if $y_t^C - y_{t-1}^C > 0$. Similarly, a *recession* happens whenever $y_t^C - y_{y-1}^C \leq 0$. The last year of an expansion corresponds to a *peak* and the last year of a recession corresponds to a trough. A turning point takes place whenever the economy hits a peak or a trough.

Figure 4

TURNING POINTS OF THE CYCLICAL COMPONENT
OF NATURAL LOG PER CAPITA GDP OF CROATIA



Source: Ibidem

In Figure 4 and Table 4 the evolution of Croatian per capita GDP in log form is presented over the business-cycle phases. A white color area on that Figure 4 means expansion and black color means recession.

The longest expansion in Croatia lasted nine years, from 1954 to 1963, and the longest recession lasted subsequently ten years, from 1964 to 1974, but it needs to be said that the intensity of the subsequent recession was mild, judging by the cyclical components of the log of real GDP per capita. Similarly, the last recession of 2000-2008 had a mild character; much more dangerous recessions were the ones with a speedily decreasing vertical amplitude curve as the recessions of 1950-1954 and 1989-1993.

Table 4 contains information on some selected features of the chronology of recessions and expansions of the Croatian economy.

There were 48 years of expansion and 41 of recession. The number of expansions (7) was equivalent to the number of recessions (7) in Croatia. The average expansion lasted about seven and the average recession about six years. The years of expansions slightly outnumbered the recessions or were more frequent in Croatia in our time series observation.

Table 4

TURNING POINT DATING RESULTS OF CYCLICAL PHASES OF LOG OF REAL GDP PER CAPITA OF CROATIA

METHOD: HARDING-PAGAN **ESTIMATION PERIOD: 1920-2008**
At the Beginning of the Year
Troughs Peaks
1921 1928
1934 1939
1944 1949
1954 1963
1974 1978
1983 1988
1993 1999
Cycle characteristics:
Average duration from peak to peak: 11.8 Average duration from trough to trough: 12 Average duration from peak to trough (recession phase): 6 Years in recession 41 Average duration from trough to peak (expansion phase): 6 Years in expansion 48 Average amplitude from peak to trough: -0.061 Average amplitude from trough to peak: 0.055

Source: Ibidem

In 1999, the value of the cyclical component was negative. It specifically concerns a recession year, when GDP per capita decreases by approx. 1.99% in comparison with 1998. The black colour in the figure 4 also covers 1999, so, according to this and the methodology, this fact is confirmed. The methodology, even more so, reveals to us that a very mild recession cycle (due to the decrease of variations of the cyclical component) in the following decade started with that year. Comparatively speaking, that recession cycle is in the second term of the nearest slope, but that methodological evidence is still questionable due to the positive growth rates between 2000 and 2008. The HP filter is biased at the end of the period, due to which we are perhaps getting a wrong picture of the existence of recession at the last stage of our analysis e.g. the years 2007 and 2008 with noted official growth rates of 5.5% and 2.7%, respectively. We would emphasise, once again, that the peak appears at the beginning of 1999 (or the end of 1998) and the subsequent trough isn't adequately foreseen due to the method's shortcomings.

- Growth and cycle fluctuations between 1920 and 1946

As we have already said, in our analysis the behavior of the average GDP per capita for the period 1920-1946 is the first coherent entirety that has been separated as a separate unit as a consequence of the results of the break date analysis.

The first period 1920-1946, encompasses pre-war, World War II, and the first year after. Croatia displayed large oscillations in the log of real GDP per capita in given distinguished sub-periods between 1920 and 1945 (see Table 1); it is true that such calculations are less credible as a consequence of the detachment from the principles of constancy of the regression coefficient. However, we must concentrate on the instantaneous [3] growth rate of the log of real GDP per capita 0.51% obtained as a slope of time trend between 1920 and 1946, along with the remark indicating that this period - time segment is the structural change of the analysis. This rate is really low but it is also higher than the extremely low growth rate of 0.2% in the period 1973-2008 (as a result of the current modern development of the Republic of Croatia).

As can be seen, a deep recession in Croatia began in 1929 (after a peak was noted in 1928, see Figure 4) – culminating in 1931, with the financial breakdown and collapse of one of the strongest and oldest banks in this region (PRVA

[3] By regressing ln Y_t on t (time) using OLS we obtain an estimate of the slope coefficient ($\hat{\beta}$) that provides an estimate of the instantaneous growth rate (ln(1+r)). Because ln(1 + r) = β for r gives compound rate of average annual growth $r\% = (e^{\beta} - 1)*100$, and difference between two average rate are practically nil we present only the first one rate of growth in Table 1.

HRVATSKA ŠTEDIONICA). It should be stressed that 1926 was a booming year. Industry production thrived when compared to some other regions in the former monarchy. However, in 1930 the purchasing power of money was still much less than in 1914, when the dissolution of Austro-Hungarian Empire started (Goldstein, I., pp. 345-346). As a consequence of the Great Depression in the United States and rest of the world (due to indirect spillovers effects from centre to periphery), although a strong recovery in the United States occurred in 1935, Croatia, as a mainly agrarian country, suffered. The agrarian crises peaked in 1932 and 1935 in Croatia – depressed prices were lower in 1933-34 than in 1926 by a margin of 43-33% when the first signs of crises occurred. In 1935, due to agrarian overpopulation, drought and even famine in some regions of Croatia, undernourishment of the poorest was the result (Ibidem, p.348). A general crisis in 1938 and subsequently the second war shock caused the ensuing recession in Croatia during World War II. By the subsequent analysis, we conclude the more detailed description of the first time segment 1920-46 described in this study.

- Growth and cycle fluctuations from 1947-1959 and 1960-1972

After World War II, Croatia experienced a sharp recession in the period 1950-54 (see Figure 4), and, as a result, the real per capita GDP instantaneous growth rate declined from 10.2% in the period 1945-50 to 0.56% in the period 1950-55. The log of GDP per capita long upswing trend happened close to 1955 after the deep first post-World War II depression. An accelerated economic development started as a consequence of communist industrialisation followed by crowding out of the agrarian sector from the economic structure. Additional evidence of industrial take-off is provided in Table 2.3. by Družić (2004). Industrial and mining fixed capital displayed a continuing increase after 1952 and surpassed other economic sectors in subsequent years. Its average growth rate annually from 1952 to 1990 was 6.5% (Družić, I., p. 79, 2004). Industrialisation is often accompanied by a rise in GDP growth because of Verdoorn's law. Verdoorn's law relates to the long-term dynamic relationship between the rate of growth in output and the growth of productivity due to increasing returns (Verdoorn, 1980). The speed-up of productivity, and the aggregate output growth was mainly a by-product of industrialisation. From the end of the 50's up to 1972, Croatia experienced extremely high growth per capita. Thus, Croatia's GDP per capita from 1960-72 rose by the unprecedented instantaneous growth rate of 5.39%.

