The Association of Academies of Sciences in Asia (AASA)

TOWARDS A SUSTAINABLE ASIA

GREEN TRANSITION AND INNOVATION

Science Press
Beijing

Springer

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ISBN 978-7-03-029168-4
Science Press Beijing

ISBN 978-3-642-16674-7 ISBN 978-3-642-16675-4 (eBook)
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2010937229

Cover design: Huabin Huang

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

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Synthesis Report of the AASA Project "Sustainable Development in Asia"

GREEN TRANSITION AND INNOVATION

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Abbreviations

AASA	The Association of Academies of Sciences in Asia
ADB	Asia Development Bank
ADRC	Asian Disaster Reduction Center
ASEAN	Association of Southeast Asian Nations
BAU	Business as Usual
BFA	Boao Forum for Asia
BOD	Biochemical Oxygen Demand
BP	British Petroleum
CAS	Chinese Academy of Sciences
CASS	Chinese Academy of Social Sciences
CCS	Carbon Capture and Storage
CDIAC	Carbon Dioxide Information Analysis Center
CDM	Clean Development Mechanism
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CRED-EMDAT	Centre for Research on the Epidemiology of Disasters. Emergency Events Database
CTI	Coral Triangle Initiative
DSM	Demand Side Management
EIA	Energy Information Administration of the United States
EKC	Environmental Kuznets Curve
EV	Electric Vehicle
FAO	Food and Agriculture Organization of the United Nations
FASAS	Federation of Asian Scientific Academies and Societies
FDI	Foreign Direct Investment
G7	Canada, France, Germany, Italy, Japan, United Kingdom, United States (Group 7)
GDP	Gross Domestic Product
GEO	Global Environment Outlook
GHGs	Greenhouse Gases
HEV	Hybrid Electric Vehicle
IAC	InterAcademy Council
IAP	InterAcademy Panel
ICT	Information and Communication Technology
IEA	International Energy Agency

IGCC	Integrated Gasification Combined Cycle
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
IPM	Institute of Policy and Management, CAS
KP	Kyoto Protocol
LCD	Low Carbon Development
MDGs	Millennium Development Goals
MEP	Ministry of Environmental Protection, China
NIEs	Newly Industrialized Economies
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substances
OECD	Organization for Economic Co-operation and Development
OWP	Organic Water Pollutant
PCI	Per Capita Resource Consumption and Pollution Discharge Index
PM_{10}	Particulate Matter with Particle Size below 10 Microns
PNA	Palestine National Authority
PPP	Purchasing Power Parity
R&D	Research and Development
REPI	Resource and Environmental Performance Index
SO_2	Sulfur Dioxide
S&T	Science and Technology
SDA	Sustainable Development in Asia (AASA project)
TFP	Total Factor Productivity
TI	Index of Total Amount of Resource Consumption and Pollution Discharge
TSP	Total Suspended Particulate
TÜBA	Turkish Academy of Sciences
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNPD	United Nations Population Division
WB	World Bank
WCED	World Commission on Environment and Development
WDI	World Development Indicators
WHO	World Health Organization

Foreword

Asia is not only the largest and most populated continent in the world, but also the region with the most diverse development models and most dynamic economies. In the past half century, Asia has been witnessing rapid economic growth and playing an increasingly more important role in world's political and economic arena. At the same time, Asia has developed the commonly-called "Asia Model", which has attracted worldwide attention. The Asia Model shows a new way for the developing nations or late-development countries on how to realize industrialization and modernization. All these achievements are made by Asian countries with a focus on the advantages of their late development, re-examination of their internal cultural values, active absorption of modern S&T and management experiences and constant exploration and innovation.

These social progresses have made great contributions to the realization of the UN Millennium Development Goals and have played a pioneering and demonstration role on what can be accomplished in today's world. However, Asia is facing big challenges. The most prominent one is that the rapid development of Asian economies is based on large input of production factors at the huge expense of natural resources and environment, which has been sharpening the conflicts in population, resources, environment, socio-economic development. The sustainable development in the region is being severely threatened and challenged. The rethinking and questioning of the Asia Model in the international community is growing especially in the era of post Asia Financial Crisis and Global Financial Crisis.

It is not only a common challenge for the governments of Asian countries, but also a common task for the Asian scientific communities to cope with the resources and environment crisis and to seek a new way of sustainable development in Asia. AASA, as a non-governmental and regional international scientific organization with 26 member academies, is mandated to initiate and conduct investigation on issues concerning S&T, economic and social development. As early as April 2007, AASA proposed to initiate a project on "Sustainable Development in Asia" (SDA) within AASA framework in the hopes to provide consultation and advice for national and regional governments in Asia and relative international organizations. This study proposal was approved at AASA board meeting held in Russia in August 2007 with the Chinese Academy of Sciences as the initiator. The project covers environment, energy, resources and culture with the establishment of four working groups among AASA member academies.

Soon after, the SDA project was officially launched and implemented at different levels. The efforts include the clarification of the research content, emphasis, structure and division of tasks. Various meetings at the working level and international workshops have been held to coordinate the research activities and project progress: the first international workshop under this project was held in February 2008; the AASA Workshop on Sustainable Energy Development in Asia in November 2008; the AASA Workshop on Agricultural Culture and Asian Sustainable Development in August 2009; and the AASA Workshop on Environment and Resources in September 2009.

With the joint efforts of AASA member academies, the SDA project has now come up with a series of studies including four thematic reports, namely, "Towards a Sustainable Asia: Energy", "Towards a Sustainable Asia: Environment and Climate Change", "Towards a Sustainable Asia: Natural Resources", and "Towards a Sustainable Asia: The Cultural Perspectives" . Based on these four reports, a synthesis report has also been written entitled: "Toward a Sustainable Asia: Green Transition and Innovation". All these reports have looked deeply into the common issues and challenges for the Asian sustainable development from different perspectives.

The synthesis report is an integration and extension of the four thematic reports. It aims at the major resource and environmental challenges and issues in Asia in the general context of the challenges of financial crisis and climate change, and in line with green transition and innovation in Asia. Of its major findings, it includes: the diagnosis of key resource and environmental issues in Asia, such as water, minerals, land resource, environmental pollution, eco-degradation, energy and environment and climate change, the revelation and reflection of the diverse, different, complicated and severe nature of resource and environmental issues in Asia, the systematic analysis of the main driving forces and future trends of resource and environmental changes in Asia, the empirical analysis and discretion of current evolution of the relationship between environment and development in Asia with the establishment of theoretical and conceptual models, the initiation of principals, strategic framework, focus and advice for promoting the green development of Asia on the basis of summarizing Asia's advantages and disadvantages.

The synthesis report differs from other similar reports. It focuses more on the combination of theoretical and empirical research in the evolution of environment and development, on the combination of trends analysis in time series and comparative study at spatial scale, and on the combination of Asia's integrated analysis and regional and national differences. Besides, attempts have been made here on the innovative modeling of the evolutionary and theoretical relationship between environment and development, analysis of the driving forces in environmental evolution, and utilization of newly developed composite index to conduct empirical research of Asia's environment and development relation in the evolution.

We hope the reports will be of good value to the facilitation of the green development in Asia, providing advice on dealing with the shortage of conventional resources, environment pollution and climate change, fostering new economic growth and enhancing Asia's competitive advantages. This is the first time that AASA has ever undertaken such a study, and it surely leaves grounds for more detailed study and analysis of various issues and challenges that Asian countries face in the future.

The SDA project is sponsored by AASA. I want to give my special thanks to all AASA member academies for their consistent support, advice and assistance, without which, the accomplishment of such an internationally interdisciplinary scientific project would be impossible. My thanks also go to all the members in the working groups, especially Professors Namık Aras and Yi Wang, co-chairs of this study, without whom, efficiency and quality of the study would not be guaranteed. I also need to thank United Nations Environment Programme (UNEP), InterAcademy Council (IAC) and InterAcademy Panel (IAP) etc. for providing us the references and various advice and inspirations. Last but not the least, I want to express my thanks to all friends and the institutions that have rendered us encouragement and assistance all the way along.

The SDA project features with a wide range of fields and a huge amount of data, some of which are still in their early stage of development. Any comments or suggestions from our friends and various international institutions are warmly appreciated.

Prof. Jinghai Li

President

The Association of Academies of Sciences in Asia (AASA)

September 20, 2010

Preface

Since the 1960s, the ongoing fast growth in Asia has created the so-called "Asian Miracle", and hence the "Asian Development Model". However, this development model is now confronted with new challenges: ①Some Asian countries are losing their comparative advantages. ②This model has largely been achieved at the expense of resources and the environment, exacerbating conflicts between economic development and environmental protection in Asia. ③Asian countries are faced with many global issues such as climate change. The exterior environment for Asia has undergone significant changes since it suffered the Asian financial turmoil in 1997 and the global financial crisis in 2008. Fending off trade protectionism, boosting domestic demands and fostering new growth areas have become the top priorities for the Asian countries. For the Asian Development Model to maintain sustainable growth in the face of current and future challenges, it is critical to introduce innovations for the transition to a green development model.

Given these challenges, the Project of Sustainable Development in Asia (SDA) was approved by the Association of Academies of Sciences in Asia (AASA) in August 2007 and formally launched in February 2008. It aims to bring together the Academies of Sciences in Asia to address the common issues on sustainable development of the region, including sustainable energy development, sustainable use of resources, environmental protection, climate change, cultural and social sustainability, and ultimately to provide decision-making advice and policy recommendations for the government agencies in Asia and relevant international or regional organizations.

This project was initiated by AASA, involving the member academies under AASA. Since the inception of the project, it has organized four international workshops, such as the First Workshop of AASA project of Sustainable Development in Asia (February 2008, Beijing, China), Workshop on Sustainable Energy Development in Asia (November 2008, Beijing, China), Workshop on Environment and Resources in Asia (September 2009, İzmir, Turkey), and Workshop on Agricultural Culture and Sustainable Development in Asia (August 2009, Beijing, China). The SDA project conducted studies through thematic research, synthesis research and consultancy under the joint funding of AASA, IAC, IAP and member academies of AASA. Four thematic reports and one synthesis report have been produced after more than two years of hard work.

The Synthesis Report, titled "Towards a Sustainable Asia: Green Transition and Innovation", presents an integration of the outputs of the workshops and meetings, and the findings of four thematic reports with assessments of the major challenges and opportunities that the Asian Development Model is faced, as well as the major drivers and possible trends of the environmental and resources change in Asia. In addition, it discusses the theory of the evolutionary relations between environment and development in Asia and conducts empirical study in this regard. Finally, the significance, preconditions and development pathway for the green transition in Asia are clarified, and proposals are made on the principles, strategic framework, priorities and policy recommendations on green development in the region.

Distinct from other related international or regional reports, this Synthesis Report features "Three Integrations": ①Integration of theoretical and empirical studies. On the basis of developing conceptual framework, appropriate resource and environmental indicators are selected to conduct empirical study to validate the reliability and rationality of the findings. ②Integration of comparisons of temporal and spatial scales. While analyzing the future trend of relevant indicators or variants over time for different countries or areas in Asia the report also compares the differences between different countries and areas within Asia and between Asia and the rest of the world. ③Integration of similarities and differences in Asia. The report focuses on the overall trend of changes in Asia while presenting the spatial differences between/among various countries and areas in the region.

Structure and Major Exploration of the Report

The Synthesis Report consists of five chapters. It mainly features four innovation aspects:

(1) The report integrates such concepts and hypotheses as Intensity-of-Use Hypothesis, Environmental Kuznets Curve (EKC) Hypothesis, Decoupling and Dematerialization into the framework of three inverted U-shaped curves on the evolution of environment and development. It also divides the evolution of the relation between environment and development into four stages, while defining the major drivers at each stage.

(2) On the basis of analyzing the evolution of the relationship between environment and development in Asia and validating the theory of three inverted U-shaped curves, the report applies three composite indicators (i.e., REPI, PCI and TI) to quantitatively assess the REPI, PCI and TI of 63 countries worldwide, including 19 Asian countries between 1994 and 2007. This has not only revealed the position of the Asian countries in the world and their gaps with the countries in other regions, but identified the trend of these variables and their relationship with per capita GDP, indicating that improved

resources and environmental performance will rest with various factors such as technological change, institutional arrangement and economic restructuring.

(3) With the IPAT formula of environmental impact, the report examines the drivers of environmental change in Asia and the trend of these drivers, suggesting that the resources and environmental pressures will continue to grow in the future. The report concludes that only by taking strong actions and accelerating the green transition of Asia's economic development model can the energy security and environmental protection in the region be fundamentally improved.

(4) The report points out that enhancing resources and environmental performance provides the precondition and basis for Asia's green development and that green innovation is the key to ensuring green development in Asia. Lastly, by examining the evolutionary stages of the relationship between environment and development in Asia, together with the preconditions and opportunities for green transition, the report proposes the basic principle, strategic framework, focuses and priorities, as well as the policy recommendations for green development in Asia.

Acknowledgements

The report would not have been possible without the generous and varied contributions of many individuals and organizations from around Asia and also the world.

We would like to thank many experts from the member academies of AASA who have contributed their input and discussions. We also highly appreciate the reviews and advice and suggestions of this report from Prof. Namık K. Aras, Prof. Seung Mo Oh, Prof. Luguang Yan, Prof. Woojin Lee, Prof. Gensuo Jia, Prof. Cahit Helvacı, Prof. Lei Shen, Prof. Andrei V. Tabarev, Prof. Dr. Mehmet Özdogan, Prof. Baichun Zhang, Mr. Jinhua Zhang, and Ms. Ling Thompson, and Ms. Jung Ah Choi from the Secretariat of AASA for her close coordination and help.

Due to the limit of the report length, not all the findings have been included in the final text. The contents of the report can in no way be taken to represent the views of the government agencies which have provided financial assistance to the project or the research institutions to which the authors are affiliated. Comments and suggestions on the report are highly appreciated.

Study Group on Green Transition and Innovation

September 2010

Executive Summary

Transition of Development Model and Sustainable Development in Asia

Asia is increasingly becoming a major political and economic regional power with more important global influence after having experienced nearly half a century's rapid economic growth and surviving the impact of the regional and global financial crises. Since the 1960s, the rising and rapid development of Japan, East Asian Tigers, as well as emerging economies such as China and India, has created the so-called "East Asian Miracle" and "Asian Development Model". Although no unified cooperation model has been put in place for the Asian countries due to their differences in political, economic, cultural and resource endowment aspects, the process for regional economic integration is accelerating and will continue to play a critical role in leading the global economic recovery.

The success of an Asian development model does not necessarily mean that it is a paragon. This model is generally regarded to have been achieved by constantly expanding the scale of production with the input of various factors and by promoting exports with favorable policies. It was in the late 1980s and early 1990s that rethinking on the "East Asian Miracle" and "Asian Development Model" began. Particularly after the shock of the Asian financial crisis in 1997 and the global financial crisis in 2008, some long-standing conflicts and problems of the Asia's economic development model have become more prominent, posing unprecedented challenges on the sustainability of this model.

At present, the Asian development model is confronted with three major challenges: ①The external environment in Asia has undergone significant changes. Since the outbreak of the global financial crisis in 2008, export-oriented Asian countries have suffered from severe impacts amid the gloomy consumption markets and rising trade protectionism in European and American regions; ②The traditional comparative advantages of some Asian countries in economic development are diminishing with the gradual decrease in the workforce and rising resources and environmental costs, and the unsustainable over-dependency of their economic growth on the input of production factors; ③As Asia features a very limited carrying capacity of resources and environment, the extensive economic growth model has brought about a large number of resource and environmental problems while it has to address new challenges such as global climate change. As a result, Asia must seek new drivers, create new needs and change its development model to achieve sustainable development. Opportunities and challenges will co-exist in the next decade, which is identified as a key period for Asian countries to transform towards a new development model.

New development targets have to be defined firstly for the transition of the Asian development model. In the long run, in a bid to achieve stable and continuous growth of Asian economies and to take the lead in the post-financial crisis era in the global economy, Asian countries are required not only to address the environmental and resources problems, but to adjust the old economic structure, create new growth areas and enhance their competitiveness against a backdrop of evolving domestic and international situations. The transition of an Asian development model, therefore, has to be comprehensive, and a new model that is green, low-carbon, smart, innovative, cooperative, and inclusive needs to be created through system innovation. This will not only challenge the wisdom, courage, confidence and patience of Asian countries, but test the willingness of the Asian countries to work together and achieve a win-win situation.

Green Transition is Key to Transform the "Asian Development Model"

Green transition, or the transition towards a green development model, is a core component to addressing the above three challenges, as well as a realistic choice to transform the development model towards a sustainable Asia. In general, innovation is recognized as an essential tool to achieve green transition.

Green Transition

Legal, administrative and economic instruments are needed to achieve green transition and green development in Asia. It is also necessary for Asian countries to adjust the energy and economic structures, gradually transform the extensive economic growth model, establish a moderate consumption model and environment-friendly and equal trading pattern through technological change and innovation, so as to address sustainability issues in terms of resources, energy, environment and poverty reduction, to mitigate and adapt to climate change, and to ultimately achieve sustainable industrialization, urbanization and modernization in Asia. Transition towards a green development model will not only break through the bottleneck of limited environmental carrying capacity in Asia, meet the severe challenges of resources and environment in the region, but will keep in line with international development trends and promote a global sustainable development process.

The major tasks for green transition and green development in Asia include:

Giving top priority to tackling the scarcity of strategic resources and conventional environmental problems in Asian countries. Emerging economies and other developing countries in Asia are required to place top priority on constantly improving resources and environmental performance, secure the safety of freshwater, food, energy and major mineral resources supply, invest in environmental infrastructure; reduce pollutants discharge, speed up the process of environmental control under the framework of an international environmental regime, accelerate the efforts of surmounting the stage of intensive use of resources and energy and pollution discharge, halt the trend of deteriorating environmental quality in Asia, and achieve economic growth at a resource and environmental cost well below that of developed countries at the same stage of income level.

