5

A Preliminary Look at the Relationship Between Environmental Change and Economic Growth in Taiwan

Kuang-Ta Lo and Ya-Ting Yang
Department of Public Finance, National Chengchi University
Taiwan

1. Introduction

The relationship between environmental change and economic growth is two-sided. On the one hand, economic development leads to a change of environmental quality. This phenomenon is usually described by the well-known environment Kuznets curve (EKC). The EKC illustrates that economic growth and environmental degradation have an inverted U-shaped relationship. During the initial industrial period, people usually care more about their jobs and a better income than they do about the issue of environment; therefore, pollution tends to grow rapidly in this period. When income increases to a certain level, people begin to pay more attention to the quality of the environment so that at higher-income levels economic growth leads to environmental improvement. In other words, the EKC hypothesis contends that pollution increases initially as a country develops its industry and thereafter declines after reaching a certain level of economic progress (Stern, 1996).

On the other hand, a changing environment also affects economic growth. Environmental change can be observed from changes of temperature, in levels of precipitation, CO2 and SO2, etc. The Intergovernmental Panel on Climate Change (IPCC) Report argues that the effects from environmental change will impact all countries of the Southeast Asia region.[8] According to IPCC, crop yields could decrease up to 30% in central and south Asia by the middle of this century. The rapid population growth and urbanization in the region will magnify the number of people malnourished and subject to the risk of hunger due to climate change. More specifically, a recent study estimates a 2~5% decrease in yield potential of wheat and maize for a temperature rise of 0.5 to 1.5°C in India.[9] Dell et al. (2009) point out that from their research of cross-sectional data, a national income per-capita will fall 8.5% on average per degree Celsius rise in temperature, suggesting a simple method to calculate

[8] http://www.searo.who.int/en/Section260/Section2468/Section2500_14162.htm
[9] Aggarwal, P. (2003). Impact of climate change on Indian agriculture. J. Plant Biol., 30: 189-198.

how warming might influence future standards of living. The Asian Development Bank (ADB) also states that climate change may have a major impact on economic growth in Asia. The results of a recent ADB study about climate change in Southeast Asia show the total cost of losses due to climate change is quite large. If nothing is done, then the total cost of climate change for the countries of Indonesia, the Philippines, Thailand, and Vietnam could reach a combined 6.7% of GDP every year until 2100.[10]

Understanding the impact of climate change on the world economy is, obviously, of paramount importance for both climate change mitigation and adaptation policies. However, as Rosen and Mensbrugghe (2010) argue, modeling climate impact is a challenging undertaking for two main reasons. First, climate change is a systemic phenomenon in terms of both natural and human systems. In the so-called "Earth System," physical elements like the oceans, winds, the stratosphere, etc., interact in the determination of global climate conditions. In terms of socio-economic consequences, market linkages and trade propagate the effects of noneconomic factors throughout the globalized economy. As climate change is an intrinsically systemic phenomenon, it is inherently affected by complexity and uncertainty. Second, socio-economic impacts of climate change have different dimensions (e.g., sea level rise, human health, et al.), each one with different mechanisms and implications. To achieve a realistic assessment of the impacts, it is necessary to separately and adequately address each dimension.

Weather patterns exhibit large variations in amplitude and intensity. When unusual volumes of rainfall or extremes in air temperatures occur in populated regions, humans often suffer serious economic crises and loss of life. There is evidence suggesting that human activities are influencing climate on a large scale. One major effect has been the enhanced greenhouse effect related to massive increases in the amounts of airborne CO2, CH4 and N2O, between 1750 and 2005 (IPCC). As observed on Mauna Loa, Hawaii, the amount of CO2 has increased since 1958 at a rate of 1.5 parts per million (ppm) per year. Meanwhile, the global mean surface temperature increased 0.74°C±0.18°C between 1906 and 2005 (IPCC). In 2005, the global annual mean surface temperature was the warmest among temperature observations made since 1880 (Shein et al., 2006).

Taiwan is a densely populated island. The development of its industry has necessitated ever-increasing quantities of fossil fuel. On the other hand, the emission of greenhouse gases also has been growing quickly. These gases will continue to accumulate as time goes by and will indirectly influence climate change. Weather thus could be influenced by both natural and human factors. Moreover, bizarre weather phenomena such as maximum temperatures, minimum temperatures and diurnal temperature changes (DTC) often cause great damage and loss of crops, fishery and so on. Thus, the primary purpose of this research is to understand how the environment has been changed in Taiwan over the past years. This study further examines the correlation between environmental changes and economic growth in Taiwan. Additionally, we also analyze whether there are any spatial variations of environmental changes in different areas.

[10] http://www.banningbusinesscenter.com/climate-change-threatens-asian-economic-growth.html.

2. Issues in the Literature

The causal chain linking economic behavior today to economic consequences tomorrow via environmental changes can be summarized as follows:

Economic activities → Emissions → Atmospheric Concentrations → Radiative Forcing → environment or climate changes → impacts on physical and ecological systems → impacts on or damage to economies.

Each of the linkages between the components above involves complex factors.[11] For example, the link between economic activities and emissions involves population change, rates of economic growth, the specific stage of economic development (e.g., an economy reliant on heavy industry versus a service-based economy), the type of energy used to fuel the economy, energy efficiency (the amount of energy used to produce a unit of GNP changes as an economy develops), and technology. In addition, it is affected by the way global incomes accrue across countries. Hence, emissions do not have any simple proportional relationship to economic activity. As far as links from emissions to atmospheric concentrations of greenhouse gases and from concentrations to temperature change are concerned, what matters is the amount of greenhouse gases in the atmosphere. Annual emissions do not therefore have any simple proportional link to concentrations. Annual emissions add to the overall amount and the stored emissions (the atmospheric concentration) also decay at various rates. Most importantly, it is the overall amount that helps to determine temperature change. Even here the link is complex because the change in "radiative forcing" is not proportional to concentrations. The link from temperature change to economic damage depends on a further set of factors: how economies adapt to temperature change, how vulnerable economies are, how rapid warming is, and whether there are abrupt changes in temperature and weather events.

Environmental change manifests itself in increases of temperature, fluctuation of precipitation, rises in sea level, and the intensification of natural hazards, such as storms, floods, droughts, and landslides. One major consequence of global warming could be greater scarcity and variability of renewable resources in many parts of the world. With increasing concerns about such global effects of climate change a group of scholars, commonly referred to as neo-Malthusians, has posited that climate change is a threat to international security because it could increase resource scarcity (Schubert et al., 2009; Homer-Dixon, 1999; Homer-Dixon & Blitt, 1998 Bächler et al., 1996). However, other scholars, commonly referred to as cornucopians or resource optimists, do not share this pessimistic view. They believe that humanity can adapt to increasing resource scarcity through appropriate market mechanisms (pricing), technological innovation, and other means (Lomborg, 2001; Simon, 1998).

The economies of some countries are more vulnerable to climate change than the global average. Developing countries in general have a larger share of their economies in

[11] House of Lords (2005), The Economics of Climate Change.

agriculture and forestry. They also tend to be in the low latitudes where the impacts to these sectors will be the most severe. The low latitudes tend to be too hot for the most profitable agricultural activities and any further warming will further reduce productivity. Up to 80% of the damages from climate change may be concentrated in low-latitude countries (Mendelsohn et al. 2006).