- Growth and cycle fluctuations between 1972 and 2008

Afterwards, summarizing the period between 1972 and 2008, real per capita GDP almost stagnated, and even decelerated in some sub-periods. The real GDP per capita peaked in 1977 and started to decrease (instantaneous growth rate was, for the first time, negative - 0.28% from 1980-85), this is a period of long-run stagnation in GDP per capita. These unpleasant phenomena are followed by inflation rate and external debt increases, shortages in goods or food supplies etc. The second major contraction of the real GDP *per capita* occurred in 1986 (the instantaneous growth rate from 1985-90 continues to be negative by -1.88%). Croatia entered into a recession in 1980 which ended in 1983. Croatia also experienced a very severe one from 1989-93, and a much milder one from 1999 to date.

This discussion can be concluded by stating that Kaldor's first stylized fact (Kaldor, 1961) held true for Croatia in the long run from 1920-2008. The proof is that long period Croatia's GDP per capita experienced pervasive instantaneous growth rate of 2.47% annually.

3.3. Descriptive Statistics and Unit Root Properties

We perform several descriptive statistics in another form on the growth rate for Croatia. The rate of growth is, now, the result of the usual transformation obtained by multiplying the first difference of natural log (GDP/capita) by 100. Accordingly, this transformation results in a time series of rates of growth between two neighbouring years in the period between 1921 and 2008. The average growth rate of real GDP per capita calculated as a simple mean in the encompassed period 1921-2008 is about 2.27 % for Croatia. It is obvious that the simple arithmetic mean represented in the table of the descriptive statistics and the earlier calculated instantaneous growth rate, analogous to these trend components, do not correspond because of the methodological differences, but the difference is not great (in total 0.2% over entire period span). The series' standard deviation and, thus, the calculated variance, which can be interpreted as unconditional volatility, is equal to 0.0771 value. The result of the Jarque-Bera test [4] for normality is 64.01 (P-value = 0.000). The null hypothesis of normality is rejected by the Jarque-Bera (JB) asymptotic test for the growth rate series.

[4] Jarque-Bera test for normality is asymptotically distributed as χ 2 (2). The 1% critical value equal 9.21.

Table 5

SUMMARY OF DESCRIPTIVE STATISTICS ON GROWTH RATE OF REAL GDP PER CAPITA

	Croatia
Mean	2.27 %
Maximum	17.4%
Minimum	-29,15%
Std. Dev.	7,7 %
Skewness	-1,28
Kurtosis	6,29
Jarque-Bera normality test	65,01
Probability	0.00
Observations	88

Source: Ibidem

Figure 5

GROWTH RATE OF REAL GDP PER CAPITA OF CROATIA

Source: Ibidem

Figure 5 describes the behavior of growth rates. Since it is necessary that the growth rate be stationary for valid inference and reliable parameter estimates from the GARCH model (applied further in analysis), various unit root tests are used to determine whether the growth rate is stationary. In addition to the ADF and PP test, we conduct unit root tests allowing for breaks in the data since, in the analysis of growth level periodisation, we showed that growth level time series is better characterised by the presence of structural breaks. Hence, Table 6 displays the results of augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Zivot-Andrews (ZA) tests for unit root for the 1920-2008 sample period.

Table 6

UNIT ROOT TEST

	LOG(GDP) PER CAPITA			FIRST DIFFERENCE OF LOG(GDP) PER CAPITA		
	ADF	**PP**	**Zivot-Andrews**	**ADF**	**PP**	**Zivot-Andrews**
Case 1	-1,813*(3)	-1,868*(3)***	-2.977 (2) 59	-5,437*(2)**	--6,941*(2)	-5.577 (2) 43
Case 2	-0,586*(3)**	-0,646*(2)***	-3.758 (2)(43)	-5,472*(2)**	-6.980*(2)	-0,586*(3)**
Case 3	1,931(3)*	2,126*(2)***	-3.712(2) (43)	-5,005*(2)**	-6,368*(1)	-6.185 (2) 69

Source; Ibidem

Notes: Case 1 shows that the auxiliary regression is run with a constant and time trend. Case 2 shows that auxiliary regression is run with a constant. Case 3 shows that auxiliary regression is run without any deterministic term.

(*) Implies that the null hypothesis of the existence of a unit root is rejected at a 1% significance level.

(**) The lag lengths are chosen according to Akaike Information Criteria (AIC) for ADF tests.

(***) PP tests are estimated for Bartlett kernel truncation lags.

We cannot reject the null hypothesis of the existence of a unit root in the case of log (GDP/ per capita). Hence, the level of per capita GDP is non-stationary and we must filter the data. On the other hand, the ADF, PP and ZA statistics reveal evidence against the unit-root null hypothesis for the growth rate variable for levels. Thus, the real growth rate per capita time series has stationary variables [I(0)]. The average growth rates, as we have said before, is about 2.27% for Croatia from 1921 to 2008 (see Table 5). Furthermore, there is no tendency towards a decline in the growth rate in the long run. This is confirmed by all the included test statistics, which clearly rejects the assumption of a unit root.[5] The endogenous structural shift for the growth rate series in the ZA unit root test with constant occurred most likely in the year 1959 (in the same year as according to the earlier calculation in regard to the appearance of the structural break). We suppose that, for the analysis, the unit root in the case of growth rate is an irrelevant regression that includes also the trend variable. For this reason, we can separate the year 1959 as the most probable year for the appearance of the structural break in a time series since 1943. During the same year of the time break, it appeared in the case of the ZA unit root test in the time series log (GDP) per capita, where we include a constant and a trend in regression, as appropriate, due to the economic intuition according to which the subsequent time series indicates a long-term trend.