Addressing the long-term severe challenge of global climate change. It is of critical importance for Asian countries to implement low-carbon development strategies that fit in with their actual domestic conditions, develop long-term institutional arrangements and roadmaps to reduce carbon emissions, actively carry out international cooperation in a principle of "common but differentiated responsibilities", constantly improve energy use efficiency, gradually expand the use of low-carbon energy, develop low-carbon technologies and industries, attempt to decouple green development from greenhouse gas emissions to achieve the target of controlling global warming.

Creating new economic growth areas and enhancing the international competitiveness of Asia. Great efforts should be made to promote the green transition of Asia, seek new sources for cleaner and sustainable growth, integrate the advantage of developing countries in Asia as latecomers to innovation, develop green and emerging industries, create new jobs, conduct cooperation on green development, promote technological progress and enhance the green and low-carbon competitiveness of the products and industries, fend off trade protectionism and break through the "green trade barriers" set by the developed countries.

Green Innovation

While innovation has become a core component of development strategy for various countries worldwide, green innovation will serve as a key target for innovation, as well as the precondition for transforming towards green development in the future. A new technological and industrial revolution that is green, low-carbon, intelligent and sustainable is most likely to take place in the next one to two decades. As a core element driving the revolution, green innovation will define the future trend of innovation and the fundamental pathway of industry transition.

Innovation calls for the guidance of policy, which, in turn, will drive the birth of a new scientific and technological revolution. In the green development area, green technological development, green consumption market and green legislation and policies constitute the drivers of green innovation. In particular, environmental regulations and policies have a strong impact on green innovation. Environmental standards, environmental, financial and taxation policies, to some extent, can promote green technological innovation. Take the best practice in China during the period of the National Eleventh-Five-Year Plan (2006-2010) for example. It has made great strides in technological, equipment and engineering development in such areas as clean coal power generation, renewable energy, high-speed railway, and environmental protection. There is no doubt that China can make significant contributions to addressing climate change and sustainable development globally in the next decade and beyond if it follows the policy of energy efficiency and pollution reduction.

In the course of green innovation, different priorities need to be identified for different countries. This is because these countries have different conditions, and their issues to be addressed and their advantages in innovation also vary. Overall, as Asia has not completely broken away from the material-intensive stage, technological change will play a crucial role in reducing resource consumption and a negative environmental impact. The major task for green transition and green innovation in Asia, therefore, is to achieve stable and continuous reduction of environmental impact intensity, or to give top priority to improving resources and environmental performance.

Innovation does not only involve technological, but also institutional, policy, administrative, and even cultural dimensions. While institutional innovation and administrative innovation were often used to support technical innovation in the past, they should become major components of green innovation in the future. In addition, as green innovation involves a system engineering process, different innovation activities should enhance their interaction and coordination, strengthen cooperation in the context of open competition, and reduce the risk of technology change to generate system innovation and offer systematic solutions.

Challenges and Favorable Conditions for Green Transition in Asia

Despite the fact that the transition from the old to the new Asian development model is of great urgency and will bring with it opportunities for each country, it will only be achieved over a long period and at high cost.

Apart from the differences of various countries, the challenges for green transition in Asia are mainly reflected in the following two aspects: ①The dilemma between the development stage, the inertia of existing development model and international labor division pattern, and economic transition. As mentioned above, many Asian countries are still at the stage of energy and material intensification and industrialization, during which it is difficult to shift the trend of resources and energy intensification in the short term. Meanwhile, to meet the overwhelming needs of improving per capita income and raise living standards, these Asian countries are faced with severe challenges in achieving green transition in the course of fast growth and boosting domestic demand. ②Achieving green development calls for comprehensive transition in terms of policy, technical, administrative and cooperation aspects, as well as the tradeoff between different development and policy targets. As a result, an incremental process is needed to achieve overall improvement.

It should be noted that many favorable conditions have already been put in place for the green transition of Asia, including development foundations, opportunities and best practices. Asian countries should grasp the chances, fully leverage their own advantages, more proactively address the existing or potential challenges in sustainable development, innovate for the development concepts and explore appropriate development pathways and priorities to achieve sustainable growth, which is of great significance to promote the green transition of Asia. These favorable conditions include:

• Strong government commitment and political will. Highly efficient and powerful government is one of the major root causes for Asia's economic success, and also provides a strong basis for Asia's green development. More and more Asian countries have recognized the concept of green development and begun to put it into practice.

• The cultural tradition of hard-work and thrift. Asia's traditional culture that advocates diligence and frugality, and its emphasis on man and nature in harmonious coexistence has been playing a significant role in promoting East Asia's rapid economic development. It can also provide an important ideological and financial support for the green transition (including green development and green innovation) of Asia, shaping a moderate consumption model that is different from western countries and that meets the actual resources and environmental conditions and needs for energy conservation and pollution reduction in Asia.

• The largest potential green consumer market in the world. Whether tackling the resources and environmental problems and climate change, or addressing the financial crisis creates a huge demand and market for Asia to develop green economy while providing new opportunities for green innovation.

• Development of renewable and new energies. Relative abundance in renewable energies, such as hydropower, solar energy, wind power, biomass and geothermal energy, has provided favorable conditions for the development of green energy in Asia. So far, significant progress has been made in terms of renewable and new energy development in Japan, Rep. of Korea, China and India, among others.

• Increasing innovation capacity. With its strong technical human capital, increased investment in R&D and its innovation capacity, Asia has already acquired a leading position in R&D, application and industry development in terms of energy conservation and pollution control, electric vehicles and other low-carbon technologies.

• Best practices in sustainable development. Asian countries have developed different models and best practices that balance environmental protection and economic development according to their own conditions in the course of promoting sustainable development. These success stories can be shared within Asia.

• Increasingly open environment and enhanced regional cooperation. While an increasingly open environment has provided possibilities and opportunities for Asia to introduce state-of-the-art green technologies and expertise, learn from the best practices and reduce the costs of green transition, the expanding regional cooperation makes it possible for Asian countries to establish a sound bilateral and multi-lateral environmental cooperation mechanism, strengthen infrastructural development in energy and other areas, and facilitate technical cooperation in resources and environmental areas.

Policy Recommendations to Promote Green Transition and Green Development in Asia

To achieve green transition in Asia, some basic principles need to be followed: ①reaching a consensus to integrate the concept of green development with the practice of sustainable industrialization, urbanization, and informationization; ②adopting systematic concepts and comprehensive supporting measures to fully promote inclusive growth while taking into account regional differences; ③reforming the government's administration model to engage more stakeholders; and ④enhancing the regional governance capacity through practical cooperation.

In addition, priorities should be given to "four transitions": ①transition from a growth model that focuses on input of factors to one that combines innovation (in particular green innovation) and comparative advantages; ②transition from a development target system that only highlights economic indicators to one that is green-oriented and covers comprehensive indicators; ③transition from an energy structure that focuses on fossil fuels to one that is diversified and decarbonized; and ④transition from a cooperation model that depends solely on economic, technical and trade collaboration to a new one that shares the green responsibility and is based on mutual benefit and a win-win result. Hence, the framework of a green economy and green development at national, regional or global scales can be gradually established.

Specific policy recommendations are proposed as follows:

(1) Develop national strategies and action plans on green growth to guide and promote green transition.

Asian countries should consider mainstreaming green development into their national socio-economic development strategies and incorporate the concept of green development into various plans and policies; develop long-term goals and phased objectives on green development, define the development roadmap and priority action plans on green transition, build a resource-efficient, environment-friendly and low carbon-oriented economic development model and social system, advance economic development, create more jobs and enhance competitiveness mainly through green growth.

(2) Formulate a package of policies to promote green transition and achieve co-benefit of development and environment.

Efforts should be made to take into full consideration the targets in terms of resources, energy, environment, climate and development, develop cross-sector package policies, establish coordination mechanisms, consolidate relevant resources and build a favorable governance structure; promote the integration of administration and economic approaches, establish a long-term, stable incentive mechanism and institutional arrangement, and gradually decouple the economic development from resource and environmental pressure.

Priority should be given to developing a system of strategic impact assessment, as well as a rational price-forming mechanism on resources, energy and environmental factors. In addition, it is necessary to formulate incentive policies to advance the development of renewable and new energies, and establish a long-term price signal to encourage low-carbon development and environmental protection; gradually promote and ultimately establish a green taxation system through pilot projects on environmental, resource, energy and carbon taxes; strengthen environmental regulation through establishing a resources and environmental performance benchmark system for industries, a market access system for highly energy- and polluting-intensive industries and products, an extended producer responsibility system and green purchasing system for development of recycling-based economy, promote the green transition of industries and create a green consumption market.

(3) Invest in green technologies and develop a green technology innovation system.

Asian countries are required to strengthen financial and policy support for the R&D of green technologies, and implement key S&T programs on green development; coordinate the existing R&D projects on energy conservation, environmental protection and low-carbon growth, establish an S&T roadmap on green development, develop key green technologies and technology clusters, focus on commercialization pilot projects and engage more enterprises in this process; engage the private sector in the R&D of green technologies through Public-Private Partnership (PPP) to establish a diversified, multi-source, green technologies investment system that engages the government, enterprises and the general public. In terms of the specific R&D of green technologies, different Asian countries should develop and deploy low-cost, alternative technologies (especially low-carbon, resource and energy-saving, renewable energy technologies) that are suitable to be disseminated to developing countries in Asia, and highlight the integration of information and communication technology (ICT) and energy conservation and environmental protection technologies.

(4) Accelerate the development of green and emerging industries that contribute to energy conservation and environmental protection through industrial, investment and financing policies.

It is important for Asian countries to develop green and emerging industries that are consistent with their actual conditions; foster new economic growth areas, enhance industry competitiveness in environmental protection and low-carbon development, and create new jobs by developing relevant industry plans, standards and policies (including investment and financing policies); wisely deploy and strengthen regulation on the emerging industries, avoid malicious competition and overcapacity, and ensure the healthy development of emerging industries, focusing on the development of such industries as new energy, electric car, energy efficiency and environmental protection; actively promote the development of green service industries, including green finance, emission rights trading, management and maintenance of environmental protection facilities, corporate carbon management advice; and achieve the greening of the overall industrial system through the joint efforts of government, market and business from a long-term perspective.

(5) Implement proactive policies on population control, and reduce the number of poor people.

Asian countries should develop forward-looking population policies that fit in with each Asian country's actual socio-economic conditions and that take into account the population growth and future aging trend, control population numbers, provide necessary social security and healthcare services, and reduce the adverse effect of population growth on resources and the environment; and take various measures to reduce poverty and achieve the Millennium Development Goals (MDGs).

(6) Further develop human resources, and innovate education and training models that adapt to green transition.

Efforts should be made to further develop human resources and improve the skills of the population and labor force to provide human capital for green development; reform the existing education and training system, develop labor force re-training and re-employment plans and policies, and establish an open training models, train professionals in skills that are urgently needed by green and emerging industries, expedite the transfer of the labor force from outdated industries and enterprises to emerging ones, and wisely deploy the labor force; and help to establish partnerships between education & training institutions and the labor force sector.

(7) Explore a green consumption model that fits in with the resource and environmental conditions, and establish green consumption.

Asian countries are encouraged to promote the long-standing cultural tradition of being thrifty, and disseminate concepts of respect for and living in harmony with nature; explore a green consumption model that is feasible in future technical and economic conditions, raise awareness of the government, business and the general public on greenness and environmental protection through education, training and public participation, and encourage consumption behaviors that contribute to energy conservation, low-carbon and environmental protection; guide and promote green consumption by strengthening demand side management (DSM) and developing relevant policies and regulations; and take the lead in implementing actions on energy conservation and pollution reduction to promote a green consumption model.

(8) Establish regional partnership on green development, and implement multi-level actions on green cooperation.

Asian countries are required to establish a regional dialogue mechanism, partnership or alliance on green development, leverage their own advantages through joint action plans, share the best practices, jointly conduct R&D to achieve a win-win situation; give top priority to strengthening dialogue, communication and cooperation in renewable energy development, regional resource security, intelligent transport network and regional environmental quality, define the obligations and responsibilities of each party, and develop and implement joint programs according to each country's advantage in terms of funding, technology and human resource in order to jointly advance the green transition of Asia; innovate the cooperative model, establish the Asia Green Transition Fund, explore an appropriate regional technical R&D and transfer mechanism, accelerate the technology transfer process within Asia, and learn from the best practices of developed countries to improve the resource and environmental performance in the region.

It is also necessary for Asia to enhance capacity building in terms of resource and environmental monitoring, early-warning and emergency systems, develop an information sharing platform, carry out integrated surveys on resources and the environment, jointly crack down on illegal deforestation, trading of wild endangered species and trans-boundary transfer of electronic wastes, and establish an emergency cooperation mechanism on addressing cross-border pollution incidents; expand and reinforce the communication network between and among different government agencies and non-governmental organizations (NGOs) within Asia, establish a regular communication mechanism, constantly improve the governance capabilities and jointly create a pathway towards a sustainable Asia.

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1 Asia's Economic Development and Rethinking on its Development Model

1.1 Asia's social and economic development

As the largest and most populous continent, Asia[1] has already become an important political and economical power worldwide. Over the last half-century, the fast growth of Asian economy, the rise of emerging economies and the rapid recovery from the financial crisis have been the important phenomena in the course of global economic development. In addition, quite a few scholars hold that in the multi-polarized world structure Asia is becoming the third economic, even political or military center which can compete against the United States and Europe (Zbicz et al., 2009), and it has aroused widespread attention all over the world. The growing impact of Asia's economy and politics in comparison to that of western countries has mainly benefited from the economic boom after World War II (WWII).

The rise of Asian economy has attracted worldwide attention. Since 1960s, Japan, East Asian Tigers, Thailand, Malaysia, Indonesia, the Philippines, together with other emerging economies such as mainland China and India, have created the "miracle" of high growth rate of Asian economy. It is worth mentioning that since 1950, the annual average economic growth rate of a total of 13 emerging economies in the world has reached or exceeded 7 percent for a quarter of a century or even longer, among which 10 emerging economies are from Asia (Table 1.1) and another two emerging economies—India and Vietnam—are marching towards it. From 1987 to 2004, the global GDP per capita (in purchasing-power-parity terms) grew by close to 1.7 percent annually, while the economic growth rate of Asia and the Pacific is twice of the global average growth rate (Commission on Growth and Development, 2008). Thus, it has laid the position for Asia as the most dynamic region of the world economy and made a great contribution to the global economic growth, including the

1 Please refer to Appendix A for more details on the spatial scope definition and sub-regional categorization of "Asia" in this report.

recovery of Asian and even the world economy after the heavy blow of the financial crisis.

Asia's economy is getting more and more important, which makes a more and more multi-polar world economic structure. Based on expected trends by IMF, within five years Asia's economy (including Australia and New Zealand) will be about 50 percent larger than it is today (in purchasing-power-parity terms), account for more than a third of global output, and be comparable in size to the economies of the United States and Europe. By 2030, Asian gross domestic product (GDP) will exceed that of the Group of Seven major industrial economies (G-7) (Singh, 2010). Now that Asia is becoming the leading powers of world economy, the center of world economic growth is unavoidably shifting from the west to the east, though Asia has to face the challenges, such as transforming growth model, implementing financial reforms and coping with international capital flows.

Table 1.1 10 success stories of sustained, high growth in Asia

Country/Region	Period of high growth[2]	Per capita income at the beginning (constant 2000 US$)	Per capita income in 2007 (constant 2000 US$)
China	1961-2008	105	1,812
Hong Kong,China[1]	1960-1997	3,100	34,041
Indonesia	1966-1997	200	1,038
Japan[1]	1950-1983	3,500	40,719
Rep.of Korea	1960-2001	1,100	15,158
Malaysia	1967-1997	790	5,008
Oman	1960-1999	950	9,978
Singapore[1]	1967-2002	2,200	29,185
Taiwan,China	1965-2002	1,500	17,926
Thailand	1960-1997	330	2,592

Note:

1. Economies that have reached industrialized countries' per capita income levels
2. Period in which GDP growth was 7 percent per year or more

Source:

Compiled from Commission on Growth and Development, 2008; World Bank (2010)

Social progress in Asian areas is similarly remarkable and it is the key region to achieve the Millennium Development Goals (MDG) set by the UN. With the rapid growth of Asia's economy, its social development has achieved noticeable advances, and its social services capability has been increasingly strengthened, making a huge contribution towards the millennium development goals (Table 1.2), and to a certain extent playing a pioneering role with demonstration effect.

There is a noticeable decline in the population growth of Asian areas and a steady increase of the living standards. Since WWII, the total fertility rate of Asian areas has dropped from 5.5 in 1950 to the present 2.2, which is below the world average of 2.6, and the average life expectancy at birth has increased by about 28 years. Currently, the male and female life expectancy in Asia is 66.6 and 70.7 years, and both are above the world average, which are 65.4 and 69.8 years, respectively (UNESCAP, 2010). However, the disparity of population development between regions is quite considerable. For instance, in Japan, Hong Kong China, Rep. of Korea, and Singapore, demographic transition has been completed, fertility rate is on the steady decline, average life expectancy is constantly prolonged, and the aging problem is emerging in some countries, whereas some countries such as India, Pakistan, Cambodia, Bangladesh, the Philippines in East Asia and Southeast Asia, demographic transition has not been completed yet, fertility rate remains high, and the population is still in the phase of fast growth.

As the region most concentrated by the poverty-stricken people (accounting for over 60 percent of the world's poor population), Asia's poverty alleviation is highly effective, and there is a dramatic decrease of the poor population. East Asia is the most successful region in its poverty eradication, among which China, Vietnam have been playing leading roles in poverty reduction. From 1981 to 2005, the proportion of extreme poor population to the total population of East Asian region slumped from near 80 percent to 18 percent, which is mainly attributed to the tremendous achievements of China in poverty eradication. The percentage of the Chinese people who live under the poverty line fell from 60.2 percent in 1990 to 15.9 percent in 2005. Being one of the poorest regions in the world, South Asian countries' poverty rate also dropped from 60 percent in 1981 to 40 percent in 2005.

