CORRELATION BETWEEN ADAPTATION AND MITIGATION OF CLIMATE CHANGE AND ECONOMIC GROWTH [1]

Zvonimira ŠVERKO GRDIĆ

Faculty for tourism and hospitality management, Primorska 42, 51410 Opatija
zgrdic@fthm.hr

Daniel DRAGIČEVIĆ

Faculty for tourism and hospitality management, Primorska 42, 51410 Opatija
danield@fthm.hr

Maja MAMULA

Faculty for tourism and hospitality management, Primorska 42, 51410 Opatija
majam@fthm.hr

Abstract: *The paper explored the relationship between economic growth and investment in environmental protection, what is "the right kind of growth", and various growth policies, financing various activities in order to reduce vulnerability to climate change. In addition, it explored how to mitigate and adapt to climate change in order to maximize positive effects and minimize possible negative effects on economic growth in the future. Regression analysis suggested, at 5% level of significance, that one percentage change in gross domestic product of Croatia results in 2,339 percentage change in environmental protection i.e. is in adaptation and mitigation to climate change.*

Keywords: economic growth, climate change, adaptation, mitigation

JEL Code: **A10, O20, Q50,M Q58**

Introduction

The modern world is characterized by various forms of global social, economic, political and natural changes. Among them, climate change represents a unique challenge to the entire human civilization and affects all aspects of human life. Global warming and its implications are assessed as the greatest threat of the 21st century. Climate change is affected by the concentration of greenhouse gases in the atmosphere, which depends on human and natural emissions. However, very little is known and researched about the impact of economic growth on investment in enviromnetal protection and the importance of implementing mitigation and adaptation policies. Understanding how climate change will affect the economic growth is very important. The first studies of adaptation and mitigation policies began in the early 1980s. This led to the implementation of a large number of policies to reduce emissions of greenhouse gases at all levels, and the introduction of mitigation policies. In order to solve the far-reaching consequences for the environment, economy and society, in addition to the adjustment of projected emissions, the adaptation to the changes caused by greenhouse emissions will be required. The problem of economic growth, climate change and adaptation and mitigation

[1] This paper has been financially supported by the University of Rijeka, for the project ZP UNIRI 4/15.

policies are very complex. Regression analysis was implemented to prove the hypothesis that the Republic of Croatia's increased economic growth leads to increasing of investments in environmental protection, which in turn leads to climate change mitigation, but also adaptation to future climate trends.

Literature review

The complexity of linkages between economic growth and investment in environmental protection is not sufficiently studied (Dell, M., Jones, BF, Olken, B. A., 2008, p.1), either in quantitative or qualitative terms (Eboli, F., R. Parrado, Roson, R., 2010, p. 516). The research, which study economic growth and the process of mitigating and adapting to climate change, are based on assumptions about future emissions and future trends of temperature and other aspects of climate (Tol, R. S. J, 2012, p. 98). While, at the beginning of the 1990s, the research focus concerning climate policy was mainly on mitigation, from the mid of the 1990s there has been an increasing interest in adaptation policies (Aakre, S., Rubbelke, D. T. G., 2010, p. 767). Economists have long since emphasized that an economic approach to climate policy must compare the entire set of measures to choose a portfolio of cost effective measures (Konard, K. A., Thum, M. 2014, p.32). Growth is a central objective of development policy. As climate resilience emerges as an equally important development concern, it is worth asking to what existing growth policies are compatible with the adaptation and mitigation needs (Bowen, A., Cochrane, S., Fankhauser, S., 2012., p. 95). Climate change is expected to increase the probability of extreme weather events. The IPCC concludes that increases in drought, heat waves and floods are projected in many regions, with expected adverse impacts such as increased water stress and damage to infrastructure (IPCC, 2008, p.65-66). Climate change is a global challenge that requires a long-term global solution in order to avoid environmental, social, and economic dislocation (Dwyer, L, Forsyth, P., Spurr, R., Hoque S., 2012. p. 143). The impact of climate change and the rise in temperature affects many human activities, especially the economic ones. The effects of these impacts are not well known, and recently the systematic collection and processing of data around the world is conducted. Nevertheless, the impact of changes in food production is already visible, and it is associated with the quality and condition of soil, water, sun, wind and climate. Temperature rise may lead to an increase of cultivated areas to the north of Europe and at the same time to decrease in the south due to the lack of water (insufficiently rain and the possibility of irrigation). Poorer harvest can become common due to the extreme weather conditions (frequency of droughts, floods, hail). Potential effects on the economy may be greater than the sum of all parts due to multiplication effects on particular sectors. For example, increase in the cost of energy and food, as well as other economic impacts may have indirect effects on the economy and society as a whole, and most of these effects will strongly affect the most vulnerable segments of the population.