3.4. Volatility and Persistence

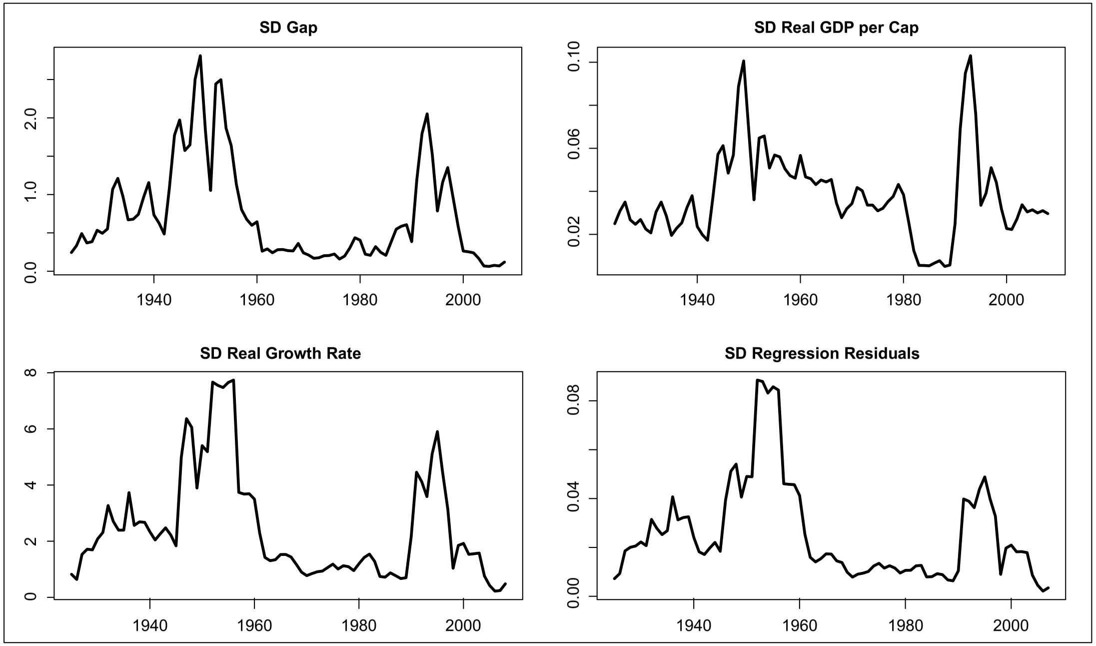
Beyond the varying definitions of volatility itself, ambiguities arise from the terms often used in conjunction with volatility, sometimes employed as synonyms, sometimes viewed as implications, such as "crisis," "risk," "fragility," and "vulnerability." Two key connotations of volatility are *variability* and *uncertainty*. Variability refers to all movement, while uncertainty refers to unknown movement (Aizenman, J; Pinto, B. p. 48, 2005). Volatility, is, in Frank Knight's (1921) classic definition, allied to risk in that it provides a measure of the possible variation or movement in particular economic variable or some function of that variable, such as a growth rate. It is usually measured based on observed realization of a random variable over some historical period (Ibidem, p.2).

Following the standard approach of the business cycle literature, we used the standard deviation and first order serial autocorrelation in an appropriate time window of the output to measure its volatility and persistence (Mantegna R. N.;

[5] The levels of per capita time series is non-stationary and this observation doesn't contradict to the first Kaldor's stylized fact about growth which says that a country in the long run has a time-trended or persistent growth of output in level, or - each new generation have higher standard of living than their ancestors. However if we take the shorter time period from 1973-2008 and the resulting change , the ADF test statistic for growth variable (or first difference in level per capita output) is – 2.32, while the 10 % critical value is -2.62, so that the assumption of non-stationarity can not be rejected. Because of the almost absent growth rate of per capita by 0.1% (obtained as a time trend) during 1973-2008 in Croatia, and very high growth per capita (about 2,34% in 1960-72) the story of this statistical evidence tells us that the growth rates of a low-income country as was Croatia in the 1920s and 1940s are higher but decline over time as it becomes richer according to Solow neoclassical theory of growth and transitional convergence. Or, maybe this does demonstrate that the Croatia (as an each other country either rich or low-income), alas, converge toward zero per capita growth rate in the long run.

Figure 6

VOLATILITY OF REAL GDP PER CAPITA GAP, REAL GROWTH RATE OF GDP PER CAPITA, REAL GDP PER CAPITA, REAL GDP PER CAPITA GROWTH SHOCK IN CROATIA, 1925-2007



Source: Author's calculations are based on data from Družić (2004), and Total Economy Database (2009); in clock-wise direction from left above, as a five-year rolling standard deviation of annual: - log of real GDP per capita gap, real growth rate of GDP per capita as a result of log first difference transformation, - log of real GDP per capita growth, - output per capita shock measured as residuals based on volatility accounting according to AR(1) regression equation ei = Δlog (GDP/per-capita)-0,288Δ log (GDP/per-capitai-1).

Stanley, H. E. p. 57, 2000). In order to analyse as precisely as possible the problem of volatility and the growth of the volatility indicator, we will apply five similar macro variables. We are talking about the standard deviation of:

a) real GDP per capita gap [6] (or SDGAP),

b) growth rate of the real GDP per capita (or SDDY),

c) real GDP per capita (or SDY),

d) real GDP per capita shock measured as residual in regard to the AR(1) process (or SDSHOCK), and

e) the squared growth rate of per capita GDP (or DDY)

Figure 6 shows the rolling standard deviation of annual growth (measured at an annual rate and different aforementioned concepts) since 1925. We use a window of five years, so that the standard deviation reported for year t is the estimated standard deviation over years t - 4 to t. In that way, a squared time data series, which measures a five-year rolling volatility, is obtained. Figure 6 shows a clear increase in the standard deviation as a moving indicator over time from a first great and explosive spike to a second one, thus, from about 2.5 percent in 1925 to more than 10 percent in 1949, or from 3.6% in 1951 to 10.6% in 1993, when we consider the rolling standard deviation of real GDP per capita. The situation remains almost identical when we examine the volatility in respect of the concept of output gap. There are lesser changes as regards the date of the first peak; the volatility of the growth rate was the highest in 1947, while the volatility of the technological innovation shock was the highest in 1952. However, the second point of the peak is present in 1995 for both last concepts of volatility. This increase is not continuous, however, due to fluctuation in the meantime between two great spikes. Volatility was the lowest in the 1980's, and this is followed by a sharp decline in the second half of the 1980's when the rolling standard deviation was less than 1% measured in respect of the real GDP per capita.