Asian countries have kept increasing investment in human capital and gradually improved the educational level and population quality. Compared with other developing countries, the Asian population's educational level is relatively higher. From 1965 to 1985, the secondary and higher education enrollment growth rate in East Asia was above that of any other regions of the world. Although Asia is currently the home to two thirds of the world's adult illiterates, the penetration rate of elementary education has been on the steady increase. For example, both the net enrollment rate of secondary education and the adult literacy rate in East Asia and Central Asia are much higher than the world average. From 2000 to 2007, the gross enrollment ratio of higher education in the Asia-Pacific region rose from 13 percent to 21 percent (UNESCAP, 2010). The relatively better educational level of the labor force has provided an abundant human capital for the development of Asian economy.

The manpower resources for science and technology in the Asia have been constantly expanded and the scientific and technological input has been constantly increased. From 2002 to 2007, the total number of the scientific research personnel had increased by 1.43 times, its share of the world increased from 35.75 percent to 41.4 percent, and its growth rate exceeded the world average. Many Asian countries have constantly enlarged the dimensions of investment, including information technology, biotechnology and nanotechnology. From 2002 to 2007, Asia had increased more expenditure on research and development (R&D) activities than any other regions in the world, its proportion to the world rose from 27.1 percent to 32.7 percent, among which China's increase of R&D expenditure is particularly outstanding. In 2007, Asian economies' total expenditure on R&D activities exceeded that of the United States and Europe: Japan, Rep. of Korea, Singapore and China's expenditure on R&D activities accounted for over 1 percent of their GDP, and the scale of R&D expenditure has been on a steady rise since 1999; other economies such as India, Turkey, Pakistan, Hong Kong China have had a steady increase in R&D expenditure, but their respective percentage of GDP is not over 1 percent yet (UNESCAP, 2010).

The constant enhancement of Asia's S&T innovation ability can be seen in the fact that the number of patent applications, and the total patent grants and the number of scientific and technical journal articles are all increasing rapidly. From 1995 to 2007, the number of Asian patent applications had increased at 4.8 percent per year, almost the same as the world average increase rate. The number of patent applications in Asia maintained between 40 percent and 45 percent of the total number of the world, mainly focused in China, Japan and Rep. of Korea (more than 90 percent). During the same period, the average growth of Asia's total patent grants is about 7.1 percent, among which the average growth of total patent grants in China, Japan and Rep. of Korea is 7.8 percent, over the world average of 5 percent. The proportion of the total patent grants to the world increased from 42 percent in 1995 to 53 percent in 2007, among which China, Japan and Rep. of Korea increased from 36 percent to 49 percent. From 1990 to 2005, the number of scientific and technical journal articles in seven Asian countries (Japan, Singapore, Rep. of Korea, Israel, India and China) had increased by 6 percent per year, surpassing the world average of 3 percent. The proportion of the total number of scientific and technical journal articles to the world rose from 13 percent to 21 percent.

Besides, Asian regions have achieved remarkable results in the prevention and control of epidemic diseases, health care, public health, environmental infrastructure construction and other fields of public services. For instance, from 1990 to 2006, its population with access to improved drinking water sources increased from 74 percent to 88 percent in Asia-pacific region (UNESCAP, 2010).

Table 1.2 The main indicators of millennium development goals in Asia and the pacific in 2007

	Indicators	2007					
		East and Northeast Asia	Southeast Asia	South and Southwest Asia	North and Central Asia	Asia and the Pacific	World
Goal 1-eradicate extreme poverty	Population living below 1.25 USD (2005 PPP) a day (%)	15.4(2005)	/	38.4(2005)	9.9(2005)	25.3(2005)	26.2(2005)
Goal 2-achieve universal primary education	Adult literacy rate (Percent of population aged 15)	94	91	65	99	82	84
Goal 3- promote gender equality	Women to men ratio in employment	85	71	41	97	65	/
Goal 4-reduce child mortality	Infant mortality rate (Deaths per 1,000 live births)	18	27	57	25	41	47
	Under-five mortality rate (Deaths per 1,000 live births)	21	34	75	28	53	68
	Prevalence of underweight children (percent of children under 5)	7.1	23.1	41.2	5.0	27.9	23.7(2005)
	Immunized against measles(Total, %)	94	84	73	98	81	81
	Immunized against DPT3 (%)	93	84	71	96	80	81
Goal 5-improve maternal health	Maternal mortality (Number)	9,149(2005)	34,503(2005)	190,816(2005)	1,739(2005)	237,199(2005)	543,342(2005)
	Maternal mortality (Deaths per 100,000 live births)	48	303	463	59	313	406
	Pregnant women receiving antenatal care coverage (Four visits, %)	66.4(2005)	46	/	/	/	/
	Pregnant women receiving antenatal care coverage (One visits, %)	89.7(2005)	89	69	79	/	78.7(2005)

Continued

	Indicators	2007					
		East and Northeast Asia	Southeast Asia	South and Southwest Asia	North and Central Asia	Asia and the Pacific	World
Goal 6-combat HIV/ AIDS, malaria	Adults aged 15 and above living with HIV/AIDS (Female, Numer)	206,100	525,700	951,500	254,400	1,960,400	14,519,000
	Adults aged 15 and above living with HIV/AIDS (Total, Number)	713,600	1,556,700	2,563,200	995,600	5,901,500	29,334,100
	Adults aged 15 and above living with HIV/AIDS (Aged 15-49, %)	0	0	0	1	0	1
	Malaria incidence (Per 100,000 population)	8(2006)	404(2006)	161(2006)	/	171(2006)	1,427(2006)
	Malaria reported cases (Number)	127,664(2006)	2,265,751(2006)	2,717,685(2006)	/	6,885,677(2006)	94,056,464(2006)
	Malaria reported deaths (Number)	38(2006)	2,910(2006)	1,791(2006)	/	5,425(2006)	162,773(2006)
	Tuberculosis prevalence (Per 100,000 population)	182	271	261	124	224	209
	Tuberculosis incidence (Per 100,000 population)	95	213	161	113	140	141
	Tuberculosis DOTS detection rate (%)	77	77	68	51	72	66

Continued

	Indicators	2007					
		East and Northeast Asia	Southeast Asia	South and Southwest Asia	North and Central Asia	Asia and the Pacific	World
Goal 7-ensure environmental sustainability	Proportion of land area covered by forests (%)	22	46	14	40	30	30
	Carbon dioxide emissions(Million tons of CO_2)	8,008(2006)	1,046(2006)	2,448(2006)	1,975(2006)	13,890(2006)	28,432(2006)
	Carbon dioxide emissions per capita (Tons of carbon dioxide)	5(2006)	2(2006)	1(2006)	9(2006)	3(2006)	4(2006)
	Carbon dioxide emissions per unit of GDP (PPP) Grams per 1,000 (2005 PPP dollars)	703	463	503	908	646	481
	Consumption of ozone-depleting substances per capita(ODP kilograms per 1,000 population)	20.2	5.8	3.1	7.2	10.1	11.0
	Consumption of ozone-depleting substances per unit of GDP (2005 PPP) ODP kilograms per 1,000,000 (2005 PPP dollars)	2.6	1.4	1.0	0.7	1.8	1.4
	Protected marine areas (Square kilometers)	26,089	87,778	8,861	85,087	1,688,115	3,270,051
	Protected marine areas (Percent of territorial water)	2.6	1.5	1.9	6.3	2.2	4.0
	Protected land areas(Square kilometers)	1,732,023	1,732,023	412,425	1,678,627	5,402,779	17,985,769
	Protected land areas(Percent of surface area)	13.8	8.4	5.1	7.4	8.8	11.7
Goal 8-develop a global partner	/	/	/	/	/	/	/

Source:
UNESCAP, 2010

1.2 Asia's economic development model and its rethinkings

1.2.1 The causes for the Asian Economic Miracle and the Asian Model

1.2.1.1 Basic factors for the Asian Economic Miracle

During the past decades, the rise and success of Asia's economy have been due to multiple factors. Early in 1993, the World Bank believed that the major reasons for East Asian Miracle consist of a stable macroeconomic development, high saving rate and investment rate, high quality of human capital, the bureaucracy system that appoints people by abilities, lower inequality of income distribution, export promotion, successful industrialization, direct foreign investment and the transfer of relevant practical techniques, and also pointed out that the solid basic conditions, international economic integration and good government are the key factors for the success of East Asia (World Bank, 1993).

In *Commission on Growth and Development* (2008), five striking points of resemblance for the success are revealed based on a close look at the 13 cases (including 10 Asian economies), of which are fully exploiting the world economy, maintaining macroeconomic stability, mustering high rates of saving and investment, letting markets allocate resources, and having committed, credible, and capable governments.

For the Asian economies, there are other factors including the direct foreign investment, the transfer of knowledge and the resource flows. Of all the factors, open economy, social inclusiveness and effective government are the most crucial ones for promoting economic growth successfully. It can be seen from different research that there is high uniformity in the summarized reasons for Asia's high economic growth.

1.2.1.2 Features of Asia's economic development model and its implication

Compared with Europe and North America, Asian countries are quite different in nature, history, nations, culture, economy and politics, which determine the diversity of development in Asian region. In terms of natural endowments, natural conditions are varied in various countries, resource distribution is unbalanced, and population carrying capacity is with much disparity. In terms of human dimension, multi-nationality, multi-religion, and multi-culture coexist, with the contradictions in different degrees. In terms of economy, there is a conspicuous gap between economic development in different countries or regions, and they are also at different stages of development and have both developed economy and emerging economy, for example, Japan is quite developed, but Afghanistan and Nepal are of the poorest developing countries in the world (Table 1.3). Since the Cold War, the countries and regions at different economic development stages both complement each other and compete against each other; the countries and regions with different political systems cooperate with each other and differ from each other; the countries and regions with different cultural traditions have both dialogues and contradictions (Chen et al., 2008).

Table 1.3 Classification of Asian economies[1]

Low income	Lower middle income	Upper middle income	High income
Afghanistan	Armenia	Kazakhstan	Bahrain
Bangladesh	Azerbaijan	Lebanon	Brunei Darussalam
Cambodia	Bhutan	Malaysia	Cyprus
India	China	Oman	Hong Kong, China
DPR of Korea	Georgia	Russia[2]	Israel
Kyrgyzstan	Indonesia	Turkey	Japan
Laos	Iran		Rep. of Korea
Mongolia	Iraq		Kuwait
Myanmar	Jordan		Macao, China
Nepal	Maldives		Qatar
Pakistan	Philippines		Saudi Arabia
Tajikistan	Sri Lanka		Singapore
Timor-Leste	Syrian Arab Republic		United Arab Emirates
Uzbekistan	Thailand		Taiwan, China
Vietnam	Turkmenistan		
Yemen	Palestine (West bank and Gaza)		

Note:

1. According to the income grouping in 2008 by World Bank.

2. Here Russia as a whole country is analyzed (the same as below)

There is much disparity and diversity in the development of Asian countries, but just as discussed above, Asia's economic growth does have some common features. Due to the constant rapid growth of economy in East Asia since WWII, the "East Asian Model" has been acclaimed by some international organizations, experts and scholars, and its discussion can also be found in many reports and articles (World Bank, 1993; Naisbitt, 1996; Chen, 2003). At the same time, as a choice taken by developing countries to speed up the modernization, this development model is quite different from development strategies, political and economical systems of western developed countries. Since the appearance of the financial crisis in East Asia, this development model, including its theoretical foundations, its values, and its universal significance and sustainability, has been challenged (Krugman, 1994; Pettis, 2009). It is certain that either the East Asian model or the Asian model is constantly developing and dynamic. Nevertheless, it is still worthwhile to summarize the achievements and experience of the Asian countries, particularly after the global financial crisis since 2008.

The rapid growth of Asian economy is spread from the take-off of Japan's economic upsurge to the other Asian countries and regions. From the 1960s to the 1990s, Asia's, especially East Asia's economic development began to take on "Flying Geese Pattern" in its spatial dynamics. Japan is the leading geese of this pattern, thus playing a crucial role in promoting the economic development of East Asia; Rep. of Korea, Singapore and other new industrial countries and regions form the middle part of the pattern; and the rear section is China and some ASEAN countries. National comparative advantages that are complementary to each other and industrial gradient transfer have been the emerging foundation and driving force for the Flying Geese Pattern. With the rise of China, India, Indonesia, Rep. of Korea, Saudi Arabia and other emerging economies, this spatial pattern has changed, and its economic growth has presented a diversified situation.

The rapid rise of East Asia and its choice of development model have important implications for promoting economic growth of the whole Asia and even of the whole globe. In the common features of the East Asian Model, effective governmental interference, development of export-oriented economy, relatively higher rate of investment and savings and swift transition can be useful references for the other developing countries. In the course of pursuing industrialization and overtaking modernization, developing countries attach importance to advantage of late-development, reexamine the values of their own culture, combine modern science and technology with managerial experience and are brave enough to explore and innovate; and the successful experience is the result of their above efforts.

1.2.2 Challenges and rethinking on the Asian economic development model

The success of Asian economic development does not necessarily mean that this development model is infallible. As a matter of fact, any development model has its limitations and it does not remain the same as ever. It is the same with the Asian development model. Rethinking on the East Asia miracle started in the late 1980s and the early 1990s, and these studies reached the peak in the mid-1990s with the slowing economic growth of Thailand, Malaysia, Indonesia, and the Philippines (Stiglitz et al., 2000). Particularly after the Asian countries were swept by Asian financial crisis in 1997 and the global financial crisis in 2008, the long existing contradictions and drawbacks of the Asian economic development model are exposed, and its sustainability suffered from the unprecedented economic impact and challenges, which therefore triggered the scholar's challenging, reexamination and further exploration of the Asian Model, especially the East Asian Model (Stiglitz et al., 2000; Yusuf et al., 2003; Chen, 2003). One scholar even claimed that these two financial crises to a large extent had broken the Asian Model or announced the bankruptcy of the Asian Model (Pettis, 2009).

The explosion of the Asian financial crisis in 1997, to a certain extent, confirmed the viewpoints of those who were skeptical about the Asian miracles. As for the reasons of the Asian financial crisis, different scholars have different focuses, but they all expose the existing drawbacks and problems of Asian economic development, including the fragile financial system, the excessive debt of the company, insufficient supervision and control, ineffective management, the overcapacity of major manufacturing industries, as well as the lack of sound social security. For example, in some respect it is reasonable for a steady macroeconomy and industrial policies to be an important influencing factor for the rapid growth of Asian economy, but when it comes to the implementation of the policies, East Asian countries have been quite slow in risk management system as well as the supervision and control of the banks (Stiglitz et al., 2000), which is one of the major causes for the Asian financial crisis. Fortunately, the economic growth of the United States and some European countries, including the increase of import demand, provided the motive force for the recovery and rebound of Asian economy.

Since the Asian financial crisis, many Asian countries have eliminated the drawbacks of the banks and the financial system, and at the same time have had a flexible floating exchange rate system, thus strengthening the anti-risk ability of the system. In 2008, the global financial crisis arising from the Subprime Mortgage Crisis, led to the devaluation of the national currency in some Asian countries, but the whole financial system did not suffer much from the economic impact, therefore did not sink into monetary crisis, whereas the shrunken European and American market exerted a severe impact on the export-oriented Asian growth model. The Asian economic growth now faces the external environment and external driving forces that are totally different from the previous crisis. Meanwhile, the financial crisis is interwoven with global warming, resulting in the double global crises.

To Asia, especially East Asia, its previous advantages, such as a stable macroeconomy, open trades, the development of human capital, will still be the foundations for its sustainable development; however, its present weak points, such as the fragility of the financial department, the administration of the company, the institutional supervision and control, the management of the exchange rate and the inadequate social security network, must be dealt with properly (Yusuf et al., 2003). From a fundamental and longer perspective, the Asian economic development model has to confront the following three problems and challenges.

1.2.2.1 The problems faced by the Asian economic growth model

The rapid growth of Asian economy is mainly based on the massive investment of the essential factors of production, therefore its economic growth pattern is rather extensive, and its quality of economic growth is not good enough. The case studies of the East Asian economic growth indicate that, in the sources of East Asian economic growth, material capital is ranked in the first place, and then the labor force and the human capital, finally TFP. The TFP dedication of most East Asian countries and regions (except Japan) lags far behind G7 (Canada, France, Germany, Italy, the UK, the U.S. and Japan) (Table 1.4). Therefore, the real challenge that East Asian economy has to face is that it cannot rely on accumulating the factors to continuously drive the future economic growth, that is to say, TFP must play a more important role through innovation (Yusuf et al., 2003).

Early in 1994, the famous economist Paul Krugman once predicted that East Asian miracle was a fictional myth, just like a paper tiger, because the new industrial countries and regions in Asia, similar to the former Soviet Union, depended on a large extent on the massive labor force and the investment of the massive capital for their development, rather than improving TFP. That is to say, it is driven by the quantity, and not propelled by the quality or innovation. This kind of growth pattern is likely to collapse eventually like the former Soviet Union. The Asian financial crisis seems to offer the proof for the validity of his prophecy to a certain extent. Since launching the reform and opening-up policies in 1978, the contribution rate of capital and the labor force to China's economic growth is generally estimated to be 60 percent and 80 percent, while the contribution rate of TFP to China's economic growth is between 20 percent and 40 percent (Wang, 2005), which is less than the contribution rate of TFP in developed economies.

Table 1.4 East Asia's economic growth factors and their dedication to economic growth in comparison to the European countries (Unit: percent)

Periods & economies	Capital	Labor force	TFP
1950–1973			
France	32.0	6.0	62.0
Italy	32.0	4.0	64.0
Japan	33.7	27.2	39.1
The U.K.	53.3	6.7	40.0
Federal Republic of Germany	36.7	8.3	55.0
1960–1994			
Mainland China	41.3	36.0	22.7
Hong Kong, China	38.4	28.8	32.9
Indonesia	51.8	33.9	14.3
Rep. of Korea	51.8	30.1	18.1

Continued

Periods & economies	Capital	Labor force	TFP
Malaysia	50.0	36.8	13.2
The Philippines	55.3	55.3	−10.5
Singapore	54.3	27.2	18.5
Taiwan, China	48.2	28.2	23.5
Thailand	49.3	26.7	24.0

Source:
Based on Crafts, 1998

Meanwhile, the rapid growth of Asian economy is accompanied by the massive consumption of the energies and material resources as well as the discharge of pollutants. From 1980 to 2007, Asian GDP had been growing at 4.2 percent per year, but the consumption of common non-ferrous metal had been growing by 7.1 percent per year, with the consumption of finished steel by 7.2 percent per year from 1994 to 2007, primary energy consumption by 4.7 percent per year, and carbon dioxide emissions from fuel combustion grew by 5.2 percent per year. As the large country of resources and energy consumption in the world and Asian regions, from 1978 to 2008, China's GDP had increased by 15 times, its energy consumption nearly 4 times, its steel 21 times, its cement 22 times, and its rotation volume of freight transport 10 times, which intensified to a large extent the environmental pressure in the Asian regions (Chen et al, 2010).