Mendelsohn (2009) has argued that some damages from environment change will not affect the global economy, but will simply reduce the quality of life. Ecosystem change will result in massive shifts around the planet. Some of these shifts are already being reflected in agriculture and timber but they go beyond the impacts to these market sectors. Parks and other conservation areas will change. Animals will change their territorial range. Endangered species may be lost. Although these impacts will likely lead to losses of nonmarket goods, it is hard to know what value to assign to these effects. Another important set of nonmarket impacts involves health effects. Heat stress may increase. Vector-borne diseases may extend beyond current ranges. Extreme events could threaten lives. All of these changes could potentially affect many people if we do not adapt. However, it is likely that public health interventions could minimize many of these risks. Many vector-borne diseases are already controlled at relatively low cost in developed countries. Heat stress can be reduced with a modicum of preventive measures. Deaths from extreme events can be reduced by a mixture of prevention and relief programs. As the world develops, it is likely that these risks may involve higher prevention costs, but not necessarily large losses of life.

Furthermore, Dell et al. (2008) argue that higher temperatures have large, negative effects on economic growth, but only in poor countries. In poor countries they estimate that a 1^{o}C temperature increase in a given year reduced economic growth in that year by about 1.1%. In rich countries, changes in temperature had no discernable effect on growth. Changes in precipitation had no substantial effects on aggregate output in either poor or rich countries. Since they find no effects on rich countries, their results thus further imply that future climate change may substantially widen income gaps between rich and poor countries.

3. Relevant Background of Taiwan

3.1 Geographic Features and Natural Resources

Taiwan occupies an area of 36,191 square kilometers, somewhat smaller than the size of the Netherlands (41,526 km2). At mid-2010, its population stood at 23.1 million. With 638 persons per square kilometer, Taiwan is one of the most densely populated areas in the world. Three-quarters of the land is mountainous, with a spine-like ridge of steep mountains extending from north to south. About 60% of the land is forested, but forest resources are minimally exploited because of limited accessibility and environmental concerns. Even though only one-quarter of the land is arable, the subtropical climate permits multi-cropping of rice and growing of fruit and vegetables all year round. However, agricultural production accounted for only 1.7% of gross domestic product (GDP) in 2009. Although Taiwan does have deposits of coal, limestone, marble, dolomite, and natural gas, it is not richly endowed by nature. Indeed, more than 90% of its energy needs are met by imports, and its rapid industrialization also has relied heavily on imports of raw materials.

However, Taiwan has an ample supply of human resources, of which it has made highly effective use.[12]

3.2 Economic Background

Through decades of hard work and sound economic management, Taiwan has transformed itself from an underdeveloped, agricultural island to an economic power that is a leading producer of high-technology goods. The first stage of Taiwan's economic development extended from 1952 through 1980. During this period, Taiwan averaged an annual economic growth rate of 9.21%, which was the highest in the world. In 1962, agriculture lost its key position as the driving force behind Taiwan's economy, making way for the rapidly developing industrial sector. With the exception of two energy crises, in 1973-1974 and 1979-1980, Taiwan's industries maintained an average annual growth rate of around 14%.[13]

The second stage of Taiwan's economic development ran from 1981 through 2000. During this period, economic conditions around the world and within Taiwan itself underwent great changes. Combined external and internal forces exerted a rather detrimental effect on Taiwan's economic development, slowing the growth rate to a low of 7.15%. The focus of Taiwan's economy slowly shifted from the industrial sector to the service sector. Meanwhile, the agricultural sector grew a mere 0.63% annually as its GDP share continued to diminish. Limited natural resources and a high population density mean that Taiwan is not self-sufficient. Hence, foreign trade has come to play a leading role in Taiwan's economic development. The development of foreign trade and the increase of foreign investment are driving forces behind Taiwan's industrial sector, which in turn fuels development in the service sector. From 1952 through 1980, the annual growth rate of commodity and labor exports averaged 16.5%, while local demand grew an average of 10.97% per year. During the second stage of economic development, commodity and labor exports grew 10.05% per year, while local demand grew 7.51%. From these figures, the importance of foreign trade to Taiwan's economic development can be seen quite clearly.

Although Taiwan enjoyed sustained economic growth, full employment, and low inflation for many years, in 2001, Taiwan joined other regional economies in its first recession since 1949. From 2002 to 2007, Taiwan's economic growth ranged from 3.5% to 6.2% per year. With the global economic downturn, Taiwan's economy slumped into recession in the second half of 2008. Its real GDP, following growth of 5.98% in 2007, rose 0.73% in 2008 and contracted 1.93% in 2009. The economy began to recover in 2010 and the GDP grew remarkably by 10.88% in 2010.[14] Some economic performance indicators of Taiwan from 1978 to 2010 are provided in Table 1.

[12] http://www.cepd.gov.tw/m1.aspx?sNo=0014790&ex=2&ic=0000153
[13] http://www.gio.gov.tw/info/taiwan-story/economy/edown/3-5.htm
[14] http://www.traveldocs.com/tw/economy.htm

	Economic Growth Rate	Per capital GDP	Unemployment Rate	Value of Export	Exchange Rate
	%	USD	%	USD	NTD/1USD
1978	13.49	1,599	1.67	12,755	36.94
1979	8.01	1,943	1.27	16,169	36.00
1980	7.32	2,385	1.23	19,878	36.78
1981	6.46	2,730	1.36	22,686	37.79
1982	3.97	2,703	2.14	22,297	39.86
1983	8.32	2,902	2.71	25,207	40.22
1984	9.32	3,219	2.45	30,580	39.42
1985	4.07	3,290	2.91	30,819	39.8
1986	11	4,007	2.66	39,931	35.45
1987	10.68	5,265	1.97	53,754	28.5
1988	5.57	6,146	1.69	60,784	28.12
1989	10.28	7,558	1.57	66,435	26.17
1990	6.87	8,124	1.67	67,425	26.88
1991	7.88	9,016	1.51	76,563	25.7
1992	7.56	10,625	1.51	82,122	25.37
1993	6.73	11,079	1.45	85,957	26.62
1994	7.59	11,982	1.56	94,300	26.16
1995	6.38	12,918	1.79	113,342	27.22
1996	5.54	13,428	2.6	117,581	27.44
1997	5.48	13,810	2.72	124,170	32.52
1998	3.47	12,598	2.69	112,595	32.16
1999	5.97	13,585	2.92	123,733	31.34
2000	5.8	14,704	2.99	151,950	32.96
2001	-1.65	13,147	4.57	126,314	34.94
2002	5.26	13,404	5.17	135,317	34.71
2003	3.67	13,773	4.99	150,601	33.92
2004	6.19	15,012	4.44	182,370	31.68
2005	4.7	16,051	4.13	198,432	32.78

	Economic Growth Rate	Per capital GDP	Unemployment Rate	Value of Export	Exchange Rate
	%	USD	%	USD	NTD/1USD
2006	5.44	16,491	3.91	224,017	32.55
2007	5.98	17,154	3.91	246,677	32.39
2008	0.73	17,399	4.14	255,629	32.81
2009	-1.93	16,353	5.85	203,675	31.98
2010	10.88	18,588	5.21	274,601	30.32

Table 1. Economic Outlook of Taiwan, 1978-2010

However, behind this image of economic achievement, the level of economic development varies significantly from one region to another (Hou, 2000). Taiwan is typically divided into five geographic units—North, Central, South, East and the outlying islands (Figure 1). The northern region with Taipei at its center is the most urbanized and populated. The central and southern regions, punctuated by a few major cities, have been predominantly agricultural, but are now rapidly becoming industrialized. The eastern region, known for its rugged coastal landscape and poor accessibility, remains largely excluded from major development. The outlying islands have also been excluded from economic development. In terms of population, the northern region accounted for 44.63% of the national population of 23.05 million in 2010. In particular, Taipei City and Taipei County together have more than a quarter of the entire population in Taiwan (28.26%). The southern region and the central region have 27.91% and 24.99%, respectively. The eastern region only has 2.47%.