The greatest volatility in Croatia is allocated in 1947-1949-1952 and 1993-1995 depending on the concept of measurement. Hence, the volatility of per capita output fluctuations seems to have increased after the fall of the Monarchy in Yugoslavia up to the end of World War II, and the Stalinist regime in Croatia, on the one hand and during the wartime events of the Croatian War of Independence, on the other hand. For the other three sub-periods, 1925-1943, 1967-1990 and 1999-2007, the volatility fluctuated around similar levels.

We measure volatility one more time as the squared growth rate of per capita output. To find the trend, we fit a HP filtered trend to the volatility series of per capita output. We plot the volatility and its trend in Figure 7.

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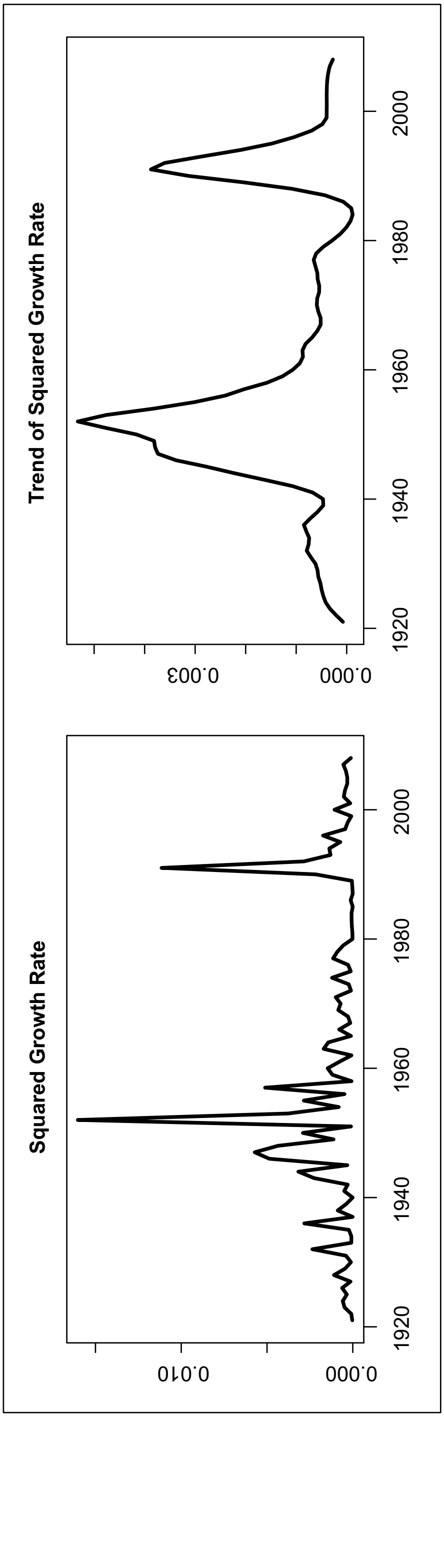
[6] The real GDP per capita gap is calculated as the difference between GDP per capita and its HP-trend component divided by HP-trend:

Figure 7

THE SQUARED GROWTH RATE OF PER CAPITA OUTPUT AND ITS TREND



Source: Author's calculations are based on data from Družić (2004), and Total Economy Database (2009)

The trend shows a slowly increasing volatility in the pre-war period, and two strong volatility phases (seen by very high spikes above the trend line) for a very short first phase lasting from 1952 to 1953 approximately, followed by a more and more moderate volatility phase afterwards (a period in which volatility was decreasing and falls below the trend line) and then, secondly, by another, somewhat longer, volatility phase, beginning approximately in 1990 and ending in 1995. As a result, the result has changed insignificantly considering the earlier measurement of volatility. One plausible explanation for the observed pattern is that at the beginning of the pre-war period Croatia, within Monarchist Yugoslavia, had an unsophisticated economic structure with the primary sector over-represented (Stipetić and Grahovac, p.47, 1991) and therefore subject to few macroeconomic shocks. Afterwards, during the Second World War, the shocks multiply. It became a socialist state - planning economy, but still with a fragile industrialised economy and without efficient institutions to conduct macroeconomic policies. Broken economic ties with the Stalin's Soviet Union economy in 1948, and orientation toward western aid programmes are the cause of extreme volatility in the immediate post-war and 1952-53 periods as extreme episodes. The subsequent cycles of damped volatility from 1958-1989 may be due to improving institutional arrangements (this is only a practical hypothesis in the spirit of the institutional economic school; in the case of Croatia there are no references connected with the empirical proofs of this affirmation). Still, it is worth noting that the change in volatility second pattern (see the second extreme spike) coincides roughly with the Homeland war duration and is abrupt, suggesting a break pattern rather than a smooth one, which is more characteristic of the first - mentioned volatility cycle.

Interestingly, when comparing the results, we see that the period of high average negative growth (in 1990-95 calculated instantaneous growth rate per capita was -2.43) seem to coincide with periods of high volatility observed in the not-so-distant past. This observation leads us to the second issue we discuss in this subsection.

Figure 8

PERSISTENCE OF REAL GDP PER CAPITA GROWTH
IN CROATIA, 1929-2008

Source: Author's calculations based on data from Družić (2004), and Total Economy Database (2009). Ten-year rolling auto-correlations in annual real GDP per capita rate

Concerning the rolling autocorrelation, the main conclusion is that two great slumps in growth persistency occurred in 1954 and in 1989, but that an appreciable increase in persistence happened in 1959-84. The Croatian economy did not display the highest variability during that period. In fact, the volatility reached its maximum in the 40s period, and in the first half of the 1990's; hence the calculated persistence does not surprise us.

3.5. The ARMA Model of Growth Rate per Capita

Before estimating the conditional variance of the real growth rate per capita only for Croatia, it must be checked whether there is autocorrelation in the residuals of the conditional mean equation. For the conditional mean equation, assuming that the Croatian GDP growth rate per capita follows the autoregressive moving average (ARMA) process, and is a function of autoregressive lags and moving average terms.