The low overall quality of Asian economic growth is also manifested in the heavy cost of social development, including the huge income gap, the unequal distribution, and unsound social security system. Generally speaking, the income gap is supposed to be first large, then small, and have an inverted U shape with the increased economic development (namely, Kuznets curve hypothesis). The gap between GDP per capita of Asian countries seems to have gone through similar changes with the rapid growth of Asian economy. Take Japan, the richest country of Asian, and Nepal, the poorest one, for example, from the variation tendency of the income gap between them (in terms of the ratio of GDP per capita) (Figure 1.1) , it can be seen that before the mid-1990s, the gap between them was noticeably widened from 9 times in 1960 to the peak 206 times in 1995; after that the gap between them has a downward trend, which seems to indicate that economic development of Asian countries is at equilibrium, but still with the gap of 88 times. If we measure the unequal conditions by Gini index, since the beginning of the 1990s, inequality in Sri Lanka, Bangladesh, Nepal, Cambodia, Indonesia, India, China and other countries seems to be growing, particularly after China's reform and opening-up policies, the gap between the city and the countryside, between the east and the west, between the classes, are generally enlarged in the aspects of income, expenditure, education, and health, which poses a big challenge to economy, social security and welfare.

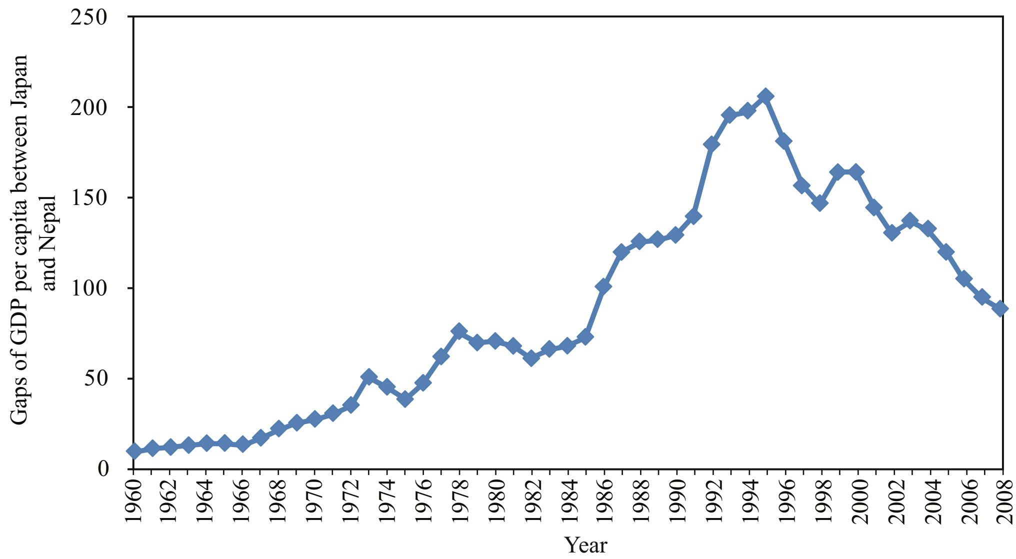

Figure 1.1 Gaps of GDP per capita between Japan and Nepal (1960-2008)

Poverty reduction still challenges the existing economic growth model. The overall level of economic development in Asia is rather low; the GDP per capita is only about half of the world average; the poverty-stricken people are large, and the task of poverty reduction is quite arduous. Asia's poverty alleviation has achieved remarkable results with the rapid growth of economic development, but in Asian regions, there still exists 60 percent of the world poor population, namely, the extreme poor population is 900 million. As the most poverty-stricken region of the world, South Asia's poverty rate falls a little; however, the number of people living in extreme poverty does not drop, but increases, for example, its poor population had increased from 470 million in 1981 to 550 million in 2005, and it is the only area of the Asian and Pacific regions whose total number of poor population grows (UNESCAP etc., 2010). The recent international financial crisis slowed down the pace of economic growth of Asian and Pacific economies, which means the increase of the poor population. Besides, estimated by the reports jointly issued by UNESCAP, UNDP and ADB, this financial crisis will result in the increase of at least 1.7 million extremely poor people who live under the poverty line of 1.25 USD per person per day in Asia (UNESCAP, etc., 2010). This will slow the efforts to implement the MDG. It is obvious that Asia will not be able to eradicate poverty with the present growth model which depends on the quantity. WCED (1987) incisively points out that poverty weakens human capability for sustainable use of resources. When people have no other alternative, the stress on the resources will be increased. Therefore, poverty reduction is the major task of sustainable development. Considering that a lot of demands have not been satisfied yet, sustainable development will still be given priority in Asian regions (UNESCAP, 2006). Once economic development stops, humans have to rely on the limited resources to improve their lives, and ecological stress will then turn into social and political stress (Commission on Growth and Development, 2008).

The aging problem of the Asian population is or will debilitate the potentials of long-term economic growth. With the constant improvement of living standards in Asian countries, the steady decline of total fertility rate and constantly prolonged life expectancy, the Asian population, especially the East Asian population is facing the threat of the aging problem. Similar to the Flying Geese Pattern of East Asian economic development, Asia has the Flying Geese Pattern of aging population. Japan is the first that has already entered into an aging society; Rep. of Korea, Hong Kong China, Thailand and mainland China immediately follow behind, and will step into aging society from 2010 to 2015. Demographic dividend is gradually disappearing, whereas demographic onus is constantly aggravated. Besides, other ASEAN countries (except Thailand) and India will successively step into aging society from 2020 to 2050 (Zhang, 2008).

This trend in Asian demographic structure will bring negative impact on Asia's economic growth by decreasing the supply of Asian labor force, increasing the expenditure of old-age pension insurance and other social security welfare, reducing the rate of savings, delaying the capital accumulation and decreasing the expenditure demand, and also weaken its potentials for long-term growth.

As the United Nations predict, between 2010 and 2015, in Asian regions, the percentage of the population between ages of 15 to 64 will reach 67.7 percent, the highest level of the world, and the best period of demographic dividend will come, and then the comparative advantage of low cost labor force in Asia will gradually disappear (UNPD, 2008). By that time the period of Asian economy when it sustains the rapid economical growth by depending on cheap labor force and labor-intensive enterprises will be over; sustainable economic development will face severe ordeals, and industrial transfer is imperative.

1.2.2.2 The challenges faced by Asia's export-oriented economy

The most striking feature of the Asian Model of economic development, particularly the East Asian Model of economic development, is export-oriented economy. It is the outcome of Asian countries' catching-up strategy which makes the use of comparative advantages, considering its relatively backward economic development in Asian countries. It resorts to the foreign capital, vigorously develops labor-intensive enterprises, earns foreign exchange through export, accumulates the capital for its economy, and thus realizes the take-off of Asian economy within the decades (Li, 2010).

Although some Asian countries have achieved high economic growth by depending on export-oriented strategy, its overreliance on export and foreign capital pull have determined that this development model is vulnerable to the fluctuations of the world market and other countries' economic development, including the economic risks and impact resulted from the rising prices of energies, iron ores, and raw materials. Two financial crises, which resulted in the sharp decrease of growth rate in Asia's newly industrialized economies and the marked rise of unemployment rate, lay bare the weakness of Asian export-oriented economy.

As to "Three Carriages" that pull the economic growth—namely, investment, expenditure and import & export, international trade and high investment rate have always been the important forces that fuel and stimulate the growth of Asian economy. The growth rate of international trade in the Asia-Pacific exceeds the world average, and currently this region covers about 34 percent of export trade of the global goods, with China and India accounting for two thirds of the ratio. As the major region of global FDI, Asia, particularly the massive consumption market of East Asia and India, makes it a magnet that attracts foreign direct investment. Moreover, with the enhancement of Asian manufacturing capability, its attraction to foreign investment is further strengthened. East Asia is not only the most open trade area, but also the biggest target for foreign direct investment (Gill et al., 2007). Meanwhile, the ratio of gross domestic investment in the Asian-Pacific regions to GDP has always been far above the world's for years, and up to now still maintains at over 30 percent (UNESCAP, 2010).

Since the overall economic level is relatively low, the low consuming capacity of the public has long been the weak spot of Asia's economic development (Yang et al., 2010), and the important factor for Asia's reliance on the demand of foreign market, especially the European and American market. The fast economic growth of Asia's newly industrialized economies is directly related to the leverage effect of the American market, namely, the newly industrialized economies earn the foreign exchange (USD) reserve by exporting to the United States, while the latter attracts the dollar-recycling by financial innovations, then transforms it into the American people's impetus for expanding or maintaining consumption through leveraging, and continues to import from Asia's newly industrialized economies, which makes it possible to keep the high growth rate of Asia's economies (Fang, 2009).

Having swept by the global financial crisis in 2008, the advanced European and American countries can hardly be restored to their previous consumption capacity, and the consumption market cannot possibly be the impetus for the growth of Asian countries as it used to be; therefore Asia's emerging economies will face the unfavorable sluggish external environment. Meanwhile, there is a tendency of de-leveraging in western countries, which poses a great challenge to the export-oriented pattern of Asia's economies. In order to protect the internal market, the developed countries once again build the barrier of trade protectionism with escalating scale and intensity, and the means of trade protection are more concealed. Export will remain as the major impetus for Asia's economic growth in a long time, but with the developed countries' attacks on Asia's export, Asia's economy will be in urgent need to transform and find another way out so as to break away from its overreliance on the external markets.

Meanwhile, under the impact of the two financial crises, the economic paradigm of Asia's Flying Geese Pattern of industrial distribution and industrial transfer in East Asia, headed by Japan, is gradually evolving and even disintegrating. The Flying Geese Pattern is based on the technology and industrial gradient difference in different countries. Nevertheless, since the 1990s, Japan's economy has been in depression and recession for more than ten consecutive years, consequently weakened its promoting function of Asia's economy which Japan exerted as the axis of economy in East Asia, and its leading position began to sway. And with the accelerated industrialization in East Asian countries, the gap between the industrial gradients is narrowed, the scale of industrial transfer is subdued, and the foundation of the Flying Geese Pattern is challenged. In addition, with the rise of China's economy and other emerging economies, the promoting function of Asia's economy is increasing, sub-regional economic cooperation in Asia is gradually launched and strengthened, and constantly breaking through the Flying Geese pattern. For the present, Asia's economic development is shifting from the Flying Geese Pattern to the Network model. A pluralistic "network" has been formed in the following aspects: the flows of labor force, materials and capital; in the policies of different governments; and the regional economic cooperation, which continues to fuel Asia's economic development.

1.2.2.3 Environmental sustainability of Asia's economic growth

Asia's economic development model confronts the challenges in the sustainable and steady growth of economy, what is more important, its production and consumption model also manifest the environmental unsustainability (UNESCAP, 2006). Asia is densely populated and its population density is about half above the world average, but the overall natural resources in Asia are not abundant: fresh water availability, the arable and permanent crop land, and biologically productive area per capita are all below the world average, and the carrying capacity of resources and environment is relatively limited.

Meanwhile, because Asia's technology and economic conditions generally lag behind, the immense stress is formed on the resources and environment. In the course of globalization and opening up, Asia has gradually established its unique position in the structure of world industrial distribution, playing the role of "world factory". Except for Japan, Rep. of Korea and a few countries and regions, most Asian countries are still in the process of industrialization, and energy-intensive, resource-intensive and pollution-intensive industries are rapidly developing. During the formation of its role as world factory, a lot of serious environmental problems have taken place, and Asia has had to pay a high cost for its environment, resources and energies, for instance, the severe land damage, the deteriorating forest and marine ecosystems, air pollution and water pollution led to the steady decline of natural capital stock in the area and increasing vulnerability to the climate changes and natural disasters. Currently, Asia has already become one of the most fragile zones under the global climate changes. The sea level rise, extreme weather disasters, the scarcity of fresh water, and the decline of agricultural production, which are all resulted from global warming, will have a great influence on Asia's economic development and living standards, particularly the most poverty-stricken countries and regions are likely to be the most severely affected areas.

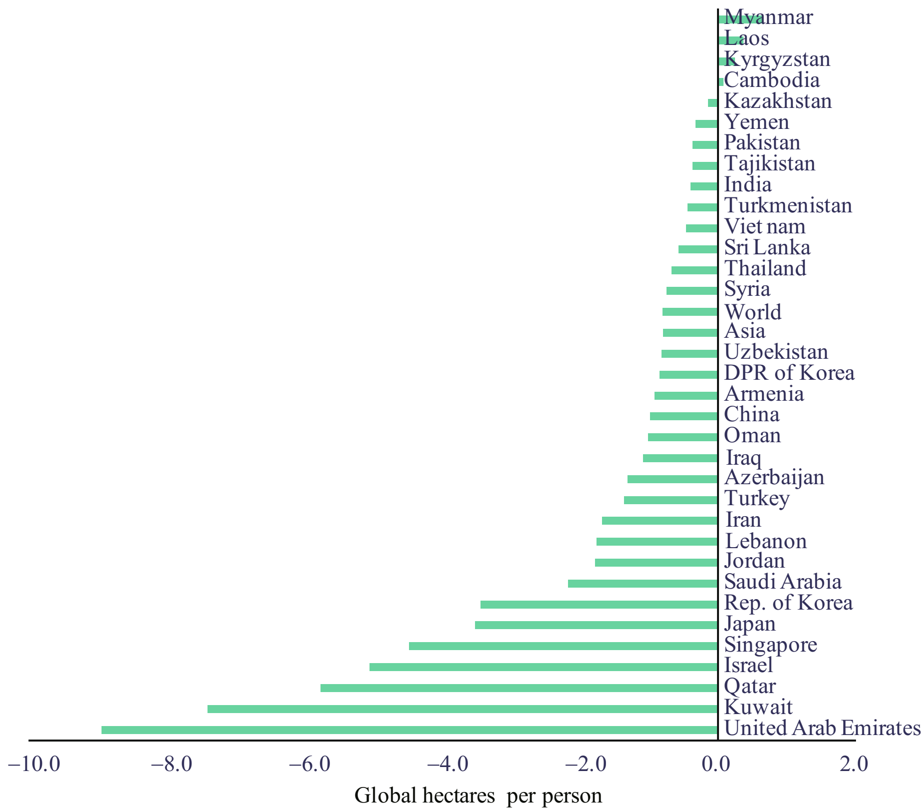

Figure 1.2 Ecological surpluses and deficits in Asia in 2006

(Source: Global Footprint Network, 2009)

The above mentioned situation means that the environmental impact of Asia's rapid economic growth is probably more conspicuous than that of any other region (UNESCAP, 2006), and the environmental cost is even higher. If we measure it by ecological footprint, the current environmental pressure has already exceeded the environmental carrying capacity of this region (in terms of bio-capacity), it is environmentally unsustainable (Global Footprint Network, 2009). If we look at the countries in the Asian area, in 2006, of 33 counted countries, except for Burma, Laos, Kyrgyzstan and Cambodia, the environmental pressure of the other 29 countries has already exceeded their own environmental carrying capacity (Figure 1.2). To the whole Asia, with the economic growth and the improvement of people's living standards in this region, the environmental pressure in this region will keep a trend of linear growth (Figure 1.3). It is predictable that the contradictions between future economic growth and environmental carrying capacity will be more acute if the current development mode still continues.

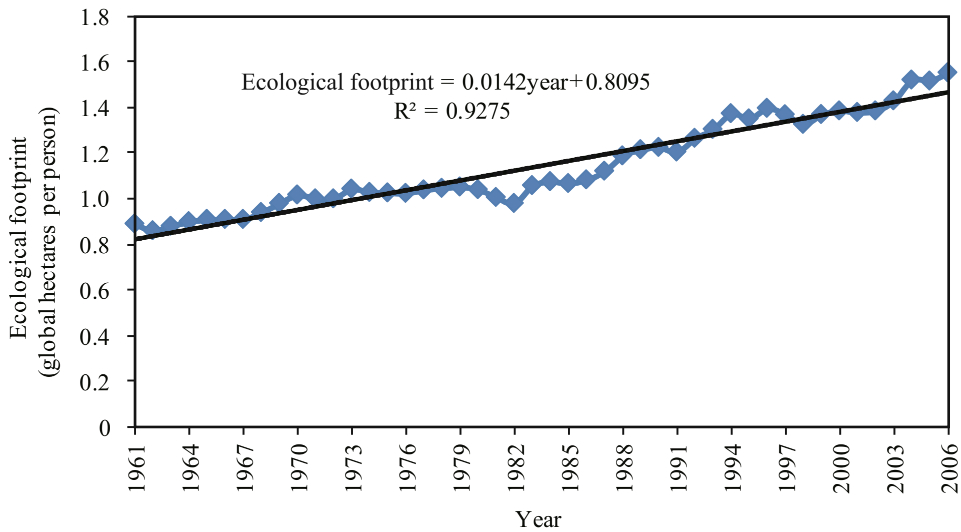

Figure 1.3 The variation in ecological footprints in Asia-Pacific region (1961- 2006)
(Source: UNEP, 2010)

1.2.3 Challenges for the Transition of Asia's Economic Development Model

With the changes of comparative advantages, the impact of global financial crisis, the need for saving resources, protecting environment and dealing with the climate change, Asia's economic development model urgently needs transition. From a longer perspective, since it has to both resolve the problems of resources and environment and create the new driving force and competitiveness, whether Asia's economy can achieve the sustainable and steady growth and preoccupy the commanding points of global economy in the Post-Financial Crisis Era depends on whether it can successfully materialize the overall transition of the development model, and rebuild a green, low-carbon, smart, cooperative, and inclusive model. The coming five or ten years will be the key and arduous period for Asia's transition into a new development model.