Regional socioeconomic differences are clearly noticeable through comparisons of household income between counties and cities. With the exception of highly urbanized Taipei, Hsinchu, and Taoyuan Counties where many of Taiwan's high-tech firms are located, the average disposable household income is consistently lower than that of the major urban areas. The average family income in the poorest area, Yunlin County, is only 54.24% of the average income in Hsinchu County, and only approximately half of that of Taipei City in 2009 (49.35%).

Concentration of firms corresponds with the regional population breakdown. Almost 46.7% of firms are located in the northern region, while 26.1% and 24.3% of firms are located in the southern and central regions, respectively. The eastern region and the outlying islands account for less than 3%. Besides, patterns of GDP per capita and concentration of firms largely correspond with the urbanization and industrialization of the area. The counties with higher percentages of employment in agriculture, fisheries, and mining, and with a larger area of cultivated land tend to have lower GDP per capita. Administrative resources at the county level also largely correspond to the wealth of the regions. Table 2 provides some economic outlook of four major cities in Taiwan.

3.3 Environmental Change

In the past 100 years, Taiwan experienced an island-wide warming trend (1.0-1.4ºC/100 years). The warming in Taiwan is closely connected to a large-scale circulation and surface air temperature (SAT) fluctuations, such as the "cool ocean warm land" phenomenon. The water vapor pressure has increased significantly and may have resulted in a larger temperature increase in summer. The probability for the occurrence of high temperatures has increased and the result suggests that both the mean and variance in the SAT in Taiwan have changed significantly since the beginning of the 20th century. Although, as a whole, the precipitation in Taiwan has shown a tendency to increase in northern Taiwan and to decrease in southern Taiwan in the past 100 years, it exhibits a more complicated spatial pattern. The changes occur mainly in either the dry or rainy season and result in an enhanced seasonal cycle. The changes in temperature and precipitation are consistent with the weakening of the East Asian monsoon (Hsu and Chen, 2002).

More specifically, the annual mean temperature in Taiwan increased significantly during the past century and especially in the past 50 years; the trend of the annual mean minimum temperature was statistically more significant than that of the annual mean maximum temperature (Lai and Cheng, 2010). Only a few studies have been conducted regarding trends in the annual mean maximum temperature, the annual mean maximum temperature, and their differences in Taiwan; furthermore, differences in air temperature changes between urban and rural areas have not been closely discussed. These two subjects are both interesting and important. The daily mean air temperature cannot exactly reflect temperature changes throughout each day, because it is an average of the daily maximum and minimum temperatures. Therefore, the average temperature may underestimate the number and duration of high-heat events.

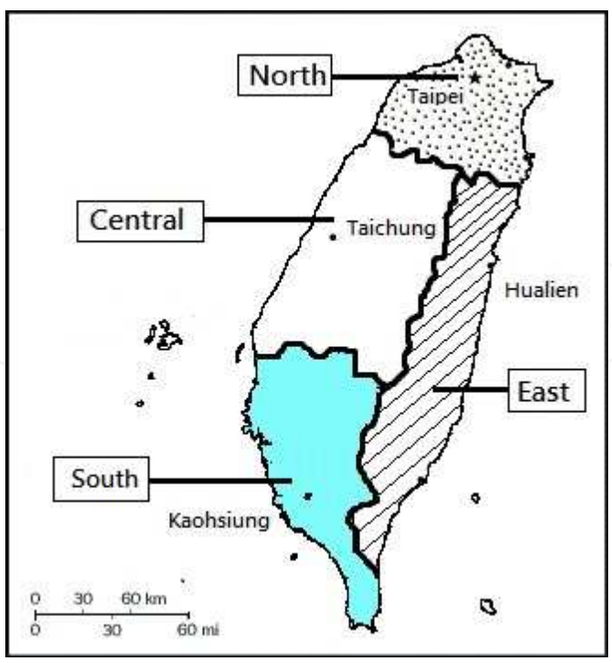


Figure 1. Major geographical areas in Taiwan

	Taiwan			Taipei (North)			Taichung (Central)			Kaohsiung (South)			Hualien (East)		
	DI	UR	UA	DI	UR	UA	DI	UR	UA	DI	UR	UA	DI	UR	UA
1998	231.6	2.6	12.3	331.3	2.6	100.0	231.0	2.6	22.2	226.1	3.1	13.9	213.3	2.8	1.8
1999	244.9	2.9	12.3	336.7	2.9	100.0	250.9	3.1	22.2	235.7	3.7	13.9	209.1	3.7	1.8
2000	246.3	3	12.3	338.2	2.7	100.0	229.3	3.4	22.2	240.1	3.9	13.9	226.2	3.9	1.8
2001	242.6	4.6	12.4	339.3	3.9	100.0	234.2	4.9	22.2	239.3	5	13.9	227.0	5.1	2.7
2002	240.0	5.2	12.5	357.2	4.6	100.0	223.2	5.4	22.5	228.3	5.5	14.0	201.0	5.5	2.7
2003	249.8	5	12.5	365.7	4.6	100.0	237.9	5.3	22.3	237.5	5.3	14.0	220.8	5.3	2.7
2004	254.6	4.4	12.5	380.5	4.2	100.0	224.2	4.6	22.3	249.8	4.6	14.0	236.7	4.8	2.7
2005	261.6	4.1	12.5	392.4	3.9	100.0	232.4	4.2	22.3	260.0	4.2	14.1	228.5	4.4	2.7
2006	267.8	3.9	12.5	378.0	3.7	100.0	246.3	4.1	22.6	259.6	4.1	14.1	256.6	4.2	2.7
2007	273.3	3.9	12.5	389.1	3.7	100.0	261.4	4	22.6	279.5	4.1	14.1	247.3	4.1	2.7
2008	272.7	4.1	12.6	386.3	4	100.0	244.9	4.2	22.6	268.9	4.3	14.1	227.1	4.2	2.7
2009	265.8	5.9	12.7	387.1	5.8	100.0	238.2	5.9	22.6	265.9	5.9	14.2	223.0	5.9	2.7
Average 1998-2009	254.3	4.1	12.5	365.2	3.9	100.0	237.8	4.3	22.4	249.2	4.5	14.0	226.4	4.5	2.5

Table 2. Economic Outlook of Taiwan and Four Major Cities in Taiwan, 1998-2009

Notes: 1. DI is the disposable income per capita, measured in NTD$1,000.