First, Box-Jenkins techniques were used to reduce the set of prospective ARMA specifications. Two functions, the autocorrelation function (ACF) and the partial autocorrelation function (PACF), were used to assist in the identification stage of the model. The ACF and PACF residuals should be indicative of a white-noise process. To further assist in the identification of the correct ARMA model, the general information criteria, Akaike - Schwartz information criteria was used. The best-fitting ARMA specification having the lowest Akaike - Schwartz information criteria for the conditional mean equation is as follows in Table 7. That is, the mean growth rate equation equals the following:

$$y_t = const + a_1 y_{t-1} + a_2 \varepsilon_{t-1} + a_3 \varepsilon_{t-2} + a_4 \varepsilon_{t-3} + \varepsilon_t$$

where the growth rate yt = 100 * ln (Yt-Yt-1), ln(Yt), equals the natural logarithm of real GDP per capita, and εt equals the serially uncorrelated error term.

Table 7

ARMA (1,3) Model Estimation, OLS estimates

$y_t = const + a_1 y_{t-1} + a_2 \varepsilon_{t-1} + a_3 \varepsilon_{t-2} + a_4 \varepsilon_{t-3} + \varepsilon_t$						
	Const	a_1	a_2	a_3	a_4	
	0.0125	0.8303	0.101	0.0387	-0.4802	
	(3.5176)	(11.4782)	(2.231)	(0.2997)	(-3.9724)	
	[0.0007]	[0.000]	[0.440]	[0.765]	[0.0002]	
JB = 93.4 P-value = 0.000						
Q(1)= 0.0657	Q^2(1)= 0.36	T* R^2 (1) = 0.34(0.95)				
Q(2)= 0.18	Q^2(2)= 1.96	T* R^2 (2) = 1.74 (0.41)				
Q(4)= 0.22	Q^2(4)= 3.95	T* R^2 (4)= 3.12(0.52)				

Notes: - z-statistics in () & prob. in [ ]

- Q and Q^2 represent the Ljung-Box test statistic for the joint significant of autocorrelations of standardized and squared standardized residuals respectively for the first 1, 2 and 4 lags. Under the null hypothesis of no serial correlation, distributed as χ 2 (1), χ 2 (2) and χ 2 (4). The 5% critical values are 3,84 5,99 and 9,49 respectively.

- In practice the maximum number of sample autocorrelations and partial autocorrelations to use is T/4. Since the observation number is 82, maximum lag length for Q and Q2 tests used is 20.

- T* R^2 shows ARCH Lagrange Multiplier (ARCH-LM) test statistics for serial correlation for the first 1, 2 and 4 lags. The 5% critical values for χ 2 (1), χ 2 (2) and χ 2 (4) are 3.84, 5,99 and 9.49 respectively.

It can be seen from the results in Table 7 that all estimated coefficients in the chosen model are significant at conventional levels, beside *εt-2*. This condition implies that the characteristic roots are inside the unit circle. Ljung-Box (Q) statistics indicate that the residual series appear to be white-noise. The Ljung-Box (Q and Q2) statistics of the residuals at 1, 2 and 4 lags shows that there is no autocorrelation in residuals. This means that the fitted model is reasonably well specified. Thus, the ARMA (1.3) model is adequate. The Lagrange multiplier (ARCH-LM) for the presence of ARCH disturbances shows and it can be seen that for the growth rate the null hypothesis of no ARCH errors (i.e. homoscedastic process) is not rejected at the 5 % level. A diagnostic test indicates that the residuals are serially uncorrelated.

4. Growth rate of per capita GDP and volatility trade-off testing

In the previous section we investigated if the volatility of the growth rates in the evolution of Croatia according to different measured volatility concept of *per capita* growth has been increasing or decreasing over time. Now, we will try to identify whether changes in the volatility of per capita GDP (for various concept of volatility) impact its growth rate.

4.1. Volatility Trend and the Fischer Black Hypothesis

Although the ARMA (1,3) model of real growth per capita in Croatia appears adequate, there are some periods of unusual volatility that are characteristic of a GARCH process. Furthermore, the structural changes in different volatility time series occurred with a high probability, within the given observation interval, while the results have been summed up in the Tables 8-12. Hence, we carry out two tasks in this subsection. The first is to assess when *per capita* output volatility due to assumed structural breaks over time occurred. The second is to study the role of volatility and its structural changes in the evolution of the growth rate of *per capita* output in a similar manner to Fang, W.S., Miller, S, M (2008)

Table 8

THE BREAK DATES OF **SDY** TIME SERIES

OPTIMAL BREAK DATES ACCORDING TO MINIMAL BIC							
m = 4	1943 1960 1978 1990						
Fit:							
m	0	1	2	3	4	5	6
RSS	0.034	0.031	0.023	0.02	0.017	0.017	0.024
BIC	-413.20	-412.41	-426.88	-432.31	**-435.16**	-427.366	-388.140

Table 9

THE BREAK DATES OF **SDGAP** TIME SERIES

OPTIMAL BREAK DATES ACCORDING TO MINIMAL BIC							
m = 4 1943 1955 1984 1996							
Fit:							
m	0	1	2	3	4	5	6
RSS	36.57	26.68	14.87	13.44	11.67	11.31	16.87
BIC	178.41	160.52	119.72	120.01	**116.90**	123.11	166.01

Table 10

THE BREAK DATES OF **SDDY** TIME SERIES

OPTIMAL BREAK DATES ACCORDING TO MINIMAL BIC						
m = 3 1945 1960 1989						
Fit:						
m	0	1	2	3	4	5
RSS	315.23	230.55	123.77	110.61	104.89	99.84
BIC	358.33	340.91	297.525	**296.94**	301.34	306.06

Table 11

THE BREAK DATES OF **SDSHOCK** TIME SERIES

OPTIMAL BREAK DATES ACCORDING TO MINIMAL BIC						
m = 3 1946 1960 1990						
Fit:						
m	0	1	2	3	4	5
RSS	0.03	0.02	0.01	0.01	0.01	0.011
BIC	-402.91	-422.93	-469.37	**-471.50**	-463.5	-447.13

Table 12

THE BREAK DATES OF **DDY** TIME SERIES

OPTIMAL BREAK DATES ACCORDING TO MINIMAL BIC						
m = 2 1942 1957						
Fit:						
m	0	1	2	3	4	5
RSS	4.5e-04	4.3e-04	3.5e-04	3.4e-04	3.4e-04	3.4e-04
BIC	-8.122e+02	-8.072e+02	**-8.168e+02**	-8.1e+02	-8.01e+02	-7.9e+02

Fischer Black (1987) argues that a positive relationship between output volatility and growth must be verified. The reason is that economies face a positive trade-off between risk (volatility) and return (output growth rates) in choosing their aggregate technologies, but because of decreasing real per capita growth in the period which spanned maximum volatility in Croatia, we ought to expect an inverse real growth rate/volatility relation.