Firstly, from the perspective of the fountain of economic growth, economic growth has to be innovation-driven rather than factor-driven or investment-driven, its dependence on the capital and the labor force should be transformed into its reliance on total factor productivity, and the quantity-increasing type should be changed into quality-oriented model. It rests on how to develop creativity in Asia's economic development, including the development of labor capital, knowledge innovation, technology innovation, management innovation and corresponding system innovation.

In the course of Asia's economic growth, the development of the economies, including Japan, East Asian Tigers and mainland China, adopts the imitation innovation and export-oriented economy, that is to say, by introducing, digesting, absorbing, transforming and integrating foreign technologies, in accordance with the actual demand of both its internal and international market, study and develop the technologies and products that can better satisfy the market demands, then able to save large investment of capital and time, greatly reduce production cost, shorten the products' production cycle, also by exploiting advantages as later-comer and abundant but cheap labor resourc partially at the expense of environment, and consequently contribute to leapfrog development and rapid economic growth in Asia and particularly in East Asian countries and regions. One negative impact of this model is that it has weakened its investment in basic research and its innovative potentials because it has adopted imitation and relevant protection policies.

Currently in most Asian countries there are still abundant labor resources and also in the demographic dividend period, the educational level of the labor force is relatively high; however, the adult literacy is on the whole below the world average, the supply of skilled laborer cannot meet with the increasing demand, and there is obviously no sufficient human capital reserve to achieve the innovative leap. The widening technological breach has both lifted commercial cost and fettered industrial productivity and manufacturing level of the enterprises, and thus has greatly restricted economic development. Therefore, it is necessary to increase investment in education and education infrastructure and speed up the cultivation of highly skilled labor force so as to provide society with abundant skilled talents, laying a foundation for achieving innovation economy and smart growth.

In terms of science and technology, since Asian countries had rather low investment in science and technology, the promotion of science and technology innovative capability has been greatly restricted. Although the total amount of the scientific research personnel and the total expenditure on R&D activities have exceeded that of the United States and Europe, the ratio of R&D investment to GDP is 1.6 percent, lower than the world average of 1.7 percent. The number of scientific personnel in every million of people is 742 persons and R&D expenditure per scientific researcher is 1,400 USD, which are respectively lower than the world average of 1,063 people and 160,000 USD, lagging far behind the United States and Europe. Moreover, with a population of more than 60% of the world population, while the number of scientists and technicians, the average patent applications and patent grants, the average scientific and technical journal articles and R&D expenditure in unit are 41.4%, 53%, 32.7% and 21%, respectively, of the world. In other words, both the capacities of knowledge innovation and scitific innovation on the whole lag behind the world average level. Therefore, it is necessary to reinforce science and technology investment, innovate unsound management science and technology, strengthen the effective cooperation between industry circles, universities and research institutes, and promote the rational flow of sci-tech talents and international science and technology cooperation, so as to promote Asia's innovative capability and give a full play to the leading function of science and technology innovation in Asia's economic development.

Secondly, in terms of Asia's export-oriented development model, Asia's economic growth needs to transform from export-oriented model, which excessively depends on export pull, to consumption-centered model, which depends more on domestic demand; at the same time, it is a crucial problem for the readjustment of Asia's economic development model to seek a balanced development between export and domestic demand. Asian economy has long existed the structural problem, which relies excessively on export, particularly the market demand of advanced European and American countries. Having withstood the impact of the global financial crisis, Asian economy now faces a totally different demand environment, for the depression and recession of the European and American market can hardly become the strong motivating force to fuel and stimulate Asia's economic growth as it used to.

To explore growth potential of Asia's economy or seek for new growth point, the following points will be necessary: firstly, try to consolidate the European and American export market, then actively seek to open new markets, diversify export channels, and maintain international competitive power by exploiting globalization. Secondly, by strengthening economic and trade cooperation between Asian countries and regions, speed up the process of integration of regional economy, develop, explore and promote the market demand between the economies within the Asian regions, activate the economic growth potentials within the region, promote Asia's economic growth, at the same time further enhance international competitive power of the whole Asian region. The newly-founded China-ASEAN Free Trade Area is exactly an important measure of promoting the transition of export-oriented economy. Thirdly, at the domestic level, materialize the sustainable growth of economy by promoting all the countries' consumption capacity and maintaining social cohesion.

Considering that there is a large gap between the rich and the poor within many Asian countries and regions, regulating income distribution, building and improving social security network and increasing employment will play a crucial role in promoting the sustainable growth of economy in Asian region. However, exploring domestic demand market cannot be applied to all Asian countries, for example, many Southeast Asian countries have limited domestic market, and it is hard to sustain the long-term economic growth by relying on internal demand or the economic growth strategy that totally relies on domestic demand will eventually reach its limits, also just with the domestic market, it is impossible for an economy to achieve specialization in its field of expertise (Commission on Growth and Development, 2008). Therefore, strengthening the integrated modernization of Asian regional economy and seeking the coordinated development between the external and internal demand, will definitely play an essential role in the economic growth of Asian region.

Thirdly, in terms of environmental sustainability, Asia's economic development is in urgent need to transform from the extensive growth model, which is resources, energies and pollution intensive, to the green model, which is resource-saving and environment-friendly, improves the quality of economic growth, and coordinates the contradictions between economic development and environment carrying capacity. To a large extent, Asia's rapid economic growth is at the expense of resources, energies and environment, and has led to complicated and diversified environmental problems. The limited environment carrying capacity of Asia not only results in the increasingly acute contradictions between economic growth and environment, but also determines environmental unsustainability of this economic growth.

Green economy transition and achievement of Asia's sustainable development have become the inevitable choice of Asia. It is both a process of readjusting and reshaping the present production and consumption patterns and a process of all-round system innovation which involves the transition of profound factors such as ideas, investment, technology, organization, system and culture.

Speeding up Asia's green transition conforms to the trend and tendency of future development of the world. Particularly in coping with the double challenge of the global financial crisis and global climate change, all countries have gradually reached the consensus of green and low-carbon-development transition (CAS Sustainable Development Strategy Study Group, 2010). Green New Deal or Green Recovery includes actively developing low carbon technology, combining the short-term economic recovery with the long-term sustainable growth, so as to promote economic growth, create employment opportunity and reduce poverty.

In October 2008, United Nations Environment Program proposed Global Green New Deal and developing Green Economy (UNEP, 2008). In March 2009, it issued a policy brief on green new deal (UNEP, 2009a), and in September submitted to G20 an updated version of Global Green New Deal (UNEP, 2009b), its essence is to achieve green economy by reshaping and refocusing the policies, investment and expenditure of the key department, recover economy, increase employment, and also deal with the climate change.

OECD countries in June 2009 made ministerial declaration and advocate green growth as the important solution to break away from or transcend the crisis, that is to say, in the short term to promote economic recovery through policy tool and green investment, while in the long term to promote sustainable growth and gear toward sustainable growth through establishing environment-friendly infrastructure of green economy (OECD, 2009).

Besides, Council of the European Union also in October 2009 passed the post-Lisbon agenda and the resolution of developing "eco-efficiency economy" which is EU's strategy for sustainable development. In the documents "Europe 2020", newly passed by the Committee of European Union, smart growth, sustainable growth and inclusive growth have been listed as the development strategies for the coming ten years, among which the essence of sustainable growth is to promote a green and competitive economy with more resource availability (European Commission, 2010). It can be seen that EU not only promotes low carbon development, but also proposes an eco-efficiency and resources-efficiency economy which is more long-term and extensive, namely, establishing a safe, sustainable low carbon and resource-saving development model through the transition to sustainable production and sustainable living style.

All in all, to achieve green transition and innovation of Asia's economic development is not only determined by the regional situation of Asia's limited resources and environment carrying capacity, but also conforms to the trend and direction of international development. The fifth Ministerial Conference on Environment and Development in Asia and the Pacific held in March 2005, Seoul, Rep. of Korea, proposed Seoul Initiative on Green Growth, which aims to promote the Asian area toward Green Growth and advocate green development as a new development model and the common path for achieving sustainable environment and economic growth for Asia and the Pacific (UNESCAP, 2005). In April 2010, The Boao Forum for Asia (BFA), with the theme of "Green Recovery: Asia's Realistic Choice for Sustainable Growth", pointed out that Asia's emerging economies should utilize the opportunity of the financial crisis, and take the development of green and lowcarbon technology as the major driving force for Asian and global economic growth and industrial upgrading, and as the important direction for future Asia's economic transition.

Considering the huge differences between each country's economy, social system and ecological conditions, the sustainable blueprint is not one and only (WCED, 1987). It is even so in the diversified and complicated Asian areas. When promoting Asia's green transition, different Asian countries and regions should, according to their own conditions and development stages, explore and choose different and suitable ways of sustainable development, including establishing different focuses and responses of green development.

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2 Environmental and Resources Problems and Sustainable Development in Asia

2.1 Fundamental characteristics of the environmental and resources problems in Asia

With the fast growth of Asian economy and its integration into the globalized world, Asia is confronted with many unprecedented challenges in terms of resources, energy and environment, such as the environmental degradation and resources depletion, posing a severe threat to its sustainable development.

The emergence of Asia's problems regarding environmental and resources problems is closely associated with those countries or areas in Asia which, after WWII, adopted an economic strategy to catch up or surpass the western economies or follow a pathway of industrialization. Compared with the industrialization process in developed countries, most of the Asian countries suffer environmental and resources problems in a short term of period due to fast industrialization and poor understanding of such problems. These problems often coexist, further complicating the prevention and control. This is particularly true in East Asia. At present, Asia faces complex and serious challenges from resources, environment and climate change unique in the history of mankind.

(1) Diversity of problems in resources and environment in Asia. The diversity is shown in both type and scale. ①Diversity in type. As for resources, Asia faces many problems such as water scarcity, reduced farmland resources, unbalanced energy structure, and inefficient use of resources. The ecological degradation includes land degradation, reduced forest and wetland areas, and biodiversity loss. With regard to environmental problems, it mainly consists of the pollution of water body, atmosphere and solid waste. Asia is also confronted with increasingly severe challenge from climate change. ②Diversity in spatial scale. In spatial terms, the environmental and resources problems at local, regional and global scales co-exist in Asia. While the local problems generally refer to resources damage and environmental pollution produced in local or domestic areas, the regional problems are mainly cross-border ones that have impacts across the region, such as water resources distribution and pollution of cross-boundary rivers, regional atmospheric pollution and acid rain, and deforestation of tropical rainforests. The global environmental problems cover those caused by climate change and cross-border transfer of dangerous wastes, among others.

(2) Spatial differentiation of the environmental and resources problems in Asia. Climate change has now become a global issue. In addition to that, the forms of environmental and resources problems across different countries and areas in Asia also vary, and the priorities to address these problems are also different from each other (UNEP, 2007).

(3) Complexity of environmental and resources problems in Asia. This is mainly evidenced by the interactions between/among different types of environmental problems at different scales. For example, the interactions among different pollutants often lead to secondary pollution or produce coupling or synergy effects, thus doing greater harm to the ecosystem and human health. Meanwhile, with the shift of development stages and modes, the environmental problems exhibit new changes and transition. Various environmental problems, old and new, combine to complicate the integrated prevention and control of these problems. This is particularly true in China (Wang, 2006). The interactions of all these environmental problems increase their complexity, making it more challenging to address them.

(4) Severity of environmental and resources problems in Asia. These problems mainly involve the pressure on resources, intensity and extent of environmental pollution and ecological degradation. Firstly, the resources in Asia are under heavy pressure. Due to a large population, Asia's per capita farmland and freshwater ownership, as well as the per capita reserve of mineral resources including non-ferrous metal, are lower than the world average level. Asia is known as one of the regions that suffer from the heaviest pressure in water resources. At the same time, with the fast economic growth, Asia's demand for resources and energy is increasing, thus putting the supply of resources under heavy pressure in this region. Secondly, Asia suffers from heavy pressure in terms of environment and severe environmental pollution. In some countries, areas or cities in Asia, the speed of pollutant discharge surpasses that of economic growth, resulting in the abrupt rise of environmental pressure. At present, the concentration of total suspended particulate (TSP) in the atmosphere of the cities in Asia generally doubles that of the world average value, and the concentration of pollutants including SO_2 is much higher than that stipulated by WHO. The lead pollution level in most large cities in Asia exceeds the threshold. Most of the cities with the heaviest air pollution worldwide are found in Asia. Furthermore, the concentration of pollutants (including organic pollutants) in the rivers is much higher than the world average level, multiplying the standard level stipulated by WHO. Thirdly, the environmental quality tends to deteriorate in Asia. Over the last two decades, most of the countries and areas in Asia have suffered from increasing environmental problems, such as exacerbating water and air quality, land and ecosystem degradation, posing a severe threat to food security in the region.

Using ecological footprint and biocapacity to indicate the severity of the overall environmental problems in Asia, it can be seen that the environmental pressure in the region has doubled its carrying capacity, with the overloading rate (110.4%) ranking first worldwide and much higher than the world average level (43.6%), as shown in Figure. 2.1. This, to a large extent, suggests that the existing growth mode in Asia is unsustainable.

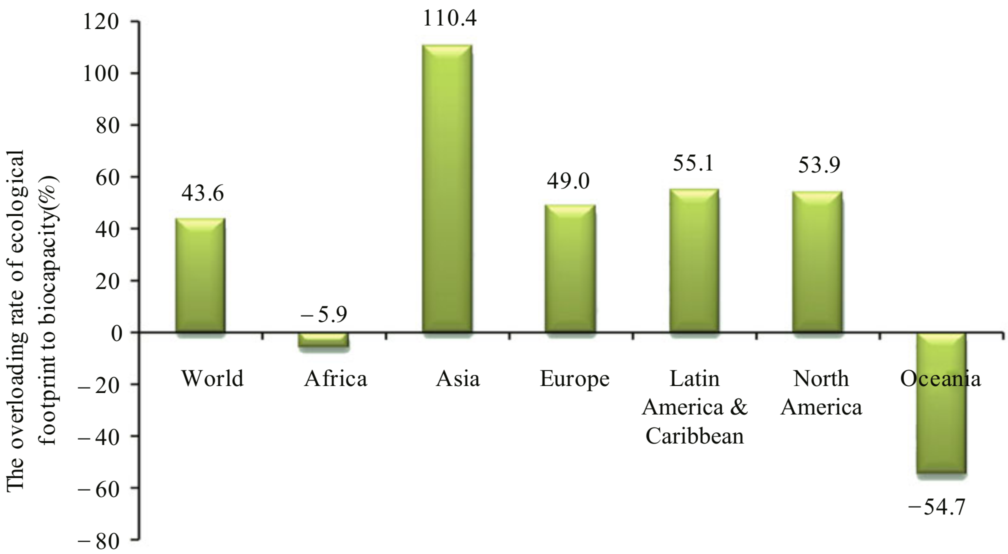

Figure 2.1 The overloading rate of ecological footprint to biocapacity in global regions in 2006

(Source: Global Footprint Network, 2009).

The developed countries are characterized with relatively long process of industrialization. Their environmental problems have emerged and have been addressed at different stages. However, as to most countries and areas in Asia, these different environmental problems, which emerged at different stages in the developed countries all broke out in a relatively short period of time. As a result, addressing these problems will be more challenging for these countries and areas in Asia and they will suffer from a low level of economic development, insufficient funding in environmental protection, weak technical support, reduced development capacity and poor environmental management capacity.

2.2 Major environmental and resources problems challenging the sustainable development in Asia

This report focuses on the key problems and challenges facing sustainable development in Asia in terms of water resources, mineral resources, land resources, environment, energy and climate change.

2.2.1 Increasing pressure on water resources

Of various uses of natural resources in Asia, water resources problem is the most prominent one, which covers water crises, water pollution, water conflicts and water politics. The freshwater resources in Asia are in short supply and the water resources available tend to decline. With the fast growth of socio-economic development, the demands for water resources in the region are increasing significantly. The situation is made worse with reduced water quality due to water pollution and with over-exploitation of surface and underground water. At the same time, the water security in the region is also threatened by global climate warming, as well as large-scaled human activities such as water storage projects and transboundary river-basin water transfer programs.

(1) Tight supply will persist for a long time in Asia due to scarcity of freshwater resources. Scarcity of freshwater resources is one of the key challenges for Asia. In 2007, Asia supported 62% of the total population in the world with freshwater resources that account for only 37% of the world total. The per capita freshwater resource in the region was recorded to be only 3,874 m^3, much lower than the world average level of 6,566 m^3. Furthermore, water resources in Asia are unevenly distributed, with a great difference in availability per capita and a multitude ranging from 10^1-10^5 (Figure 2.2). The situation is particularly serious in West Asia. Using water resources availability per capita of 1,000 m^3 per annum as the standard for water scarcity, 17 countries in Asia in 2007 were considered below this level.

Asia suffers from less per capita water resources, and freshwater resources available also tend to decline. The figures indicate that from 1955 to 1990, the per capita water resources in Asia have fallen by 40%-60%. As one of the regions worldwide with the heaviest pressure on water resources, West Asia has seen its figure reduced from 1,770 m^3 per annum in 1985 to 907 m^3 per annum in 2005.

In the next decades, with further population growth and industrialization and urbanization in Asia, the demands for water resources will continue to increase and the scarcity of water resources, therefore, will persist for a long time in the region. The competition for water resources may even lead to inter-regional political and military conflicts. For example, since the collapse of the former Soviet Union in 1991, the conflicts for water resources in Central

Asia have been increasing. The total amount of freshwater withdrawals for the countries in Central Asia has grown from 37 km^3/year in 1950 to 102 km^3/year in 2000, and the figure is expected to reach up to 122 km^3/year (Shiklomanov et al., 2001) by 2025. As for West Asia, by 2050 the per capita freshwater resource available is predicted to fall to 420 m^3 as a result of population growth. Meanwhile, climate change is most likely to exacerbate the scarcity of water resources for a majority of countries and areas in Asia. For this reason, cooperation between and among different countries in Asia and Middle East in addressing water problems may become more difficult.