The economic impact of climate change is usually measured as the extent to which the climate of a given period affects social welfare in that period (Fankhauser, S., Tol, R.S.J., 2005, p. 1). Underdeveloped countries suffer the most visible effects of climate change (Bowen, A., Cochrene, S., Fankhauser, S., 2012, p.95). It is expected that there will be an increase in budget expenditure due to treating the negative effects of global warming – from increased storms to the changes in weather patterns of drought and flooding. All this has a direct (i.e. personal standard) or indirect (redistribution of GDP) impact on the ability of people to redistribute personal income to some other purposes.

It seems evident today that further economic growth must be of a different kind from the carbon-based ecpansion which modrnization has relied upon since the industrial revolution. Non-renewable energy sources dannot be given eternal life even if consumed more cautiously, nor are carbon emissions likely to be fully mitigated by carbon storage technology (Brantberg, O., Brandal, N., Thorsen, D.E., p.141).

The process of mitigation and adaptation to climate change as a possible response to future opportunities

There are two basic strategic guidelines in the area of climate change: one is the mitigation and the other adaptation strategy. Their implementation should not be viewed separately as a choice either – or. It is a case of interrelated, alternative strategies which for achieving the best results assume the use of well-designed instruments and measures and their simultaneous application (Denona Bogović, N., Črnjar K. Šverko Grdić,

Z, 2011, p. 36). Mitigation aims at slowing climate change, while the adaptation is considered to be a desensitisation from the impact of climate change (Jopp, R., Mair, J., Delacy, T., M. Fluker, 2015, p. 301).

Mitigation strategy aims to reduce harmful emissions into the atmosphere, and thus reduces the greenhouse effect. Within mitigation, the reducition of grenhouse gas emissions requires the particiption voluntary of invoulntari of all sectors of society (Keskitalo, E.C.H., Juhola, S., Baron, N., Fyhm, Klein, J., 2015., p.7). This strategy is possible to achieve by various environmental and economic instruments (such as various norms and standards, environmental taxes, tradable permits, voluntary agreements between different subjects). By applying, this strategy reduces the consumption of goods whose combustion causes intense CO2 emissions into the atmosphere, primarily by investing in less-intensive technologies where possible.

There are several mitigation strategies and the most significant are (Climate Change and Tourism, 2008, p. 145):

- Reducing energy use - that can be achieved by changing transport habits (more widely uses of public transport; railway or bus instead of air transport) but also by changing the management process;
- Improving energy efficiency - can be achieved by using new innovative technologies;
- Increasing the use of renewable energy or carbon neutral sources - this includes the replacement of fossil fuels with renewable energy that causes less emissions e.g. biomass, hydro-wind-solar energy;
- Capturing CO2 through carbon discharges - CO2 can be stored in biomass, aquifers, oceans and geological outlets. UNWTO stresses that this option is particularly important for the tourism, since most developed countries and small island destination rely on air transport

The basic components of effective mitigation strategy are: the process of defining costs over time, an initiative that leads for mitigation to appear in certain areas, the initiative to develop new behaviour patterns of households, firms and government and technology that will affect the reduction of mitigation costs over time (Spence M., 2009, p.13).