The GARCH (1,1) is a model for the conditional variance of a time series. In order to capture the effect of volatility on output growth, we introduce the conditional variance in the equation for the mean of *per capita* output growth process. Before presenting the results, some notation is in order. The conditional variance is denoted by σ_t and ε_t stands for the residual in the mean equation.

$$R.1.\ y = const + a_1 y_{t-1} + a_2\varepsilon_{t-1} + a_3\varepsilon_{t-2} + a_4\varepsilon_{t-3} + a_5\sigma_t + \varepsilon_t$$

$$R.2.\ \sigma_t^2 = const + \alpha_1\varepsilon_{t-1}^2 + \beta_1\sigma_{t-1}^2$$

In addition, σ_t^2 equals the conditional variance of the growth rate, given information available at time t-1. The volatility clustering is shown by the size and significance of α. β is the GARCH term. The conditions that $\alpha_1 \geq 1$, $\beta_1 \geq 1$, and $\alpha_1 + \beta_1 < 1$ ensure positive and stable conditional variances of σ_t^2. The sum, $\alpha_1 + \beta_1$, measures the persistence of shocks to the conditional variances. Any shock to volatility is permanent if $\alpha + \beta = 1$. The unconditional variance is infinite. Engle and Bollerslev (1986) call it the integrated GARCH or IGARCH process. In the IGARCH process, volatility persistence is permanent. Past volatility is significant in predicting future volatility. Volatility is explosive if $\alpha + \beta > 1$. A shock to volatility in one period will lead to even greater volatility in the next period.

4.2. The Results Of GARCH (1.1)-M Model

The parameters in the model are estimated using the maximum likelihood procedure, as described in Engle (1982) and Bollerslev (1986) and results are reported in Table 13. Estimates for the conditional mean and conditional variance of real growth rate are reported according to equation (1) and equation (2) respectively, in Table 13.

The estimated coefficients in the GARCH (1, 1)-M model are similar to the OLS coefficients reported in Table 7 as an ARMA(1,3) structure.

The estimation results suggest that volatility does not enter in a statistically significant way in the mean equation. Nevertheless, the point estimate doesn't contradict the Fischer Black hypothesis. Therefore, that conjecture seems to hold for Croatia, and if volatility influences growth at all, it is in a positive fashion as Black also suggested.

The GARCH (1, 1) parameters in the conditional variance are unstable because their sum is more than one and the volatility shows an explosive pattern (this is an intuitive result and in accordance with our sharp spikes in Figures 6 and 7). The coefficient on the lagged, squared, residuals ε_{t-1}^2 is significant at 5 % level. The coefficient on the lagged error variance σ_{t-1}^2 in the equation is significant too, indicating that the real growth rate shocks have a persistent effect on real growth rate.

The normality test (Jarque-Bera) of standardised residuals is significant which is consistent with the hypothesis that the residual from GARCH model is normally distributed. Diagnostic tests on the residuals and its square are reported at Table 13. Ljung-Box (Q and Q2) test statistics clearly indicate that there is no the serial correlation in the conditional variance. Lagrange multiplier test also indicates that the residuals are serially uncorrelated. As a result the model appears adequate.

Table 13

MODEL ESTIMATION, GARCH(1,1) ESTIMATES OF GROWTH RATE OF REAL GDP PER CAPITA IN CROATIA

$$R.1.\ y = const + a_1 y_{t-1} + a_2\varepsilon_{t-1} + a_3\varepsilon_{t-2} + a_4\varepsilon_{t-3} + a_5\sigma_t + \varepsilon_t$$
$$R.2.\ \sigma_t^2 = const + \alpha_1\varepsilon_{t-1}^2 + \beta_1\sigma_{t-1}^2$$

	CONST 0.014 (4.962) [0.000]	a_1 -0.120 (-0.193) [0.846]	a_2 0.201 (0.331) [0.740]	a_3 0.464 (4.114) [0.0000]	a_4 0.222 (0.643) [0.519]	a_5 *0.139* (*0.738*) [0.602]
	Const 5.76E-05 (1.7409) [0.0817]	α_1 0.813 (2.910) [0.003]	β_1 0.354 (2.682) [0.007]			
JB = 2.984 P-value = 0.224						

Q(1)= 2.1468	Q^2(1)= 0.0015	$T * R^2$ (1) = 0,0013(0.97)
Q(2)= 2.178	Q^2(2)=0.165	$T * R^2$ (2) = 0,16 (0.93)
Q(4)= 2.230	Q^2(4)=0.39	$T * R^2$ (4)= 0.39(0.98)

Croatia also experiences a few sharp drops in its growth rates in addition to the moderation in its volatility at the break dates 1945, 1960 and 1989 (see Table 10). To capture the mean shifts, three dummy variables, defined as $D1$ =1 for t>1945, $D2$ =1 for t>1960, $D3$ =1 for t>1989, zero otherwise, enter into the mean equation as follows:

$$y = const + a_1 y_{t-1} + a_2\varepsilon_{t-1} + a_3\varepsilon_{t-2} + a_4\varepsilon_{t-3} + a_5\sigma_t + b_1 D_1 + b_2 D_2 + b_3 D_3 + \varepsilon_t$$

To see the effect of the mean changes, Table 14 – Panel C reports the estimation results, where we include these three dummy variables in the mean equation. The result of subsequent regression indicates the existence of a negative trade-off between higher growth rates and the growth rate volatility but at an insignificant level of the obtained conditional variance coefficient. It has been done in the same manner considering the calculation of break dates in volatility and other time series treated in this chapter in order to test on a base as amply as possible the basic hypothesis of this study which affirms the existence of a positive trade-off between the different concepts of volatility and the higher growth rates. Only one result from the econometric point of view can be accepted, and at the same time this result confirms our original intuition according to which there is a positive trade-off between the growth volatility and the higher growth rates in the case concerning the application of the dummy variable with which it is possible to control the appearance of break dates in the volatility of output per capita shock (see Table 14 -Panel D). As a result, the final evidence of the study whose purpose is to test the basic hypothesis are inconclusive.