2. UR is the unemployment rate (%).

3. UA is the percentage of urbanized areas (%).

According to the analysis in the Statistics of Climate Changes in Taiwan, recently published by the Central Weather Bureau (CWB), the average temperature in Taiwan of the last 100 years has increased 0.8ºC, with an increase of 1.2ºC in flat area, 1.4ºC in urban area, 0.9ºC over western suburban area, 1.3ºC in eastern suburban area, 0.6ºC for mountain area, and 1.1ºC at outlying islands. In urban areas, the increased minimum temperature (2.1ºC) is three times that of the area's maximum temperature (0.7ºC), which indicates that the increase of night-time temperature is greater than in day time. In terms of the season, the amplitude of temperature increase is larger in spring and autumn.

There are slight changes in the trend of precipitation in the last 100 years in Taiwan. Northern flat area appears to have more rainfall, especially in autumn; while southern Taiwan and mountain area get less rainfall, especially in winter. A decrease in raining hours indicates that the precipitation intensity (precipitation per unit time) has increased. Except in mountain area, the number of days with precipitation over 30 mm has increased over the last 100 years.

4. Empirical Design

4.1 Interest of Data

The purpose of this study is to understand how and to what extent environment changes affect economic growth in Taiwan. The indicators of environment changes used in this study include temperature, precipitation and ozone level (O3).

The existing literature provides significant amounts of evidence that the change of temperature and rainfall will affect economic output.[15] Such evidence also suggests that climate change should affect economic growth. If climate change affected only the level of economic output, for example, by reducing agricultural yields when temperature rises (precipitation falls), this would imply that subsequent temperature decreases (precipitation increases) – due, for example, to stringent abatement of emissions – should return the GDP to its previous level. But this is not the case if climate change affects economic growth. Koubi et al. (2010) provide the following two reasons. First, economic growth will be lower even if GDP returns to its previous level because of forgone consumption and investment due to lower income during the period of higher temperature (lower precipitation). In addition, as long as countries spend some resources to adapt to climate change, they incur opportunity costs in terms of not spending these resources on R&D and capital investment. This has negative effects on economic growth. Moreover, given the short time-series data used in existing research on climate effects on economic conditions, even slightly persistent effects on the level of output will impact on the sample mean of growth. That is, using economic growth rates will also capture the effects on GDP levels. But using the level of GDP instead of its growth rate may miss the effects on the growth rate. For these reasons we concentrate on climate change effects on economic growth.

[15] For instance, Mendelsohn et al., 1998; Mendelsohn, Dinar & Williams, 2006; Nordhaus & Boyer, 2000; Tol, 2002; Deschenes & Greenstone, 2007.

In addition to the change of temperature and precipitation, we also consider ozone concentrations. Although the ozone layer in the upper atmosphere is beneficial, preventing potentially damaging electromagnetic radiation from reaching the earth's surface, ozone in the lower atmosphere is an air pollutant with harmful effects on the respiratory systems of animals and will burn sensitive plants. The increase in ozone is of further concern because ozone present in the upper troposphere acts as a greenhouse gas, absorbing some of the infrared energy emitted by the earth. Quantifying the greenhouse gas potency of ozone is difficult because it is not present in uniform concentrations across the globe. However, the most widely accepted scientific assessments relating to climate change (e.g., the Intergovernmental Panel on Climate Change Third Assessment Report) suggest that the radiative forcing of tropospheric ozone is about 25% that of carbon dioxide. However, tropospheric ozone is a short-lived greenhouse gas, which decays in the atmosphere much more quickly than carbon dioxide. Because of its short-lived nature, tropospheric ozone does not have strong global effects, but has very strong radiative forcing effects on regional scales.

The data in this study are mainly collected from the 30 observation stations of the Central Weather Bureau (CWB), and the Directorate-General of Budget, Accounting and Statistics.

4.2 Trend and Correlation Analyses

In this subsection, we will investigate the relationship between environmental changes and economic development in Taiwan and its four major cities. Taipei City has been considered the cultural, economic and political center of Taiwan; it is also the largest city in northern Taiwan. Taichung City, a city of mixed commercial and industrial activities, is the largest city in central Taiwan. Kaohsiung, the largest city in southern Taiwan, has been the heavy industry center of Taiwan. Hualien, located in eastern Taiwan, is the smallest of the four cities, and agriculture is its major economic activity.

From Figure 2.1, it is obvious that the mean temperature in Taiwan increased during the period of 1952-2010. For example, it was 22.75^{o}C in 1955, 23.14 ^{o}C in 1975, 23.25 ^{o}C in 1995, and 23.73^{o}C in 2005. However, the standard deviation of 12 months per year is smaller (Figure 2.2). It can be further explained by the trends of the maximum and minimum temperatures (Figure 2.3). The figures also indicate that the maximum mean monthly temperature (Tmax) and the minimum mean monthly temperature (Tmin) increased in Taiwan, and that the rate of increase for Tmin was higher than that for Tmax. Thus, TDiff decreased significantly (Figure 2.4). In most areas in Taiwan, Tmin increased more than Tmax, inducing an obvious reduction in TDiff and a smaller variation (standard deviation) over the past years.