(2) Reduced water quality due to water pollution increases the tight supply of water resources. Large amounts of pollutants produced by agricultural and industrial production and domestic sewage are discharged into the water body in Asia, deteriorating the water quality in the region. These pollutants also reduce the water resources available, exacerbate the tight supply of water resources and even pose a major threat to human health. According to Global International Waters Assessment published by UNEP in 2006, half of the 24 areas in Asia and Australia were affected by pollution at a severe or moderate degree. It is also expected that pollution in 17 areas will deteriorate by 2020.

Human health is closely associated with water quality. However, a large population in Asia still cannot access safe drinking water. Overall, the condition of accessing drinking water in the region has been significantly improved over the years, with the proportion of people who can access improved drinking water facilities growing from 72% in 1990 to 87% in 2006. By contrast, for a few countries in Asia, such as Afghanistan, Cambodia, Laos and Tajikistan, the figure is still less than 60% (Pacific Institute, 2009). Each year, 865,000 people suffer from diarrhea in Asia (Chen, 2009). Even by estimating under the optimistic scenario of halving the people who cannot access safe drinking water and hygiene by 2015 as per the MDGs, 34-76 million people in Asia may die of water-borne diseases by 2020 (Pacific Institute, 2002).

(3) Over-exploitation of water resources triggers a series of environmental problems. Over-exploitation of surface water resources and underground aquifers is another key problem in Asia. Generally, when the water supply pressure index exceeds 40%, i.e., the ratio of water supply or water use versus its usable water resources in a river basin or area, this river basin or area will be considered severely short of water resources, or its water resources are considered under heavy pressure. When the figure reaches 30%, it will be considered close to the threshold. So far, the water supply pressure indexes for many river basins or areas in Asia have exceeded the threshold. For this reason, Asia is suffering from an over-exploitation of water resources. For instance, in the Indo-Gangetic Plain in West and South Asia, and the North China Plain in China, human use of water resources has largely gone beyond the annual average replenishment capacity of these river basins.

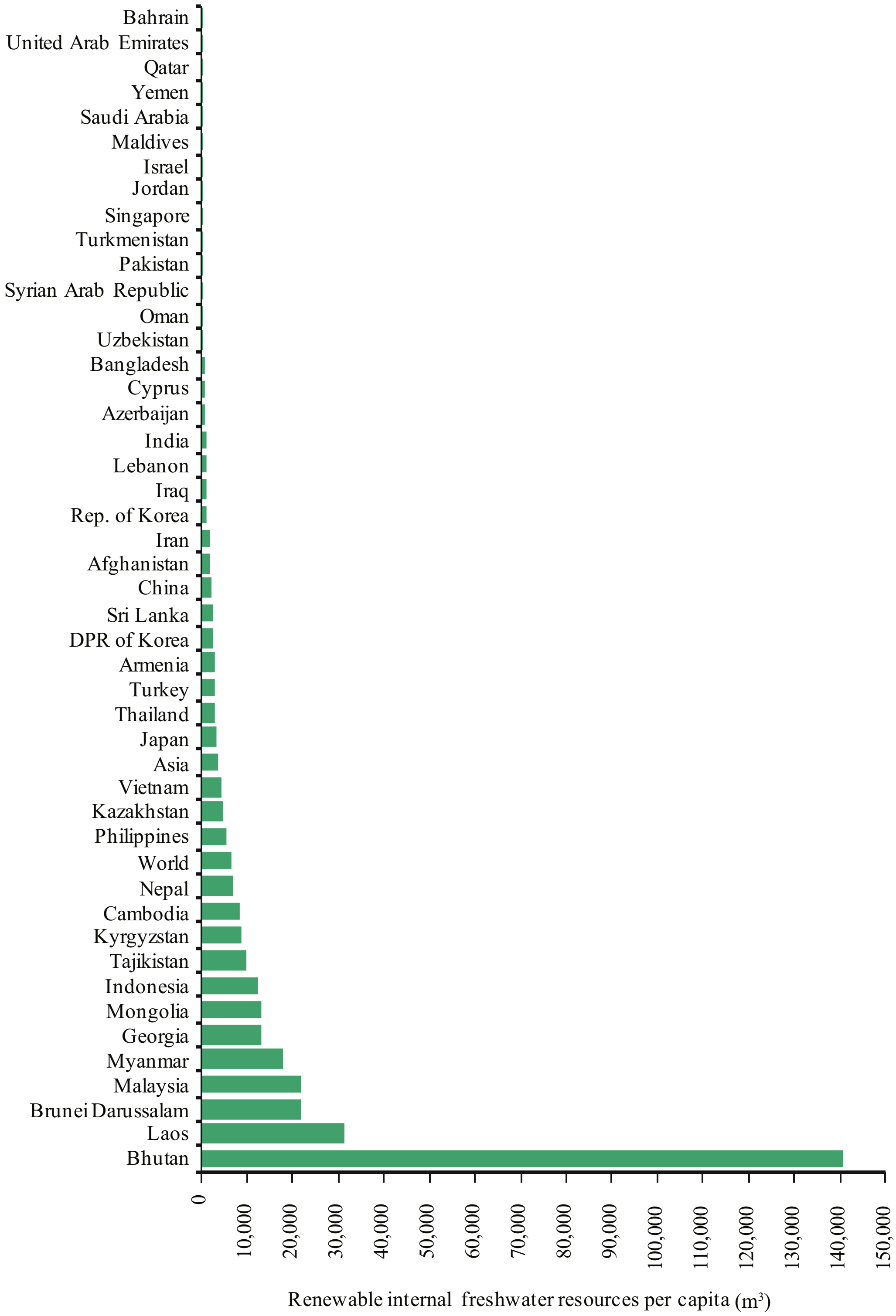

Figure 2.2 Water resources availability per capita in Asia in 2007

(Source: World Bank, 2010)

Over-exploitation of water resources has triggered a series of environmental problems in Asia, such as salinization, land subsidence, and seawater encroachment. For example, in some countries like China, India, Iran, Pakistan, Cambodia, the Philippines and Indonesia, the underground water level has declined abruptly due to over-exploitation. In West Asia, as a result of over-exploitation of underground water, the quality of limited surface and underground water resources has been deteriorating, which has exacerbated the scarcity of water resources and adversely affected human health and the ecosystems in the region. In particular, over-exploitation of underground water has depleted many springs, and damaged some of their historical and cultural heritages.

(4) Inefficient use of water resources also increases the water resources pressure. Agriculture is known as the largest sector for water demand in Asia. In 2007, 79% of the total water use in the region was consumed by the annual freshwater withdrawals for agriculture (Figure 2.3). As water resources are mainly used by the agricultural sector with low production efficiency, combined with relatively poor technology and management, water resources use in Asia is based on an extensive pattern, which results in inefficient use and severe waste of water resources, and this in turn, increases the pressure on water resources.

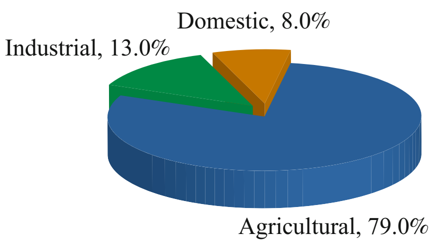

Figure 2.3 The proportion of annual freshwater withdrawals in Asian sectors (1998-2007)
(Source: FAO AQUASTA data, 2007)

As is shown by World Bank, in 2007, water consumption per unit of GDP in the whole Asia was recorded to be 163.1 m^3/1000 USD, more than doubling the world average level of 68.3 m^3/ 1000 USD. As for the sub-regions in Asia, the highest water consumption per unit of GDP was found in Central Asia, with a figure of 971.9 m^3/ 1000 USD. It was followed by South Asia (652.1 m^3/1000 USD), West Asia (128.5 m^3/1000 USD) and East Asia (103.5 m^3/1000 USD), all exceeding the world average level. In terms of countries, water use perunit of GDP for 25 countries in Asia has gone beyond the world average level. Generally, the intensity of water consumption in a country is negatively correlated with its economic development level (Figure 2.4).

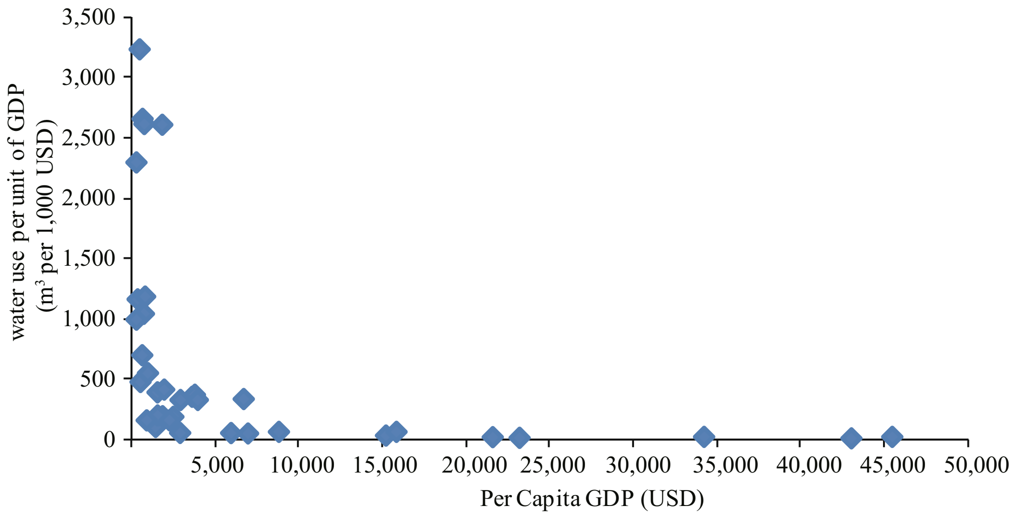

Figure 2.4 Water use per unit of GDP vs per capita GDP in Asia in 2007
(Source: World Bank data, 2010)

2.2.2 Extensive use of mineral resources

The mineral resources in Asia play an important role worldwide. For example, 25%-50% of global reserves of non-ferrous metal and precious metals are distributed in Asia. Lead, zinc, tungsten, and tin reserves, and antimony mines in the region exceed or are close to 50% of global reserves. This is also the case for ferrous metals like manganese and chrome mines in Asia.

For the above-mentioned reason, the mineral industry as a basic industry plays a major part in the national economic development for many countries in Asia. However, due to different physical conditions for the formation and growth of mineral resources in various countries, the shares of mineral industry output in their GDP vary greatly. For example, countries like Kazakhstan, Mongolia and Uzbekistan are rich in mineral resources, and the mineral industry in these countries is defined to be the pillar industry in the national economic development, the output of which accounts for more than 10% of their GDP; while in countries like DPR of Korea, Tajikistan, Malaysia, Vietnam, India, China, Indonesia, Thailand and the Philippines, the mineral industry output takes up a share between 1% and 10%, also playing an important role in their national economic development.

Nevertheless, Asia is faced with serious challenges from sustainable exploitation and utilization of mineral resources. In some countries of the region which are highly dependent on mineral resources and where the mineral industry and national economic development are highly sensitive to the global economic shock and international mineral resources price changes, far-reaching impacts on employment and the environment have been brought about. This is particularly true in West Asia. More importantly, with the fast economic growth in Asia, the demands for regional and global mineral resources have increased markedly. Under the context of extensive economic growth pattern and due to inefficient use and limited production of mineral resources, the rising demands for mineral resources in Asia have exacerbated the already tight supply of mineral products, highlighting the scarcity of raw materials in the region.

(1) Strong growth in both production and consumption of mineral products; severe shortage of raw materials. In recent years, with its fast economic growth, the consumption of various mineral resources in Asia tends to rise sharply, and its proportion in the global figure is also increasing year on year. From 1998 to 2007, the share of crude steel consumption in Asia versus the global total has grown from 45.87% to 63.5%; while the figures for primary aluminum, copper, lead and electro-galvanized steel sheet have increased to 52.42%, 53.63%, 48.74% and 54.99% in 2007 from 32.10%, 36.21%, 28.73% and 38.53 % in 1998, respectively.

Globally, a large proportion of the newly-increased consumption of various mineral resources is driven by the increasing needs in Asia. This not only highlights the growing roles of Asian market, but demonstrates that the economic growth in Asia has been achieved at the cost of heavy consumption of mineral resources.

Although the production capacity of mineral resources in Asia is steadily expanding, its growth fails to match the growth of consumption, resulting in the deterioration of the scarcity of raw materials in the region. For example, despite Asia's rising share of refined aluminum, copper, lead and electro-galvanized steel sheet production in the world, it cannot satisfy the huge demands for their consumptions in Asia and large amounts of mineral resources have to be imported from other markets in the world (Table 2.1).

(2) Extensive use of mineral resources with much low use efficiency. Mineral resources use in Asia is characterized by an extensive pattern and low efficiency. In 2007, the consumption of crude steel per unit of GDP in the region was recorded to be 54.7 kg/1000 USD, more than doubling that of the world average level of 23.9 kg/1000 USD; while the figure for non-ferrous common metals was 2.70 kg/1000 USD, nearly twice the world average level of 1.39 kg/1000 USD.

In terms of the elasticity of mineral resources consumption (Table 2.2), the figures for crude steel and non-ferrous common metals in Asia both surpassed the world average levels, suggesting that the growth rate of mineral resources consumption in the region was faster than that of its GDP. It also reflects the fact that economic growth in Asia is highly dependent on mineral resources and that its use of these resources is extensive and inefficient.

Table 2.1 Production and consumption of Asia's major non-ferrous mineral resources (Unit: 10^6 tons)

Minerals	Category	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production of Baux-ite	Asia	1,784.64	1,946.1	2,144.94	2,205.71	2,892.16	3,169.41	3,555.05	3,676.52	3,946.17	4,847.74
	World	12,303.42	13,015.82	13,891.52	13,904.39	14,731.21	15,831.5	16,803.5	17,636.28	18,316.86	19,165.49
	Percentage of world(%)	14.51	14.95	15.44	15.86	19.63	20.02	21.16	20.85	21.54	25.29
Production of refined aluminum	Asia	428.58	471.38	515.73	576.5	675.06	818.43	965.74	1,126.78	1,368.54	1,653.86
	World	2,265.39	2,370.71	2,441.81	2,443.6	2,607.6	2,800.06	2,992.17	3,202.08	3,396.51	3,808.73
	Percentage of world(%)	18.92	19.88	21.12	23.59	25.89	29.23	32.28	35.19	40.29	43.42
Production of sec-ondary aluminum	Asia	124.77	125.07	130.26	125.93	132.89	135.04	110.38	112.75	121.91	123.43
	World	759.42	813.24	819.7	762.36	764.87	765.61	763.56	776.19	786.5	880.37
	Percentage of world(%)	16.43	15.38	15.89	16.52	17.37	17.64	14.46	14.53	15.50	14.02
Production of refined copper	Asia	380.9	411.95	460.28	493.76	505.1	532.57	573.94	643.17	715.39	774.48
	World	1,411.99	1,446.52	1,481.58	1,567.53	1,534.98	1,522.06	1,585	1,661.03	1,732.45	1,797.21
	Percentage of world(%)	26.98	28.48	31.07	31.50	32.91	34.99	36.21	38.72	41.29	43.09
Production of sec-ondary copper	Asia	384.1	386	404	388.8	367.2	366	356.1	350.5	355.7	352.3
	World	597.6	588.3	602.8	574.7	542.7	536.7	548.4	555.8	575.5	574.5
	Percentage of world(%)	64.27	65.61	67.02	67.65	67.66	68.19	64.93	63.06	61.81	61.32
Production of refined lead	Asia	166.78	188.04	215.48	218.86	234.36	261.4	284.87	345.24	379.84	385.62
	World	599.84	636.33	671.42	661.33	670.23	681.25	681.25	771.93	806.42	811.02
	Percentage of world(%)	27.80	29.55	32.09	33.09	34.97	38.37	41.82	44.72	47.10	47.55

Continued

Minerals	Category	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Production of secondary lead	Asia	70.17	76.52	77.41	80.66	85.58	90.63	94.57	116.3	137.49	137.58
	World	324.62	329.22	345.91	348.69	357.11	360.91	364.78	404.53	427.02	433.13
	Percentage of world total(%)	21.62	23.24	22.38	23.13	23.96	25.11	25.93	28.75	32.20	31.76
Production of electro-galvanized plate	Asia	315.49	339.52	379.25	394.5	420.72	445.87	467.48	500.78	552.22	606.51
	World	804.34	842.07	906.39	922.24	964.6	993.11	1,016.04	1,015.48	1,058.98	1,123.79
	Percentage of world(%)	39.22	40.32	41.84	42.78	43.62	44.90	46.01	49.31	52.15	53.97
Consumption of primary aluminum	Asia	702.55	817.64	907.47	880.19	966.08	1,144.82	1,296.75	1,421.57	1,600.54	1,952.38
	World	2,188.93	2,335.55	2,505.91	2,372.15	2,537.23	2,760.65	2,996.06	3,170.93	3,399.46	3,724.64
	Percentage of world(%)	32.10	35.01	36.21	37.11	38.08	41.47	43.28	44.83	47.08	52.42
Consumption of copper	Asia	483.46	538.41	602.52	616.85	695.94	731.31	803.48	824.96	833.79	963.45
	World	1,335.26	1,405.67	1,519.19	1,468.56	1,505.14	1,531.7	1,666.44	1,663.24	1,698.8	1,796.36
	Percentage of world(%)	36.21	38.30	39.66	42.00	46.24	47.74	48.22	49.60	49.08	53.63
Consumption of lead	Asia	174.53	181.66	202.67	212.85	242.33	269.01	302.95	349.62	377.05	399.92
	World	607.42	618.03	641.5	656.05	658.93	668.3	723.76	777.39	812.35	820.46
	Percentage of world(%)	28.73	29.39	31.59	32.44	36.78	40.25	41.86	44.97	46.41	48.74
Consumption of electro-galvanized plate	Asia	307.7	337.1	366.65	375.64	410.5	447.21	506.46	559.68	578.32	622.13
	World	798.55	839.03	886.52	886.64	935.51	943.5	1,020.51	1,043.37	1,081.75	1,131.42
	Percentage of world(%)	38.53	40.18	41.36	42.37	43.88	47.40	49.63	53.64	53.46	54.99

Source: World Bureau of Metal Statistics, 2008

Table 2.2 Elasticity of mineral resources consumption of global regions (1994-2007)

Continent	Annual growth rate of apparent consumption of Crude Steel (%)	Annual growth rate of non-ferrous common metal consumption (%)	Annual growth rate of GDP (%)	Crude steel consumption elasticity	Non-ferrous common metal Consumption elasticity
Africa	3.55	5.27	4.16	0.854	1.269
Asia	6.63	8.09	3.74	1.770	2.161
Europe	3.59	1.76	2.61	1.373	0.675
South America	4.75	4.07	2.88	1.650	1.414
North America	0.59	–0.01	3.06	0.191	–0.003
Oceania	2.04	–0.34	3.64	0.561	–0.09
World	4.76	4.23	3.08	1.547	1.374

Source:
IISI, 2008; World Bureau of Metal Statistics, 2008; UNEP, 2009

In addition, the recycling efficiency of waste mineral resources in Asia is also very low. Compared with other continents, the efficiency of recycling aluminum, lead and copper resources in Asia is much lower than the world average level. The figures for aluminum and lead recycling rank last, while the figure for copper recycling is only higher than that of Africa and 5.24 percent lower than the world average level (Table 2.3).