Adaptation strategy is based on acceptance of the claim that climate change is something that is very likely to happen. This strategy aims to define the measures for adapting to adverse effects, as well as measures for better evaluation of favourable opportunities. The goal of adaptation strategy is to reduce vulnerability to climate change. Adaptation strategy can operate at two levels (Dwyer, L., Forstyth, P., Dwyer, W., 2010. p. 715):

- Building a customized capacity - the creation of information and requirements (regulatory, institutional and management) needed to support the adaptation and reducing the vulnerability to climate change. The development of proper framework will encourage various subjects to adaptation such as households, public organizations and businesses. Government institutions can support the adjustment in such a way to ensure the legislation but also economic and institutional support for private sector and public community.
- Perform various adaptation actions - performing various actions to reduce vulnerability to climate risks and the research of other options, such as, exploring how the physical infrastructure can be protected from certain climate risks (such as floods, large water waves ...), introducing new technologies, investing in new products ... Adaptation actions must be associated with the development policy and planning at all levels.

The capacity to adapt to climate change depends on the existing sectors and sub-sectors (destination and individual ones). Due to the current uncertainty about future global emissions, environmental, social and economic impacts, flexibility becomes a key to successful adaptation, and it can be divided into three types: technical, business management and behaviour (Scott, D. Freitas, C. Matzarakis, A., 2006, p.302). Technical adaptation includes innovative and new technologies in order to adapt to climate change. Due to the high cost of technical adjustments, the decisions on the level of strategic management are inevitable, and they cannot take lightly. Adaptation in business management includes various processes at local and regional level that affects people in a country. Behaviour adaptation is strongly linked to the behaviour of people. It refers to e.g. adaptation in the type of clothes, a change of outdoor activities, the selection of other tourist destinations and the like (Dawson, J., Havitz, M., Scott, D., 2011, p. 392). Behaviour adaptation may be the result of technical and adaptation in business management. The challenge of adapting to climate change is greates in developing countries, for three reasons (Millner, A., Dietz, S., 2015., p.381). First is geography, becouse many

developing countries are located in tropical and subroptical regions and as such are already hotter than is optimal for various forms of economic activity. Second reason is often called sensitivity: a relatively large share of developing countries emanates from sectors sepecially sensitive to climatic contidtions, notably agriculture. The third reason is a lack of adaptive capacity. There is growing acceptance, that adaptation is critical since further warming is inevitable even if radical emissions reduction policies are implemented (Howell, R.A., Capstick, S., Whitmarsh, L., 2016., p. 3).

The overall objective of adaptation and mitigation policies, for Croatia, is to be more resistant to climate change, which means increasing the readiness and capability to respond to the climate change effects, but also to reduce the activities that work to the aggravation of climate change. The design and implementation of future measures should involve all stakeholders such as businessmen, citizens, associations and politicians. Their involvement is very important in order to build capacity for adaptation and mitigation to climate change in a broader context. It is also very important to adopt new ways of thinking about the use of fossil fuels and face the risks and uncertainties in the future. Therefore, what is needed is more focus on renewable energy sources and to use them as much as possible. On the other hand, it is necessary to continuously update the adaptation rules with new scientific achievements and information in order to respond appropriately. It would be desirable for Croatia to make The Adaptation and Mitigation Strategy with an Action plan wherein would in a uniform manner define criteria for mitigation and adaptation to climate change. It is advisable for The Strategy to include cost-benefit analysis which would facilitate the definition of future goals. Republic of Croatia should use available financial instruments of the EU, such as cohesion funds, agricultural funds and infrastructure funds as well as funds from the LIFE program and Horizon 2020. In this way, certain infrastructure could be financed with ultimate goal to mitigate and adapt to climate change. Mitigation and adaptation policy have the same goal and that is to reduce environmental pollution and adjustment to the new situation.