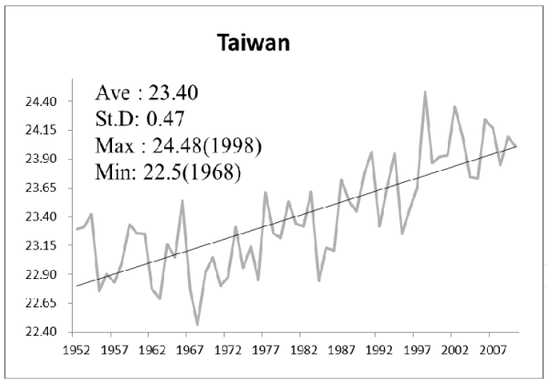


Figure 2.1. Trend of Temperature

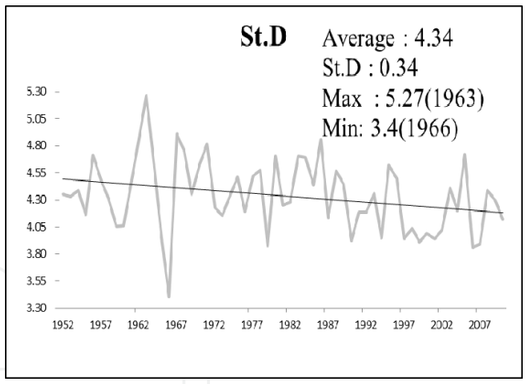


Figure 2.2. Variability of Temperature

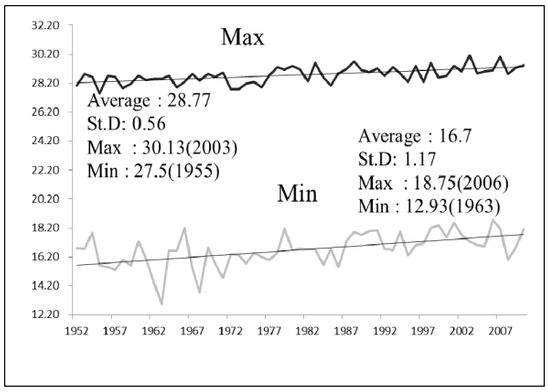


Figure 2.3. Temperature Extremes

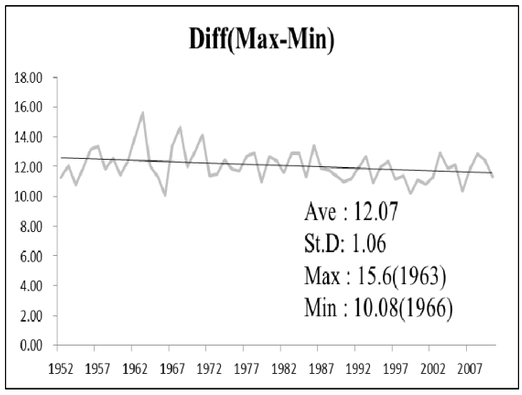


Figure 2.4. Gaps of Temperature Extremes

In addition, interesting patterns were observed among different regions and cities. The mean monthly temperature was higher in southern Taiwan than in northern Taiwan, and lower at higher altitudes than at low altitudes (Figure 3.1 – Figure 3.4). Besides, the rates of Tmax increase in rural regions (e.g., Hualien 5.09%, 1952-2010) were greater than those in urban regions (e.g., Taichung, 3.18%, 1952-2010), but the rates of Tmin increase in rural regions (e.g., Hualien 5.71%, 1952-2010) were lower than those in urban regions (e.g., Taichung, 6.88%, 1952-2010). In comparison to the urban regions, Tmax increased more significantly in rural regions. Thus, the trends of Tmax and Tmin in Taiwan were not only associated with global warming, but also with local climate change; in addition, human activities also played considerable roles. Lai and Cheng (2010) argue that urban development influences local climate by changing the land-surface characteristics. For example, compared to rural areas, an urban area is characterized by lower wind speeds, fewer hours of sunshine, lower visibility, larger turbidity and a higher daily mean temperature. It is also a fact that the amount of anthropogenic greenhouse gas concentrations has increased steadily in the past 40 years, which in turn has very likely caused the global average temperature to increase rapidly.

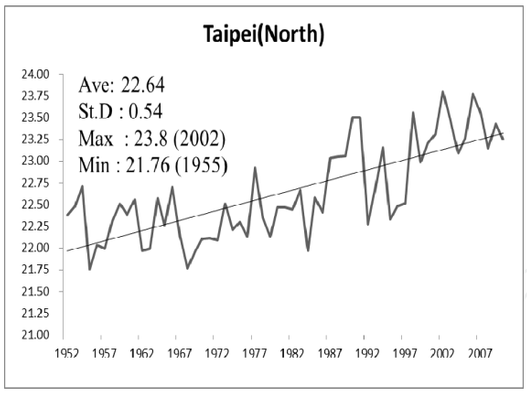


Figure 3.1. Temperature Trend in Taipei

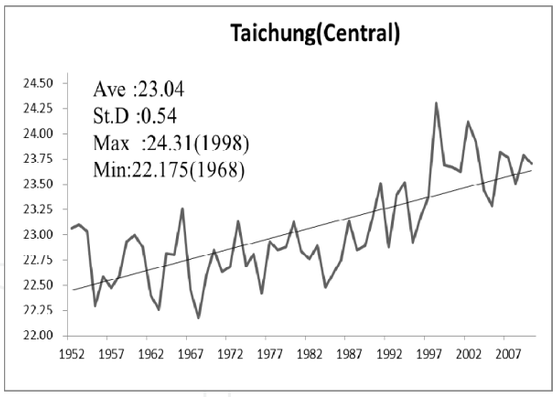


Figure 3.2. Temperature Trend in Taichung

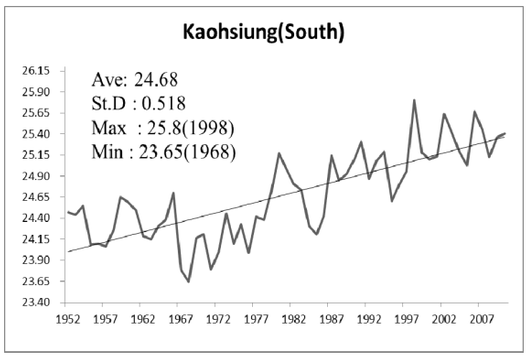


Figure 3.3. Temperature Trend in Kaohsiung

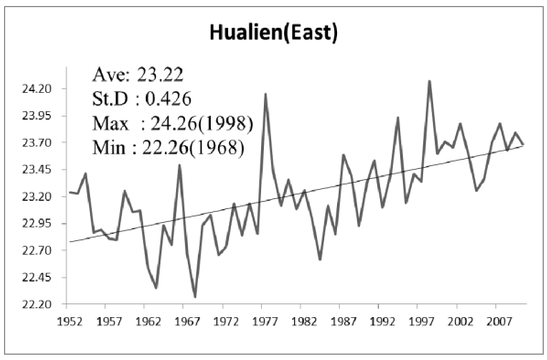


Figure 3.4. Temperature Trend in Hualien

As for precipitation, the main stream of the northward-moving Kuroshio Current passes up the eastern coast of Taiwan, thus bringing in warm and moist air. Summer and winter monsoons also bring intermittent rainfall to Taiwan's hills and central mountains. Figure 4.1 indicates that the mean monthly precipitation in Taiwan also increased from 1952 to 2010, at an average of 163.4 millimeters (mm) per month. However, unlike the trend of temperature, the variability of monthly precipitation per year has become larger (Figure 4.2). More importantly, the minimum monthly rainfall has not changed too much in the past 50 years; therefore, the variation mainly comes from the variability of the maximum monthly precipitation (Figure 4.3 – Figure 4.4).

From Figure 5.1 – Figure 5.4, we can see that the mean precipitation was much higher in northern (Taipei) and eastern Taiwan (Hualien) but lower in southwest Taiwan (Taichung and Kaohsiung). More rain falls in the mountains than in the plains, on the east coast than on the west coast, and on the windward side of hills than on the leeward (sheltered) side. The north has rain all year round while the south is rainy in summer and dry in winter. In winter, when the northeastern monsoon system is active, the north is constantly visited by drizzle while the south remains dry. However, in summer when the southwestern monsoon comes in force, afternoon thunderstorms and typhoons carry heavy rains to central and southern Taiwan. This intensive and concentrated summer rainfall, which constitutes up to 80% of annual precipitation, often causes flooding and landslides. As northern Taiwan has

more rainy days than the south, the variability of rainfall slightly increases as it moves toward the south.[16]

Tropospheric ozone (O3) is a global air pollution problem and an important greenhouse gas. In large areas of the industrialized and developing world, ground-level O3 is one of the most pervasive of the global air pollutants, with significant impacts on human health, food production and the environment. Economic losses for South Asia are estimated to be in the region of US$ 3.9 billion per year for 4 staple crops (wheat, rice, soybean and potato) in Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. The largest losses are found in India (US$ 3.1 billion), Pakistan (US$ 0.35 billion) and Bangladesh (US$ 0.4 billion).[17] Figure 6.1 – Figure 6.5 show the O3 concentrations in Taiwan and its four main cities from 1998 to 2010. The trend of O3 concentrations also shows increases in Taiwan. Additionally, the average parts per million (ppm) of O3 concentrations increases as it moves toward the south, whereas the least developed eastern area, Hualien, has the lowest O3 concentrations.