Table 14

MODEL ESTIMATION WITH INTERCEPT DUMMY VARIABLES IN MEAN

Panel A. GARCH(1,1) Estimates

R.1. $y = const + a_1 y_{t-1} + a_2 \varepsilon_{t-1} + a_3 \varepsilon_{t-2} + a_4 \varepsilon_{t-3} + a_5 \sigma_t + b_1 D_1 + b_2 D_2 + b_3 D_3 + b_4 D_4 + \varepsilon_t$

R.2. $\sigma_t^2 = const + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$

where $D1$ =1 for t>1943, $D2$ =1 for t>1960, $D3$ =1 for t>1978, and $D4$ =1 for t>1990 ; 0 otherwise

Note: dummy is defined as breaking dates in time series SDY which measure the volatility

	CONST	a_1	a_2	a_3	a_4	a_5
	0.004 (1.348) [0.177]	0.583 (5.043) [0.000]	-1.036 (-7.808) [0.000]	0.430 (4.267) [0.000]	-0.193 (-3.427) [0.000]	-0.164 (-2.144) [0.032]
b_1 0.025 (9.767) [0.000]	b_2 -0.006 (-2.143) [0.032]	b_3 -0.016 (-7.994) [0.000]	b_4 0.011 (5.866) [0.00]	Const 7.04E-07 (0.165) [0.868]	α_1 2.242 (3.344) [0.0008]	β_1 0.061 (1.468) [0.141]

JB = 4.013 P-value = 0.123		
Q(1)= 0.41	Q^2(1)= 1.29	$T * R^2$ (1) = 1.24(0.26)
Q(2)= 1.62	Q^2(2)=1.58	$T * R^2$ (2) = 1.65 (0.43)
Q(4)= 2.29	Q^2(4)=2.4	$T * R^2$ (4)= 2.8(0.59)

Panel B. GARCH(1,1) Estimates

$R.1.\ y = const + a_1 y_{t-1} + a_2 \varepsilon_{t-1} + a_3 \varepsilon_{t-2} + a_4 \varepsilon_{t-3} + a_5 \sigma_t + b_1 D_1 + b_2 D_2 + \varepsilon_t$

$R.2.\ \sigma_t^2 = const + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$

where $D1$ =1 for t>1943 $D2$ =1 for t>1955; 0 otherwise.

Note: dummy is defined as breaking dates in time series SDGAP which measure the volatility

	CONST 0.007 (0.830) [0.406]	a_1 -0.202 (-0.474) [0.634]	a_2 0.234 (0.566) [0.571]	a_3 0.485 (4.890) [0.000]	a_4 0.273 (1.05) [0.291]	a_5 0.104 (0.538) [0.590]
b_1 0.019 (1.116) [0.264]	b_2 -0.007 -(0.410) [0.681]	Const 7.05E-06 (0.355) [0.722]	α_1 1.055 (3.140) [0.001]	β_1 0.331 (2.426) [0.015]		
JB = 2.34 P-value = 0.313						
Q(1)= 1.59	Q^2(1)= 0.21	$T * R^2$ (1) = 1.21(0.64)				
Q(2)= 2.04	Q^2(2)=0.55	$T * R^2$ (2) = 0.54 (0.75)				
Q(4)= 3.13	Q^2(4)=1.35	$T * R^2$ (4)= 1.48(0.43)				

Panel C. GARCH(1,1) Estimates

$R.1.\ y = const + a_1 y_{t-1} + a_2 \varepsilon_{t-1} + a_3 \varepsilon_{t-2} + a_4 \varepsilon_{t-3} + a_5 \sigma_t + b_1 D_1 + b_2 D_2 + b_3 D_3 + \varepsilon_t$

$R.2.\ \sigma_t^2 = const + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$

where $D1$ =1 for t>1945, $D2$ =1 for t>1960, $D3$ =1 for t>1989 ; 0 otherwise.

Note: dummy is defined as breaking dates in time series SDDY which measure the volatility

	CONST 0.0051 (0.418) [0.675]	a_1 -0.033 (-0.059) [0.952]	a_1 0.131 (0.255) [0.800]	a_1 0.506 (4.650) [0.000]	a_1 0.213 (0.682) [0.492]	a_1 **-0.048** (**-0.113**) [**0.903**]

b_1	b_2	b_3	Const	α_1	β_1	
0.046 (2.727) [0.004]	-0.027 (-1.681) [0.090]	-0.009 (-0.582) [0.557]	7.43E-06 (0.304) [0.767]	0.868 (3.498) [0.0005]	0.426 (3.793) [0.0002]	
JB = 2.12 P-value = 0.35						
Q(1)= 0.97	Q^2 (1)= 0.48	$T * R^2$ (1) = 0.48 (0.48)				
Q(2)= 2.4	Q^2 (2)=0.59	$T * R^2$ (2) = 0.81 (0.73)				
Q(4)= 2.81	Q^2 (4)=1.52	$T * R^2$ (4)=1.73 (0.78)				

Panel D. GARCH(1,1) Estimates

$$R.1.\ y = const + a_1 y_{t-1} + a_2 \varepsilon_{t-1} + a_3 \varepsilon_{t-2} + a_4 \varepsilon_{t-3} + a_5 \sigma_t + b_1 D_1 + b_2 D_2 + b_3 D_3 + \varepsilon_t$$
$$R.2.\ \sigma_t^2 = const + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

where $D1$ =1 for t>1946 $D2$ =1 for t>1960, $D3$ =1 for t>1990; 0 otherwise.