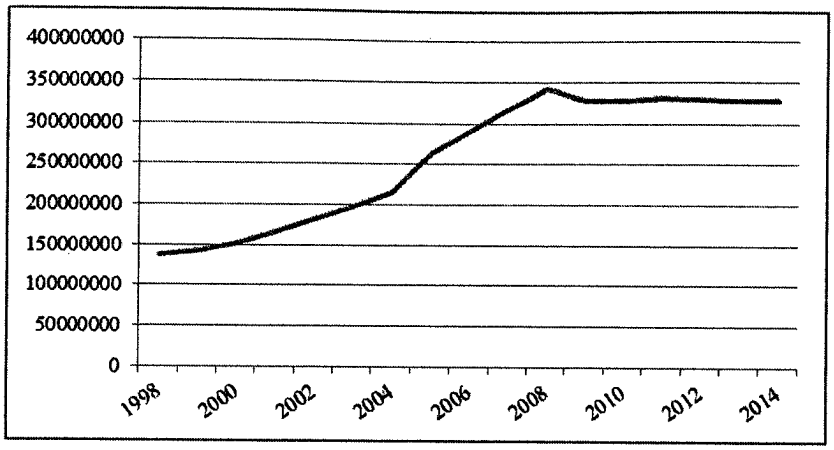
Adaptation, along with mitigation, is a very important strategy of responding to climate change. Without early and timely mitigation, the costs of adaptation will rise, and the ability of countries and individuals to adapt effectively will be constrained (Perić, J., Smolčić Jurdana, D., Šverko Grdić, Z., 2012. p.24). Understanding the nature and consequences of climate change is at the basis of any serous mitigation or adaptation policy (Galeotti, M., Roson, R., 2012, p. 27). In mitigation and adaptation, it is important to assess what would be the costs of inaction, that is, the economic impact of climate change in a baseline scenario, in which no policies are implemented.

Data and methodology

Regression analysis was implemented in order to test the hypothesis that the Republic of Croatia increased economic growth leads to increased investment in environmental protection, which in turn leads to climate change mitigation, but also adaptation to future climate trends. The data was collected from the Statistical Yearbook, published on the website of the Central Bureau of Statistics and UNDP's Human Development Reports from 1998 - 2015. The lack of availability of monthly or quarterly data could be viewed as limitation of this research. Therefore, in this research annual data for the period 1998-2014 were used. Total investments in environmental protection were defined as dependent variable, and gross domestic product and dummy as independent variable. As the dummy variable the human development category was taken. The Human Development Index is summary measure of average achievement in key dimensions of human development; a long and healthy life, being knowledgeable and have a decent standard of living. According to UNDP – Human Development Report 2015, there are four categories of development; low, medium, high and very high. Higher levels of HD, affect the economy through enhancing people's capabilities and consequently their creativity and productivity. There is empirical evidence at both micro and macro level importance of Human Development Index and economic growth relationship (Ranis, G., Stewart, F., 2000, p. 201). In observed period, Croatia was in medium and high category.[2] That fact was included in the model in the form of dummy variable; it takes two values (0 if Croatia wasn't in the category of high developed countries, and 1 if Croatia was in the category of high developed countries). The analysed data is shown in the figures below.

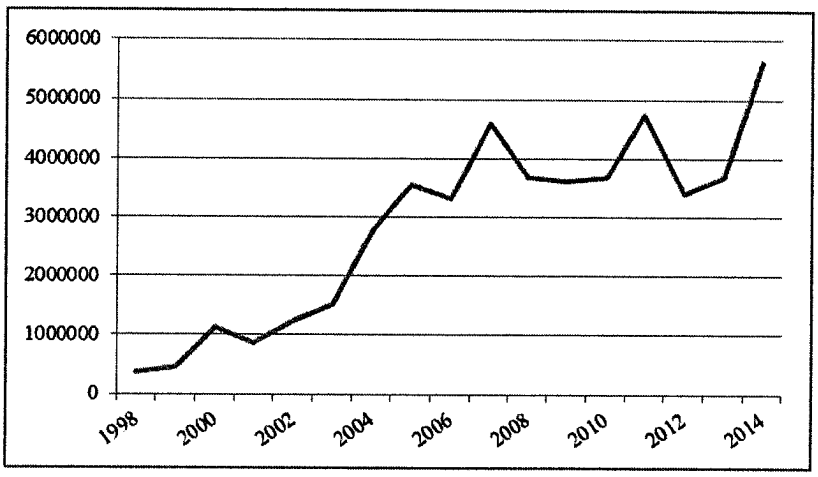
[2] The Republic of Croatia was in medium developed countries category in: 1998, 2008,2009 and 2010, and in high developed countries category in: 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2011, 2012, 2013 and 2014 year.