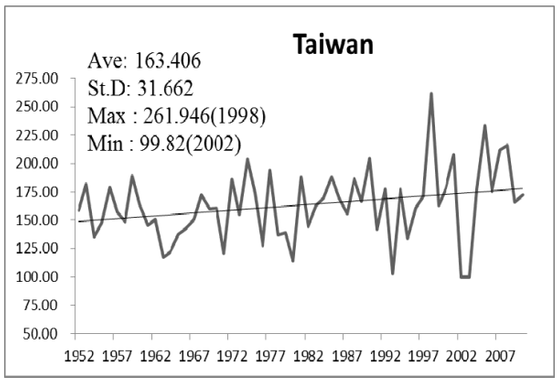


Figure 4.1. Trend of Precipitation

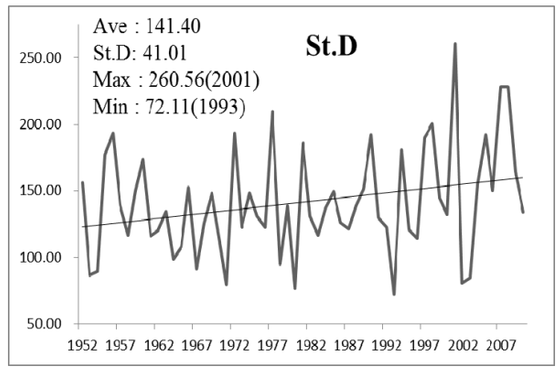


Figure 4.2. Variability of Precipitation

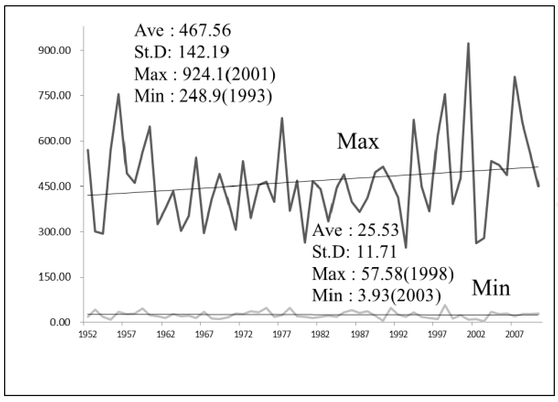


Figure 4.3. Precipitation Extremes

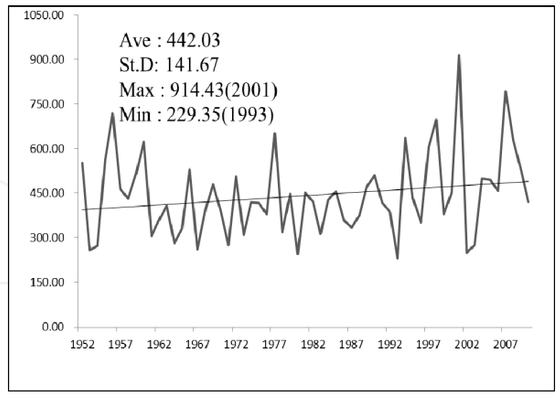


Figure 4.4. Gaps of Precipitation Extremes

[16] http://twgeog.geo.ntnu.edu.tw/english/climatology/climatology.htm
[17] http://seiinternational.org/mediamanager/documents/Publications/Climate/food_security_ozone_climate_policybrief.pdf.

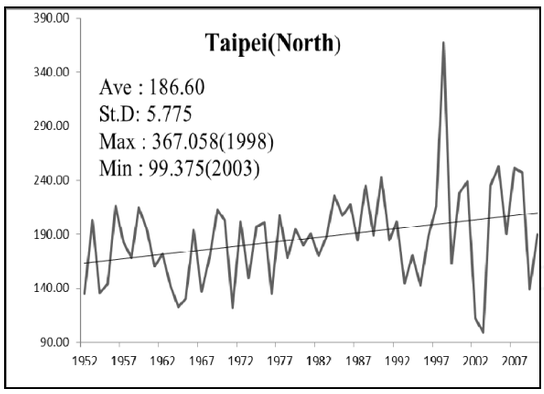


Figure 5.1. Precipitation Trend in Taipei

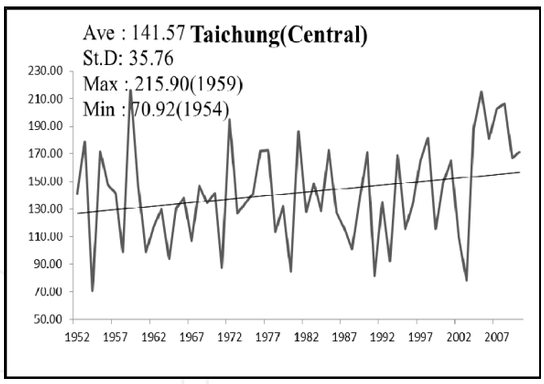


Figure 5.2. Precipitation Trend in Taichung

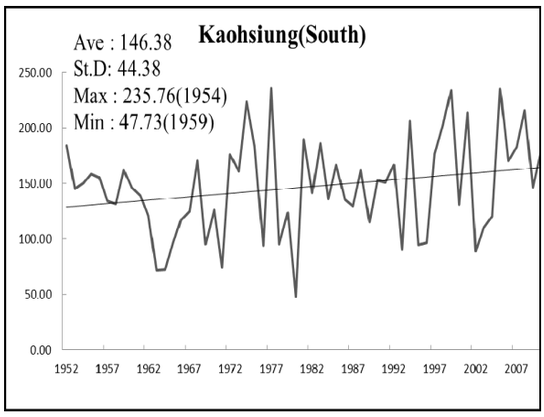


Figure 5.3. Precipitation Trend in Kaohsiung

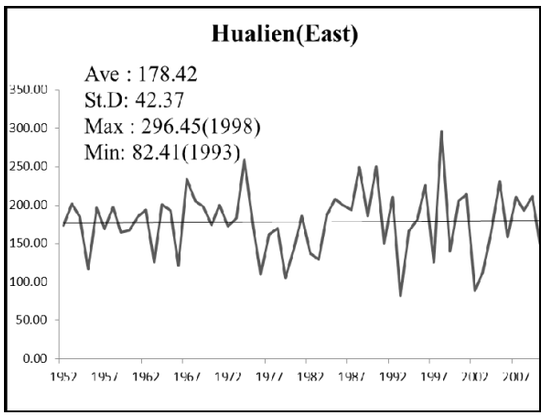


Figure 5.4. Precipitation Trend in Hualien

The correlation analyses of environmental changes and economic growth are presented in Table 3 – Table 7. From Table 3, we can find that the correlation coefficient of temperature and economic growth is negative (-0.469), implying that these two variables are negatively correlated. It still remains the same if we only focus on the agricultural sector (-0.354) or the manufacturing sector (-0.226). However, the variability of temperature shows positive values as well. As we mentioned earlier, since the variation of temperature becomes smaller as time goes by, it could be the reason why we observe this outcome. If we look at the results in different areas, with the exception of Taichung city, the three other main cities also have an inversely correlated relationship between temperature and economic growth (Table 4).