Note: dummy is defined as breaking dates in time series SDSHOCK which measure the volatility

	CONST	a_1	a_2	a_3	a_4	a_5
	0.007 (1.001) [0.315]	-0.244 (-0.753) [0.444]	0.164 (0.564) [0.5533]	0.410 (4.644) [0.000]	0.223 (1.497) [0.144]	**0.247** (**1.972**) [**0.067**]
b_1	b_2	b_3	Const	α_1	β_1	
0.014 (1.2143) [0.2246]	-0.0066 (-0.6773) [0.4982]	0.0051 (1.2227) [0.2214]	2.72E-06 (0.3995) [0.6895]	1.6717 (3.4243) [0.0006]	0.1577 (1.7166) [0.0860]	
JB = 0-12 P-value = 0.9						
Q(1)= 1.2	Q^2 (1)= 0.87	$T * R^2$ (1) = 0.9 (0.34)				
Q(2)= 1.5	Q^2 (2)=1.8	$T * R^2$ (2) = 2.08(0.35)				
Q(4)= 1.7	Q^2 (4)=4.2	$T * R^2$ (4)=5.73 (0.20)				

Panel E. GARCH(1,1) Estimates

$R.1.\ y = const + a_1 y_{t-1} + a_2 \varepsilon_{t-1} + a_3 \varepsilon_{t-2} + a_4 \varepsilon_{t-3} + a_5 \sigma_t + b_1 D_1 + b_2 D_2 + b_3 D_3 + \varepsilon_t$

$R.2.\ \sigma_t^2 = const + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$

where $D1$ =1 for t>1942 $D2$ =1 for t>1957; 0 otherwise.

Note: dummy is defined as breaking dates in time series DDY which measure the volatility

	CONST 0.009 (0.651) [0.505]	a_1 -0.268 (0.368) [0.477]	a_2 0.277 (0.793) [0.421]	a_3 0.514 (5.619) [0.000]	a_4 0.298 (1.342) [0.179]	a_5 0.238 (1.350) [0.170]
b_1 -0.0009 (-0.087) [0.93]	b_2 0.018 (1.574) [0.113]	Const 4.31E-06 (0.377) [0.709]	α_1 1.214 (2.895) [0.007]	β_1 0.204 (2.237) [0.025]		
JB = 1.25 P-value = 0.63						

Q(1)= 0.34	Q^2(1)= 0.85	$T * R^2$ (1) = 0.92(0.33)
Q(2)= 3.3	Q^2(2)=2.74	$T * R^2$ (2) =1.5(0.46)
Q(4)= 3.99	Q^2(4)=2.87	$T * R^2$ (4)=3.91(0.41)

The model estimation with intercept dummy variables in mean due to structural break dates of time series (in 1946, 1960 and 1990) in the volatility of output per capita shock time series result in a positive and significant coefficient of 0.24 before the GARCH term, so the sign obtained before the conditional variance variable is in harmony with Black Fisher assumption. On the other hand, the significant result from the aspect of conditional variance obtained in the case of regression with the structural breaks in the analysis of time series in the volatility of real GDP *per capita* growth does not confirm the previous results. As a result, our testing of Black Fisher's hypothesis has produced inconsistent results. In the case of Croatia, the negative result gets an opposite image, and in conformity with him we should agree with Caballero (1991) who has an alternative view on the theoretical relationship between growth and volatility. It is often argued that large swings in the economy make investment extremely risky, and as a result induce less investment (as a major volatility component inside of GDP structure), less capital accumulation and, consequently, less output growth. On this point we have to emphasise a possible negative relationship between instability and growth while studying the performance of the Croatian economy in the 40's, 80's and 90's. The generalized uncertainty that affected the country (change of the economic and political regime in the 40's, at first stagflation, then hyper-inflation in the 80's, war shock, transition toward the capitalist state of economy, a poorly carried out transformation of social into private ownership, de-industrialisation, rising unemployment, bank crises in the 90's etc.) was responsible, in our view, for the stagnation and even decelerated rate of real GDP per capita during those two decades. We may suggest that the galloping inflation in the 80's and afterwards produced disturbance in the optimal allocation of investment resources.

5. Conclusions

By applying an econometric technique we were able to trace important breaking points in the process of long term GDP per capita growth. We distinguished four economic phases with different real GDP per capita growth rate, which ran from 1920 to 1946 (0.51%), from 1947 to 1958 (1.95%), from 1959 to 1972 (5.39%) and from 1973 to present (0.2%). This research clearly shows that the period from 1959 until the early 70's can be seen as a 'golden age' in which growth rates of output per capita were significantly higher than in the preceding and following periods. This study has examined the volatility in GDP per capita growth rate for Croatia during the period 1920 to 2008 as well as the relationship between output per capita growth volatility (in various but similar conceptual forms) and real GDP per capita growth. We proceed by considering the possible effects, if any, of structural change on the volatility process. Our final results, based on a GARCH model, find strong evidence of a positive trade-off between the growth volatility and the higher growth rates in the case concerning the application of the dummy variable with which it is possible to control the appearance of break dates in the volatility of output per capita shock.

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POSTOJI LI KOMPROMIS IZMEĐU VOLATILNOSTI I RASTA? SLUČAJ HRVATSKA, 1920.-2008.

Sažetak

U ovom radu proučavamo ponašanje stopa rasta realnog BDP-a po stanovniku za Hrvatsku tijekom razdoblja 1920.-2008. sa različitih stajališta. Istražuje se postoje li zajednički strukturni prekidi u vremenskoj seriji rasta. Empirijski se istražuju neke osnovne značajke poslovnog ciklusa, kao što je volatilnost, istrajnost, točke okreta, i duljine recesija i ekspanzija u stopi rasta realnog BDP-a po stanovniku. Uvjetovana volatilnost procjenjuje se primjenom modela opće autoregresivne uvjetovane heteroskedastičnosti (GARCH model). Naši su glavni zaključci: (1) stopa rasta po stanovniku proživljava strukturne prekide tijekom razdoblja analize i intervali prekida ukazuju na to da su jedan ili kombinacija događaja (osnivanje nove socijalističke vlasti u 1946., u 1958. novi zakon koji stimulira industrijalizaciju, veliki pad poslije 1972. uslijed neefikasnosti novog rukovodstva) doprinijeli strukturnim prekidima stope rasta BDP-a po stanovniku u Hrvatskoj; (2) empirijski rezultati pokazuju da je bilo važnih događaja u nekim razdobljima analize, dva izrazita volatilna šiljka u 1952. i 1991. na što ukazuju stope rasta po stanovniku; (3) učinke volatilnosti stope rasta u Hrvatskoj prema Black-ovoj hipotezi o pozitivnom volatilnost - rast kompromisu nalazimo samo u modelu procjenjenom pomoću dummy varijable koja kontrolira promjenjivost output šoka vremenske serije.

Ključne riječi: poslovni ciklusi, GARCH-M model, BDP po stanovniku, stopa rasta, Hrvatska