Table 2.3 Waste recycling efficiency of the world's main non-ferrous mineral resources in 2007 (Unit: 10^4 tons)

Aluminum	Recovery	World	Europe	Africa	Asia	Americas	Oceania
Copper	Consumption	880.4	284	3.2	123.4	457.2	12.6
	The waste recycling efficiency (%)	3724.6	914	47	1952.4	771.7	39.6
	Recovery	23.64	31.07	6.80	6.32	59.24	31.81
Lead	Consumption	580.6	194.4	2.8	260.9	116.5	6
	The waste recycling efficiency (%)	1796.4	472.6	23.3	963.5	322.3	14.7
	Recovery	32.32	41.14	12.01	27.08	36.14	40.84

Continued

Aluminum	Recovery	World	Europe	Africa	Asia	Americas	Oceania
Aluminum	Consumption	433.1	123.5	8.1	137.6	159.3	4.7
	The waste recycling efficiency (%)	820.5	195.4	11.3	399.9	210.9	3
	Recovery	52.79	63.19	71.57	34.40	75.53	158.98

Source:
World Bureau of Metal Statistics, 2008

In recent years, with the fast growth of consumption, the efficiency of waste mineral resources recycling in Asia tends to decline year on year. For example, the figures for aluminum, copper and lead have been reduced from 17.76%, 39.69% and 40.21% in 1998 to 6.32%, 12.09% and 34.40% in 2007, respectively (Table 2.4).

Table 2.4 Waste recycling efficiency of Asia's mineral resources utilization (Unit: 10^4 tons)

Minerals	Types	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Aluminum	Recovery	124.8	125.1	130.3	125.9	132. 9	135	110.4	112.8	121.9	123.4
	Consumption	702.6	817.6	880.2	880.2	966.1	1144.8	1296.8	1421.6	1600.5	1952.4
	The waste recycling efficiency (%)	17.76	15.30	14.80	14.31	13.76	11.80	8.51	7.93	7.62	6.32
Copper	Recovery	191.9	194.2	220.3	205.3	204	213.2	114.4	113.4	115.1	116.5
	Consumption	483.5	538.4	602.5	616.9	695.9	731.3	803.5	825	833.8	963.5
	The waste recycling efficiency (%)	39.69	36.07	36.56	33.28	29.31	29.15	14.24	13.75	13.80	12.09
Lead	Recovery	70.2	76.5	77.4	80.7	85.6	90.6	94.6	116.3	137.5	137.6
	Consumption	174.5	181.7	202.7	212.9	242.3	269	303	349.6	377.1	399.9
	The waste recycling efficiency (%)	40.21	42.12	38.20	37.90	35.32	33.69	31.22	33.26	36.46	34.40

Source:
World Bureau of Metal Statistics, 2008

As the inefficient use of mineral resources in Asia has exacerbated the already tight supply of these resources, this situation needs to be reversed in a fundamental way.

2.2.3 Insufficient land resources and unwise use threaten food security in the region

The limited land resources in Asia support a growing population. The intensifying land development and unwise land use in some areas in the region has already led to some ecological problems such as land degradation and has weakened the production potential of land, posing a threat to food security and sustainable development in the region.

(1) Insufficient agricultural land resources; enormous pressure from the population. Asia (including Russia) supports more than 60% of the world population with a land area that accounts for only 36% of the world total. As a result, population pressure on land resources in the region is much higher than the world average level. In particular, its agricultural land resources (mainly consisting of farmland, crops, grassland and pasture) are terribly insufficient, representing less than 60% of the world average level. Although the total agricultural land resources in Asia are on the rise since the 1960s, the per capita agricultural land in the region tends to decrease (Figure 2.5), thus exacerbating the short supply of agricultural land.

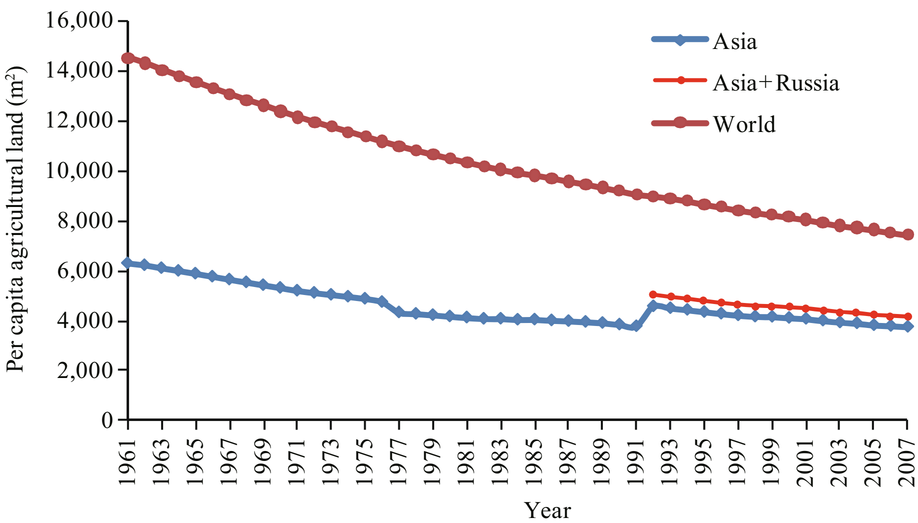

Figure 2.5 The variation of agricultural land per capita in Asia and the world (1961-2007)
(Source: World Bank data, 2010)

(2) Unwise land use leads to land degradation and threatens food security. Since the 1930s, unwise land and water use has destroyed the original water, land and vegetation patterns in the central inland areas in Asia which are affected by desertification. This has not only accelerated desertification and increased the frequency of sandstorms, but reduced the production potential of land and posed a major threat to food security in the region. In particular, China and Mongolia are the two countries in Asia that suffer from the most serious land degradation and desertification.

Land degradation is increasingly threatening food security in some areas in Asia. Generally, land degradation reduces the production potential of land and soil quality, and in turn, produces negative impact on the food production and supply. Since 1961, the grain production in Asia has increased rapidly, but it cannot fully meet the needs for food consumption in the region. The gap between supply and demand in Asia is widening, while its dependence on other regions tends to grow. Land degradation in Asia will exacerbate this situation, posing greater challenges to the future food security in the region.

(3) Continuous decline of woodland in some areas threatens biodiversity and ecosystem services. Over the past decade, the woodland area in Asia generally exhibits a V-shaped trend (Figure. 2.6). It can be seen from the figure that the woodland area in Asia has experienced two different stages: the stage of linear depression (1992-2000) and the stage of linear increase by degrees (1992-2000). At the stage of linear depression, the reduction of woodland area in Asia is mainly caused by the sharp decline of woodland area in Southeast Asia, particularly in Indonesia. At the stage of linear increase by degrees, this is mainly due to the significant rise of woodland area in Northeast Asia, especially in China, while it continues to fall in Southeast Asia.

Deforestation or conversion of woodland has jeopardized biodiversity and ecosystem services in Asia, particularly in Southeast Asia which is rich in rainforests and biodiversity. The continuous decline of woodland in Southeast Asia is closely associated with its role as the major timber suppliers in the global market.

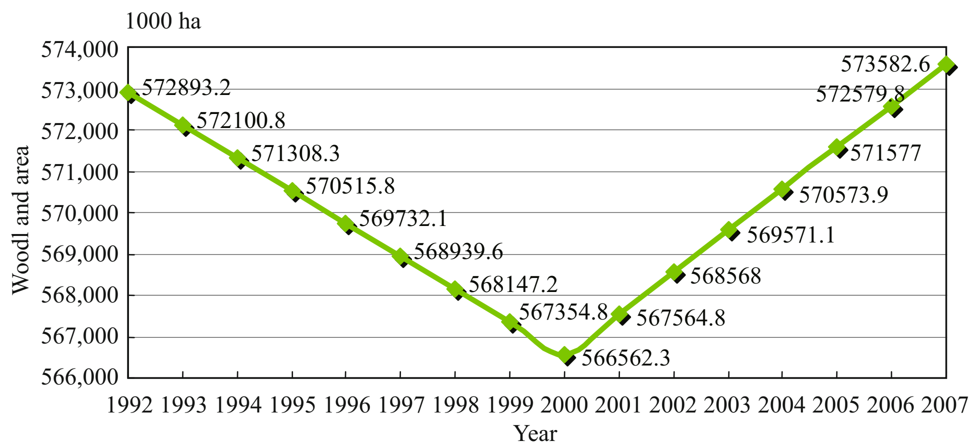

Figure 2.6 Annual changes of woodland areas in Asia (1992-2007)

2.2.4 Severe environmental pollution

Over the last decades, apart from its outstanding economic achievements, Asia is also well-known for its serious environmental pollution. Currently, the environmental quality in most of the countries and areas in the region is deteriorating, mainly evidenced by the atmospheric, water and solid waste pollution.

(1) Reduced air quality in the urban areas. The rising demands for energy and the rapidly growing vehicles have exacerbated the air pollution and substantially reduced the air quality in many cities in Asia. In addition to SO_2 discharged by coal-fired power generation and industrial production, NO_x and

TSP discharged by automobiles are becoming major sources of atmospheric pollution in many cities in the region (Krupnick et al., 2000).

Most of the cities with the severest air pollution worldwide are found in Asia. The concentration of air pollutants in many cities in the region is not only higher than the world average level, but far exceeds that of the developed countries and the standard defined by WHO. In 2006, of the 41 Asian countries about which data are available, the urban-population weighted PM_{10} concentration in 39 countries exceeded the standard of 20 $\mu g/m^3$ suggested by WHO. The figures for major cities in Asia were estimated to be 23 $\mu g/m^3$-136 $\mu g/m^3$.

Over the recent years, thanks to increased public awareness of environmental protection, more stringent regulation on pollution control and the use of desulfurizing technology, the emissions of SO_2 and the concentration of SO_2 in the air have declined to some extent in some countries and cities in Asia.

However, the discharge of NO_2 still remains at a high level in many cities in Asia. In 2001, of the 51 large cities in the region, 26 cities, or nearly fifty percent were found with their concentration of NO_2 exceeding 40 $\mu g/m^3$, the standard recommended by WHO. In addition, NO_x and fine particles are also the major causes for the frequent occurrence of photochemical smog or haze in many cities in Asia.

Air pollution has incurred heavy financial and economic costs to individual health, families, businesses and governments in Asia. 20%-30% of the respiratory diseases are caused by air pollution. In Asia, as many as over 1 billion people are exposed to an environment in which air pollution exceeds the standard defined by WHO (WHO, 2000a). Globally, about 2.40 million cases of premature-deaths were due to inhalable of fine particles each year (WHO, 2002; WHO, 2006b). In developing countries in the Asia-Pacific Region, the situation is particularly grave (Cohen et al., 2004).

(2) Ongoing deterioration of water quality in the water bodies. Industrial wastewater, domestic sewage and agricultural non-point source pollution are defined to be the major causes for water pollution in Asia. Although the discharge of organic water pollutants in wastewater for some countries in the region has declined, the accumulated pollutants still exceed the self-cleansing capacity of the water bodies, leading to the deteriorating of water quality. This has not only exacerbated the tight supply of water resources and jeopardized the human health, but posed a major risk to the ecosystem health. The organic pollutants caused by domestic sewage are also commonly seen in Asia, particularly in South Asia where the nitrate pollutants caused by the use of fertilizers are very serious.

Since the 1990s, the total discharge of organic water pollutants in such countries as Japan, Rep. of Korea, Israel, China, Kyrgyzstan, Tajikistan, Azerbaijan and Syria tends to decline, while the figure in Singapore, Vietnam, Kazakhstan, Cyprus, Iran, Jordan, Oman and Qatar is on the rise. Specifically for Turkey, the figure rose for a few years before it began to fall.

To better reflect the pressure of water pollutants discharge on the water environment in different countries in Asia, the relative concentrations of organic water pollutants, i.e., the ratio of the total discharge of organic water pollutants of each country versus the renewable internal freshwater resources, are used to measure the pollutants dilution and self-cleansing of the water bodies or the relative extent of water pollution (Table 2.5). The table shows that the relative concentrations of organic water pollutants vary greatly in Asia, with an average value of 322.4 mg/m^3, higher than that of 281.0 mg/m^3 for the developed countries in Europe and North America. Overall, the water body pollution level in Asia, particularly in West Asia and Southeast Asia, is higher than that of the developed countries. This indicator is mainly aimed to reflect the average water pollution in each country, but does not exclude the possibility of serious water pollution in some local areas in certain countries.

Table 2.5 The relative concentrations of organic water pollutants between Asian countries and developed countries in Europe and America in 2006

Country	The relative concentrations of organic water pollutants of countries in Asia(mg/m^3)	Developed countries in Europe and North America	The relative concentrations of organic water pollutants of developed Countries in Europe and North America(mg/m^3)
Afghanistan	1.3	Austria	562.8
Armenia	285.7	Belgium	2,977.8
Azerbaijan	847.2	Canada	39.7
Bangladesh	1,053.3	Denmark	3,680.4
China	790.2	Finland	210.1
Cyprus	3,674.2	France	1,182.3
India	440.1	Germany	3,255.0
Indonesia	98.3	Greece	368.8
Iran	456.7	Italy	951.6
Iraq	79.8	Netherlands	4,051.5
Israel	20,829.3	Norway	48.3
Japan	953.0	Portugal	1,008.6
Jordan	14,561.3	Sweden	208.3
Kazakhstan	8.2	United Kingdom	1,313.2
Rep. of Korea	1,798.8	United States	246.3
Kyrgyzstan	93.0	Average	281.0

Continued

Country	The relative concentrations of organic water pollutants of countries in Asia(mg/m^3)	Developed countries in Europe and North America	The relative concentrations of organic water pollutants of developed Countries in Europe and North America(mg/m^3)
Laos	1.0		
Lebanon	1,117.8		
Malaysia	131.1		
Myanmar	2.6		
Oman	1,728.9		
Philippines	74.6		
Qatar	26,663.2		
Russia	117.5		
Saudi Arabia	1,030.4		
Singapore	21,475.1		
Sri Lanka	1,942.6		
Syrian Arab Republic	234.6		
Tajikistan	88.6		
Thailand	580.2		
Turkey	285.7		
Vietnam	498.4		
Yemen	279.1		
Average	322.4		

Source:
World Bank, 2010

Eutrophication of lakes is another key issue relating to water pollution in Asia. The lakes in many countries in the region suffer from eutrophication in different degrees due to the loading of nutrients in the water.

The marine pollution in the region is also very serious. In East Asia and South Asia, 89% and 85% of wastewater are directly discharged into the sea without being treated (UNEP, 2007). In the coastal and marine areas in West Asia, a large amount of wastes from industrial and agricultural production and domestic sewage are discharged into the sea. Even the wastewater containing bromine and chrome, as well as the pathogenic microbes, is discharged into the sea by the desalinization plants. Oil leakage incidents often occur in the Mediterranean Sea, while the coastal refineries, petroleum processing enterprises located along West Asian coasts and many oil carriers passing through the Strait of Hormuz pose a major risk to the seawater resources and marine environment. In addition, the war and military conflict in some areas may also lead to oil leakage and chemical pollution. Specifically for China, its inshore areas are suffering from pollution in different degrees, with some local areas being severely affected by pollution, and with a more frequent occurrence of red tide.

(3) Deteriorating wastes pollution. The quantity and types of wastes have significantly increased with population growth, economic development, improved living standards and consumption level and the change of living style in Asia (Figure 2.7). This has resulted in larger pollution areas and degrees and caused severe problems to human health and environmental protection, making the waste management one of the major challenges facing some cities and the whole Asia.