	Overall Economy (1952-2010)	Agricultural, forestry, fishery and husbandry sectors (1982-2009)	Manufacturing sector (1982-2009)
Temperature	-0.469	-0.354	-0.226
Variability (St. D)	0.212	0.453	0.193

Table 3. Correlation Coefficients of Temperature and Economic Growth in Taiwan

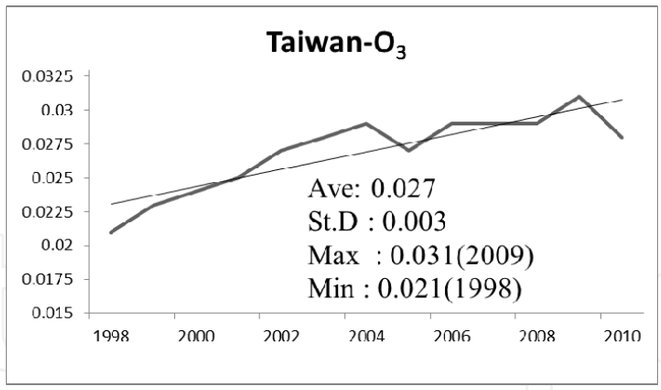


Figure 6.1. Trend of Ozone Concentrations

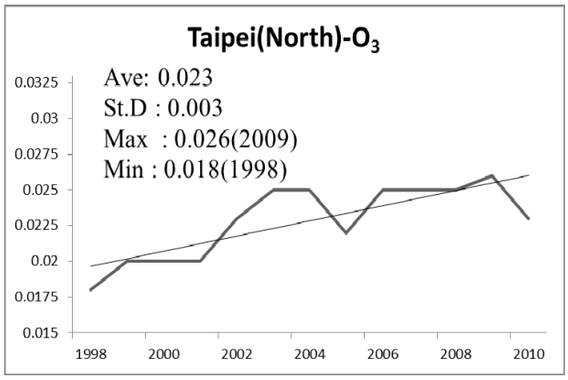


Figure 6.2. Trend of Ozone in Taipei

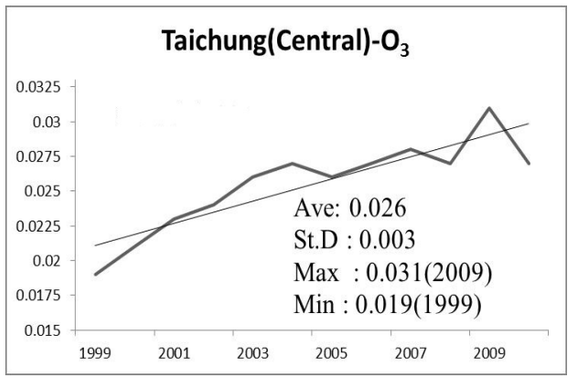


Figure 6.3. Trend of Ozone in Taichung

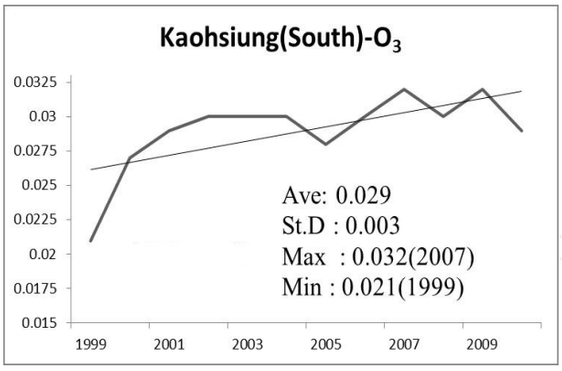


Figure 6.4. Trend of Ozone in Kaohsiung

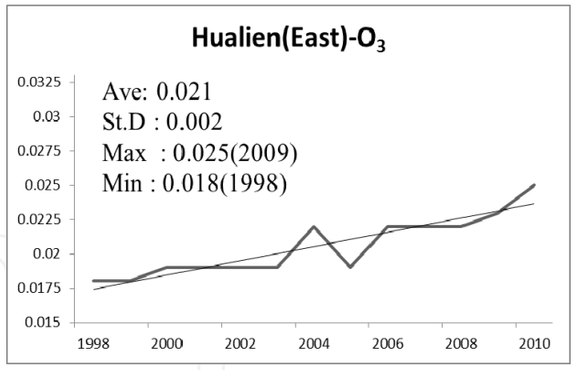


Figure 6.5. Trend of Ozone in Hualien

	Taipei (North)	Taichung (Central)	Kaohsiung (South)	Hualien (East)
Temperature	-0.061	0.118	-0.214	-0.309
Variability (St. D)	0.117	-0.132	0.053	-0.234

Table 4. Correlation Coefficients of Temperature and Economic Growth in Four Major Cities
Note: The study periods are 1999-2009.

On the other hand, the correlation coefficients of precipitation have some differences from those of temperature analyses. First, in Table 5, the correlation coefficient of precipitation and economic growth is negative (-0.365), implying precipitation level is negatively correlated to economic growth; and it still remains a negative sign in the agricultural sector (-0.343) and the manufacturing sector (-0.281). Second, variability of precipitation is inversely correlated to economic growth (-0.42), indicating that higher variability of rainfall is more likely to come with lower economic growth. Third, except for Kaohsiung City (south), the results still indicate that higher precipitation level and variability are negatively related to economic growth in three other major cities in Taiwan (Table 6). Furthermore, the correlation analyses of ozone concentrations are shown in Table 7. It also demonstrates that ozone level and economic growth have negative correlation in Taiwan, and in the four different major cities.

	Overall Economy (1952-2010)	Agricultural, forestry, fishery and husbandry sectors (1982-2009)	Manufacturing sector (1982-2009)
Precipitation	-0.365	-0.343	-0.281
Variability (St. D)	-0.42	-0.376	-0.429

Table 5. Correlation Coefficients of Precipitation and Economic Growth in Taiwan

	Taipei (North)	Taichung (Central)	Kaohsiung (South)	Hualien (East)
Precipitation	-0.157	-0.176	0.154	-0.03
Variability (St.D)	-0.147	-0.369	0.129	-0.19

Note: The study periods are 1999-2009

Table 6. Correlation Coefficients of Precipitation and Economic Growth in Four Major Cities

	Taiwan	Taipei (North)	Taichung (Central)	Kaohsiung (South)	Hualien (East)
O3	-0.195	-0.241	-0.083	-0.017	-0.018

Note: The study periods are 1999-2009.

Table 7. Correlation Coefficients of Ozone and Economic Growth in Taiwan

From the correlation analyses above, we can conclude that the temperature, precipitation and ozone concentrations are inversely correlated to economic growth in Taiwan. In

addition, not only the level, but also their variability has the same inverse correlation to economic growth.