Figure 1. Gross domestic product (1998 – 2014), in 000 HRK current prices



Source: Statistical Yearbook of the Republic of Croatia, various issues

Figure 2: Investments in environmental protection (1998– 2014), in 000 HRK



Source: Statistical Yearbook of the Republic of Croatia, various issues

Data presented indicate a large variation. In order to stabilize the variance data has been log-transformed and as such used hereinafter. An advantage of logarithmic transformation is that the regression coefficients still have a simple interpretation, in terms of multiplicative effect. Its great advantage is that small changes in the natural log of variable are directly interpretable as percentage changes, to a very close approximation.

Estimated parameters and basic statistics are given in the table below.

Table 1: Regression analysis output

Dependent Variable: ln_environ Method: Least Squares Date: 00/00/00 Time: 00:00 Sample: 1998 2014 Included observations: 17				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-30.85123	3.421545	-9.016756	0.0000
ln_gdp	2.339596	0.176228	13.27593	0.0000
dummy	0.355668	0.139012	2.558542	0.0227
R-squared	0.926581	Mean dependent var		14.61424
Adjusted R-squared	0.916092	S.D. dependent var		0.830628
S.E. of regression	0.240607	Akaike info criterion		0.147480
Sum squared resid	0.810483	Schwarz criterion		0.294517
Log likelihood	1.746422	Hannan-Quinn criter.		0.162096
F-statistic	88.34260	Durbin-Watson stat		1.843667
Prob(F-statistic)	0.000000			

Source: author's interpretation

In general, the model fits the data well with relatively high adjusted R^2. Adjusted $R^2 = 0.916092$ which means that approximately 92% of variations observed in environmental protection investment (by which mitigation and adaptation is achieved) can be explained by gross domestic product and dummy variable variations. Overall, the estimated model can be considered as well specified. The explanatory variables are consistent and significant at 5% level. Estimated parameter sign is correct and consistent with economic theory as expected; suggesting that chosen independent variables has significant influence on investment in environmental protection in Republic of Croatia.

The OLS estimation gives:[3]

$$ln\_environ = -30.85123 + 2.339596 ln\ GDP + 0.355668\ dummy$$
$$t= \quad -9.016756 \quad 13.27593 \quad 2.558542 \qquad (1)$$
$$(0.0000) \quad (0.0000) \quad (0.0227)$$

where:

ln_environ - log – transformed environmental protection investment
lnGDP - log – transformed gross domestic product
dummy - dummy variable
t - the t-statistics

For model estimated in (1) the assumptions of classical linear regression model were tested. The testing for the presence of autocorrelation is preformed using the Breusch-Godfrey test.

Table 2: The Breusch-Godfrey test results

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.115890	Prob. F(2,12)	0.8916
Obs*R-squared	0.322133	Prob. Chi-Square(2)	0.8512

[3] Values in parentheses are empirical p-values.

As the value of the calculated nR^2 (0.322133) is smaller than the critical value of the $\chi^2_{(0.05;2)} = 9.48773$ the null hypothesis of absence of autocorrelation can be accepted.

To test the model for the presence of heteroscedasticity the White test is used. The results of the performed White test are shown in the table below.