5. Conclusion

Understanding the impacts of environmental changes on the nation's economy is, obviously, of paramount importance for both the mitigation of environmental change and the development of adaptation policies. This is a preliminary study to investigate how the environment in Taiwan has changed in the past years, and how it is related to economic growth in Taiwan. This study, first, collects a set of long-term data of temperature, precipitation and ozone concentrations in Taiwan and its four major cities. By observing the data, we find that the temperature in Taiwan significantly increased during the period of 1952-2010; however, the temperature variability within a single year becomes smaller. On the other hand, the mean monthly precipitation in Taiwan also increased during the same period, but unlike the temperature, the variability of monthly precipitation becomes larger. More importantly, the minimum monthly rainfall has not changed significantly in the past 50 years; therefore, the variation mainly comes from the variability of the maximum monthly precipitation. Besides, the trend of O3 concentrations also shows an increase in the past years, and the O3 level increases as it moves toward the south in Taiwan.

The correlation analyses demonstrate that the level of temperature, precipitation and ozone concentrations are negatively correlated to economic growth in Taiwan. Furthermore, the variability of precipitation is also found to be inversely related to the economic development, but we do not find the same result for temperature variability. Therefore, from this study, although environmental changes are shown to be inversely related to economic growth in Taiwan, the temperature, precipitation and ozone concentrations seem to have their own different ways to affect economic growth, not only from their level but from their variability. In order to investigate how and to what extent these environmental changes influence the economic development in Taiwan, a more comprehensive econometric model is suggested in the future.

6. References

[1] Aggarwal, P. K. (2003)Impact of Climate Change on Indian Agriculture, Journal of Plant Biology, Vol.30,No.2, pp.189–198.

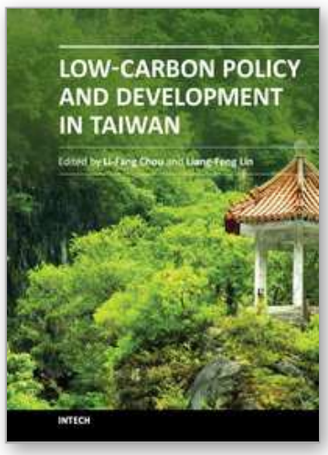
[2] Bächler, G. & K. R. Spillmann (1996). Environmental Degradation as a Cause of War, Regional and Country Studies of Research Fellows. Zürich: Verlag Rüegger.

[3] Deschenes, O. & M. Greenstone (2007). The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather, American Economic Review, Vol.97, No.1, pp.354-385.

[4] Dell, M., B. F. Jones & B. A. Olken (2008). Climate Shocks and Economic Growth: Evidence from the Last Half-Century, , National Bureau of Economic Research, No.14132.

[5] Dell, M., B. F. Jones& B. A. Olken (2009). Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates, American Economic Review Papers and Proceedings, Vol. 99, No.2, pp.198-204.

[6] Homer-Dixon, T. & P. Gizewski (1998). The Case of Pakistan, in Homer-Dixon, T., Blitt, J., (Eds), Ecoviolence: Links Among Environment, Population, and Security. Rowman and Littlefield, Lanham, pp.147-200.
[7] Homer-Dixon, T. (1999).Environment, Scarcity, Violence, Princeton, NJ: Princeton University Press.
[8] Hou, J. (2000)From Dual Disparities to Dual Squeeze: The Emerging Patterns of Regional Development in Taiwan Berkeley Planning Journal, Vol.14, No.1, pp.4-22.
[9] House of Lords (2005). The Economics of Climate Change, HL Paper 12-I, Select Committee on Economic Affairs 2nd Report of Session 2005-06, London.
[10] Hsu H. H. & C. T. Chen (2002). Observed and Projected Climate Change in Taiwan.Meteorology and Atmospheric Physics, Vol. 79, No. 1, pp. 87-104.
[11] Koubi, A, T. Bernauer, V. Kalbhenn,& G. Ruoff (2010), Climate Change, Economic Growth, and Civil Conflict, Climate Change and Security, pp.21–24
[12] Lomborg, B. (2001).The Skeptical Environmentalist: Measuring the Real State of the World, Cambridge: Cambridge University Press.
[13] Lai, W. L. & W. L.Cheng (2010). Air Temperature Change Due to Human Activities in Taiwan for the Past Century, International Journal of Climatology, Vol. 30, No. 3, pp. 432–444.
[14] Mendelsohn, R., W. Morrison, M. Schlesinger & N. Andronova (1998). Country-Specific Market Impacts of Climate Change , Climate Change, Vol. 45, No.3, pp. 553-569.
[15] Mendelsohn, R., A. Dinar & L. Williams (2006).The Distributional Impact of Climate Change on Rich and Poor Countries, Environment and Development Economics, Vol.11, No.2, pp. 159-178.
[16] Mendelsohn, R. (2009). Climate Change and Economic Growth, World Bank Working Paper 60.
[17] Nordhaus, W. & J. Boyer (2000).Warming the World: The Economics of the Greenhouse Effect, Cambridge, MA: MIT Press.
[18] Roson, R. & D.V. Mensbrugghe (2010). Climate Change and Economic Growth: Impacts and Interactions , Department of Economics, University Ca' Foscari of Venice Research Paper Series, No. 2010_07.
[19] Stern, D. I. (1996). Economic Growth and Environmental Degradation: The Environmental Kuznets Curve and Sustainable Development, World Development, Vol. 24, No.7, pp.1151-1160.
[20] Simon, J. L. (1998). Lebensraum: Paradoxically, Population Growth May Eventually End Wars, Journal of Conflict Resolution, Vol.33, No.1, pp.164-180.
[21] Shein, K. A., A. M. Waple, M. J. Menne,& J. C. Christy (2006). State of the Climate in 2005, Bulletin of the American Meteorological Society, 87: S6–S102.
[22] Schubert, R., H. Schellnhuber, N. Buchmann, A. Epiney, R. Grießhammer, M Kulessa, D. Messner, S. Rahmstorf & J. Schmidt (2009). Climate Change as a Security Risk, German Advisory Council on Global Change (WBGU) Flagship Report. Earthscan Publications Ltd.: London.
[23] Tol, R. (2002). Estimates of the Damage Costs of Climate Change-Part II: Dynamic Estimates, Environmental and Resource Economics, Vol. 21, No.2, pp.135-160.



Low Carbon Policy and Development in Taiwan

Edited by Dr. Liang-Feng Lin

ISBN 978-953-51-0156-7
Hard cover, 97 pages
Publisher InTech
Published online 24, February, 2012
Published in print edition February, 2012

Taiwan a typical small Asian country with few energy resources is well known for its high-tech industry in the last 20 years. However as a member of the global village Taiwan feels the responsibility to reduce carbon emissions. The book tells you how Taiwan transforms itself from a high-tech island to become a low carbon island. The book address Taiwan's low-carbon developmental policies of the past 10 years, applies an econometric approach to estimate Taiwan's sector department CO2 emissions, shows how environmental change affects the economic growth of Taiwan, and provides two successful examples of low-carbon pilot regions in Taiwan. Stephen Shen, the Minister of the Environment Protection Agency of Taiwan, believes that the book arrives at the right time, because this is the time to educate the people of Taiwan, about the necessary action for achieving a low carbon society.

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

IntechOpen