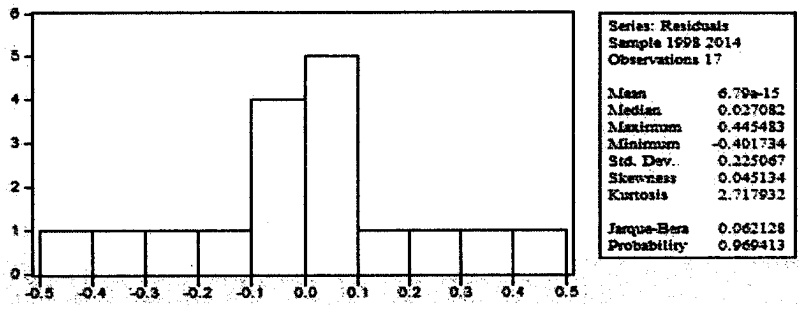
Table 3: The White test results

Heteroskedasticity Test: White			
F-statistic	0.908932	Prob. F(4,12)	0.4895
Obs*R-squared	3.952958	Prob. Chi-Square(4)	0.4124
Scaled explained SS	2.302800	Prob. Chi-Square(4)	0.6803

Calculated White statistics is 3.952958, and it is smaller than the critical value $\chi^2_{(0.05;4)} = 11.070$; the null hipotehesis that there is no heteroscedasticity can be accepted.

The testing for normality of residuals is performed using Jarque – Bera test.

Figure 3: Histogram and Jarque-Bera test results



Source: Statistical Yearbook of the Republic of Croatia, various issues

As the value of Jarque-Bera statistics JB=0.062128 is smaller than critical value of $\chi^2_{(0.05;2)} = 599146$, the null hypothesis of normalyy distributed residuals can be accepted. To test the multicollinearity of the variables the Variance Inflation Factor is used.

Table 4: Variance Inflation Factor

Variance Inflation Factors	
Date: 00/00/00 Time: 00:00	
Sample: 1998 2014	
Included observations: 17	
Minimum possible value = 1.0	
Values > 10.0 may indicate a collinearity problem	
C	NA
ln_gdp	1.021042
dummy	1.021042

Source: author's interpretation

As shown, the calculated VIF are smaller than 10, indicating that there is no evidence of serious multicollinearity between variables in the estimated model. According to performed test it can be concluded that the model is well specified; the assumptions of classical linear regression model are not violated.

Estimated equation shows that one percentage change in gross domestic product results in 2.339596% change in environmental protection investment that is in adaptation and mitigation of climate change. Also, the fact that Croatia is in the category of high developed countries, results in increase in environmental protection investment. This confirms the hypothesis that the Republic of Croatia increased economic growth leads to increased investment in environmental protection, which in turn leads to climate change mitigation, but also adaptation to future climate trends.

Conclusion

Climate change is already affecting economic growth in certain areas. In order to better adapt it is necessary to explore this interrelationship in multiple ways. Mitigation and adaptation policies are very important strategies to respond to climate change. Without timely and strong mitigation adjustment costs will grow and efficiency to adapt, by countries or individuals, will be limited. Climate change mitigation and prevention of negative impacts on the environment is one of the most important tasks of mankind, and it refers to attempts to reduce the greenhouse effect i.e. reduce the amount and rate of climate change. This paper introduced regression model that examined the relationship between the growth of the gross domestic product and funds invested in environmental protection in Croatia, and therefore in the process of adaptation and mitigation. The model has proven, for Croatia, the interconnection between GDP, human development index and investments in environmental protection in a way that the higher the GDP and human development index the higher investments in environmental protection.

References

1. Aakre, S., Rubbelke D.T.G.; Objectives of public economic policy and the adaptation to climate change, Journal of Environmental Planning and Management, Vol. 53., No. 6, p. 767-791
2. Bowen, A., Cochrane, S., Fankhauser, S., (2012), Climate change, adaptation and economic growth, Climatic Change, p.95-106.
3. Bratberg, O., Brandal, N., Thorsen, D.E., The Nordic Model of Social Democracy, DOI:10.1057/9781137013279.
4. Climate Change and Tourism - Responding to Global Challenges (2008), World Tourism Organization and United Nations Environment Programme, Madrid.
5. Croatian Bureau of Statistics; Statistical Yearbook of the Republic of Croatia (various issues; 1998 2015).
6. Dawson, J., Havitz., M. &Scott, D. (2011); Behavioural adaptation of alpine skiers to climate change: Examining activity inflolvement and place loyality, Journal of Travel & Tourism Marketing, 28(4), p. 388-404.
7. Denona Bogović, N., Črnjar, K., Šverko Grdić Z. (2011); Climate Change impact on Croatian tourism and possible alternatives of development; 1st International Scientific Conference Tourism in South East Europe, p. 29-39.
8. Dwyer, L., Forsyth P., Dwyer, W. (2010), "Tourism, Economics and Policy", Channel View Publications, Bristol.
9. Dwyer, L., Forsyth, P., Spurr, R., Hoque, S. (2012); Economic Impacts of a Carbon Tax on the Australian Tourism Industry, Journal of Travel Research 52(2), p. 143-155.
10. Eboli, F., Parrado, R., Roson, R.; Climate change feedback on economic growth: explorations with a synamic general equilibrium model, Environment and Development Economics, Vol. 15., p. 515-533.
11. Fankhauser, S., Tol.R.S.J.; On climate change and economic growth, Resource and Energy Economics, Vol. 27, p. 1-17.
12. Howell, R.A., Capstick, S., Whitmarsh, L. (2016); Impacts of adaptation and responsibility framings on attitudes towards climate change mitigation, Climatic change, p.1-17, DOI 10.1007/s10584-016-1627-z.
13. Galeotti, M., Roson, R. (2012); Economic Impacts of Climate Change in Italy and the Mediterranean: Updating the Evidence, Joural of Sustainable Development, Vol. 5, No. 5, p 27-41.
14. IPCC, 2008; Climate change 2007: Synthesis report, Cambridbe, Cambrigbe University Press.
15. Keskitalo, E.C.H., Juhola, S., Baron, N., Fyhn, H., Klein, J., (2016); Implementig Local Climate Change Adaptation and Mitigation Actions: The Role of Various Policy Instruments in a Multi-Level Governance Context, Climate, 4, 7, p. 2-11; doi:10.3390/cli4010007.
16. Konard, K.A., Thum, M. (2014); The Role of Economic Policy in Climate Change Adaptation, CESifo Economic Studies, Vol. 60, p. 32-61.

17. Jopp, R., Mair., J., Delacy T., Fluker, M. (2015); Climate change adaptation: Destination Management and the Green Tourist, Tourism Planning & Development, Vol 12. No. 3, p. 300-320.

18. Millner, A., Dietz, S. (2015); Adaptation to climate change and economic growth in developing countries, Environmnet and Development Economics, Vo.. 20, Issue 03, p.380-406

19. Peleikis, J., Gratz, M., Brnada, I. (2014), Prilagodba klimatskim promjenama u Hrvatskoj, radnimaterijal za nacionalno savjetovanje, p. 1-13.

20. Perić, J., Smolčić Jurdana, D., Šverko Grdić, Z, (2013), Croatian Tourism Sector adjutement to climate change, Tourism Management Perspectives, Vol. 6, p. 23-27.

21. Ranis, G., Stewart, F. (2000); Economic Growth and Human Development, World Development, Vol. 28., No 2, p. 197 – 219.

22. Scott, D., de Freitas, C. & Matzarakis, A. (2006); Adaptation in the tourism and recreation sector, Biometeorology for adaptation to climate variability and change, Vol. 1., p. 171-194.

23. Spence, M. (2008); Climate Change, Mitigation, and Developing Country Growth, Commission on Growth and Development, The International Bank for Reconstruction and Development / The World Banks, 2009., str. 13.

24. Tol. R.S.J.; On the Uncertainty About the Total Economic Impact of Climate Change, Environmental Resource Economic, Vol. 53, p. 97-116.

25. United Nations Development Programme, Human Development Report (various issues; 1998 – 2015).