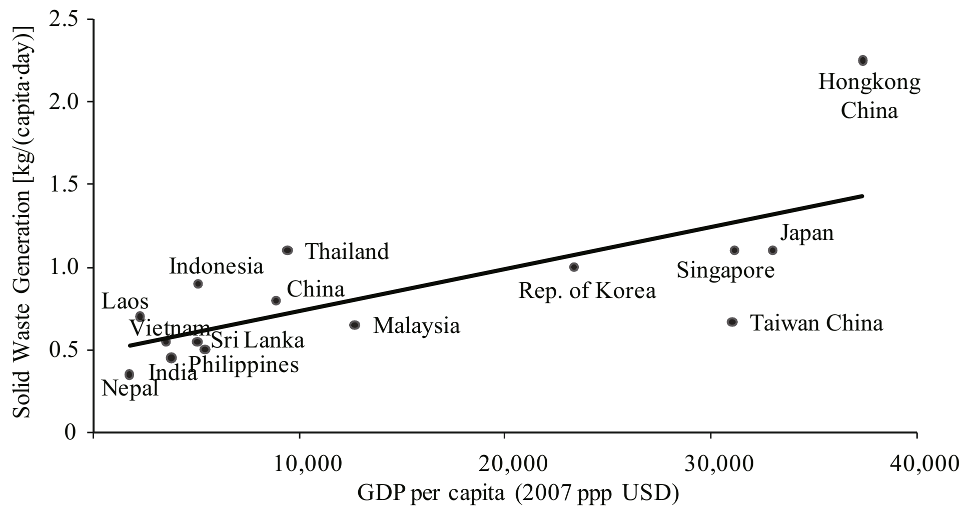

Figure 2.7 The relationship between solid waste generation and GDP per capita in typical Asian economies

(Source: Based on A.V. Shekdar, 2009)

While the wastes, in particular the urban wastes, in Asia are generated at a too fast speed, and the capacity and approach of treating such wastes still lag behind, leading to the pollution of land and underground water resources, and posing a great threat to human health. This is particularly true in the urban areas in the developing countries in this region.

The illegal trans-boundary transfer and circulation of used materials and hazardous waste has become a major source to threaten environmental health in Asia. Most Asian countries have signed the Basel Convention on Hazardous Wastes, which bans the transfer of hazardous materials and controls the movement of some waste materials. However, the effectiveness of implementing the Convention has been reduced due to the different domestic legal and administrative systems in different countries. This has resulted in serious illegal transfer of electronic and other hazardous wastes to Asian countries, and has posed new challenges in environmental protection and human health for this region. Each year, approximately 90% of the global electronic wastes, mainly generated by US, Japan, UK and EU, are transferred to Asian countries, including Cambodia, China, India, Myanmar, Pakistan, Indonesia, and Turkey. As the electronic wastes are often disassembled and recycled in the small-sized workshops, they usually threaten the local environment and people's health due to poor technologies and unwise use of such wastes.

In addition, Asia is confronted with serious soil pollution, which has reduced soil quality and threatened food security in the region.

2.2.5 Energy security and energy environmental problems in Asia

A continuous supply of sufficient, reliable, convenient, affordable, clean and low-carbon energy is a prerequisite for sustainable social and economic development in Asia. With the exception of OPEC countries, other countries in this region (particularly EastAsian countries) face unprecedented challenges in energy and environment security due to rapidly increasing energy demand, growing external dependence, rising oil prices and the transition towards low-carbon energy.

(1) Rapidly-increasing energy demand puts intense pressure on energy supply. With the growth of population and economy and the advancement of industrialization and urbanization, energy demand in Asia is rapidly increasing. From 1990 to 2007, Asia's GDP registered an average annual growth of 3.52%. Its energy consumption witnessed an average annual growth of 2.80%, 1% higher than the global average growth rate over the same period, but Asia's energy production grew at an average rate of 2.46% annually—lower than the growth rate of energy demand. At the same time, the proportion of Asia's energy consumption to the world total is climbing, rising from 39.8% in 1990 to 46.7% in 2007 (Figure 2.8). Additionally, energy consumption per capita in Asia at present accounts for only about 75% of the world average; the potential for further growth is enormous. Anyway, it would be a major challenge to ensure a sustainable energy supply to satisfy Asia's ever-increasing energy demand.

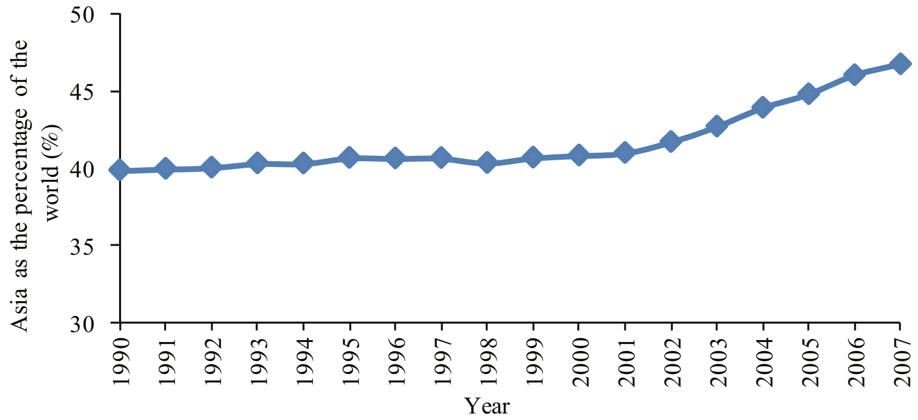

Figure 2.8 Asia's share of total world energy consumption (1990-2007)
(Source: World Bank, 2010)

Asia's energy demand in the future will continue to rise. According to IEA (2006) forecasts, the growth rate of primary energy demand in the Asia-Pacific region will slightly slow down from 2007 to 2030; the average annual growth rates of South Asia, East Asia, Central Asia and West Asia will be 3.5%, 2.4%, 2.8% and 2.6%, respectively, which would still be much higher than the global average. In 2030, the Asia-Pacific region, particularly China and India, is expected to generate over 70% of newly-increased global primary energy demand. This would completely change the world energy consumption pattern and make Asia the center of global energy consumption. By then, the share of the Asia-Pacific region's primary energy demand in global energy consumption will have exceeded 50%. The major driver for Asia's primary energy demand will be the development needs of the power sector.

(2) Energy supply and demand is regionally and structurally unbalanced, and dependence on foreign oil and gas will continue to grow. On the whole, Asia produces more energy than that which is consumed. However, energy resources across the region are unevenly distributed and Asian countries differ greatly in their energy endowment. There exist regional and structural conflicts in Asia's energy supply and demand.

From a regional perspective, energy in East Asia and South Asia is characterized by short supply, low self-sufficiency rates (i.e., the ratio of energy production to energy consumption), and dependence on imports (Figure 2.9). By country, in 2007, 22 Asian economies produced less energy than needed; among these countries, Turkey, China, India, Rep. of Korea and Japan had a large gap between supply and demand. Self-sufficiency rates in 15 economies are less than 60%, and external dependence is heavy (Figure 2.10).

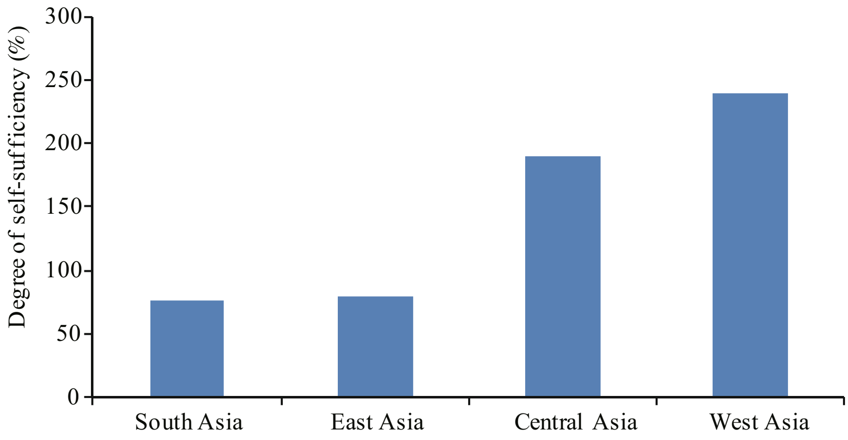

Figure 2.9 The degree of self-sufficiency of energy in sub-regions of Asia

(Source: World Bank, 2010)

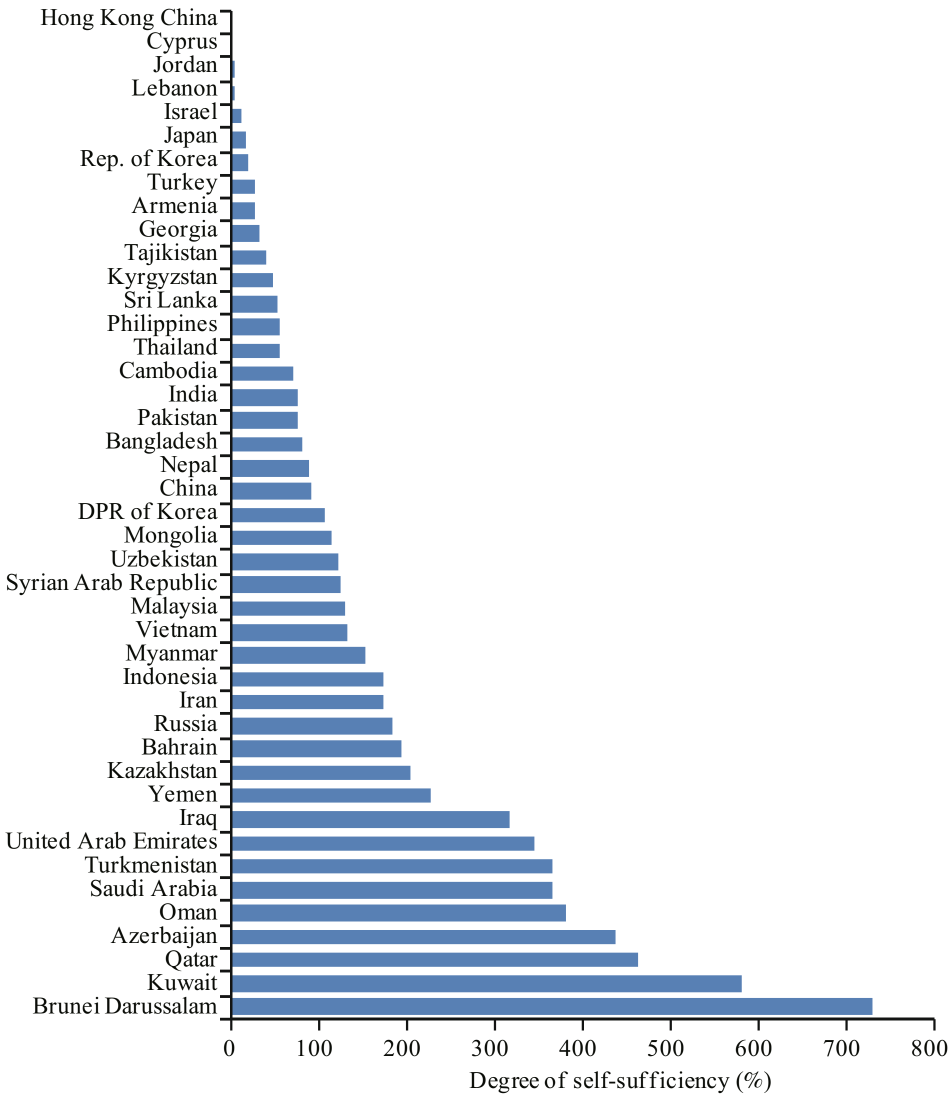

Figure 2.10 The degree of self-sufficiency of energy in Asian economies

(Source: World Bank, 2010)

In terms of the structure of energy varieties, in 2007, oil production in East Asia could satisfy only 32.3% of the region's consumer demand and South Asia's dependence on foreign oil was as high as 75.5%. Gas and coal also needed to be, in varying degrees, imported from outside the two regions. Even in West Asia, where oil and gas resources are rich, a certain amount of coal imports is needed every year. It is predicted that the Asia-Pacific region's external dependence on oil and gas will continue to rise in 2030. Developments in the power sector will bring coal and gas demand forward and rapid advancements in the transport sector will push oil demand ahead. By 2030, other Asian regions, with the exception of West Asia and Central Asia, will continue to import coal, oil and gas; external dependence on foreign oil will have reached 84.4%.

(3) Inefficient use of energy aggravates the imbalance between supply and demand. By and large, Asia's use of energy is extensive, resulting in low energy efficiency (Figure 2.11) and putting great pressure on energy supply. Since 1990, Asia's energy intensity (i.e., energy consumption per unit GDP) has been on the decline, while China's energy intensity has come down by over 50%, which indicates that Asia's energy efficiency is improving. Nevertheless, this energy intensity rate is still about 50% higher than the world average level.

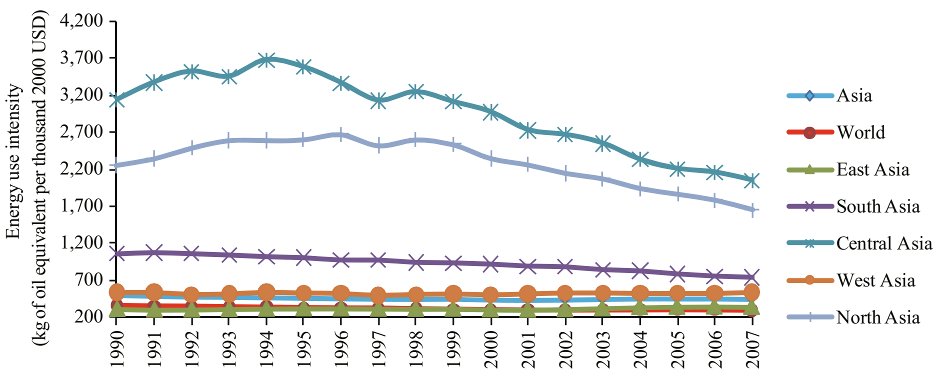

Figure 2.11 The variation in energy intensity between Asia and World (1990-2007)

(Source: World Bank, 2010)

The energy intensity in all sub-regions of Asia exceeds the world average level, with Central Asia being at the top and followed by South Asia, West Asia and East Asia, where energy intensity is 7, 6, 2.5, 1.8 and 1.2 times the world average level in 2007. Only 6 economies in Asia, including Japan, Hong Kong China, Israel, Lebanon, Singapore, Cyprus and Turkey, have an energy intensity level lower than the world average. Energy intensity is in inverse relation to economic development, i.e., the higher per captia GDP, the lower energy intensity (Figure 2.12).

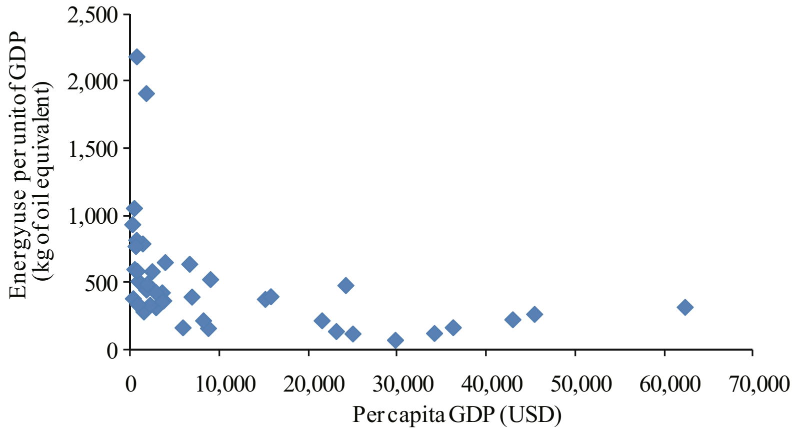

Figure 2.12 The relationship between energy use intensity and GDP per capita of Asian economies in 2007

(Source: World Bank, 2010)

(4) Fluctuation of energy prices endangers energy security. Due to their heavy dependence on fossil fuel, most areas in Asia are highly vulnerable to the fluctuation of energy prices. In 2008, fossil energy consumption in the Asia-Pacific region accounted for 91.7% of its total energy consumption, a percentage which will rise as high as 82% in the year 2030 (BP, 2009). Because of the impact of the Asian market and other elements, world oil prices have been fluctuating markedly and keeping at a high level. This poses a direct threat to energy and economic security in Asia. The least developed countries, landlocked developing countries, small island developing states and other fossil fuel importers in Asia are particularly vulnerable to price fluctuations (UNESCAP, 2008).

Since the significant fall in the 1980s, crude oil price has been kept at a low level for two decades. In the 21st century, owing to the tight supply of oil, geo-political instability and other factors, oil price soared from 25 to 100 USD per barrel within a few years and, in 2008, rose sharply to 147 USD per barrel. In 2009, as a result of the impact of the financial crisis, world oil price went down slightly. But with the recovery of the economy, oil price is expected to rebound to $100 USD per barrel in 2020 and to $115 USD per barrel in 2030 (IEA, 2009). The era of cheap oil will have ended. Future high-level operation of oil price will mean that Asia must pay a lot for oil imports. After 2025, Asia will have 3 of the 4 largest oil importers in the world, that is, China, India and Japan (IEA, 2009). Sustainable energy development can reduce vulnerability to energy price and safeguard energy security in Asia. Its significance cannot be underestimated.

(5) A huge gap in infrastructure construction funds weakens support capabilities for energy security. To satisfy Asia's ever-increasing energy demand and safeguard energy security for Asian countries, the construction of energy infrastructure must be strengthened. This is a basis and also a prerequisite. Whether or not sufficient funds can be supplied for the construction of energy infrastructure is one of the key factors that ensures energy security. According to the baseline scenario reported by UNESCAP, in 2030, $9 trillion is expected to be spent in enlarging and building a modern energy system in the Asia-Pacific region (UNESCAP, 2008). If the Middle East is included, about $10 trillion (calculated on the basis of the value of USD in 2008) will be needed (Table 2.6). Normally, the government alone cannot close this huge financing gap. The public sector and the private sector must cooperate in raising the necessary capital, or, even make use of carbon finance. This will inevitably pose great challenges to the present energy management system and energy policy.

Table 2.6 Cumulative investment in energy-supply infrastructure in Asia (2008-2030) (Unit: billion US$ in year 2008)

Region	Coal	Oil	Gas	Power	Total
East Asia[1]	355	776	758	4,579	6,490
South Asia	66	184	273	1,740	2,269
Middle East	1	903	577	479	1,960
Central Asia	9	240	139	237.5	626
Asia	431	2,103	1,747	7,036	11,345

Note:

1. China + ASAN (Association of Southeast Asian Nations) + OECD Pacific (Japan + Rep. of Korea + New zealand + Australia)

Source:

Based on IEA(2009) and UNESCAP (2008)

(6) The task to eliminate energy poverty is challenging. In Asia, although the per capita energy consumption level is low, it also varies greatly among different countries. The whole region, particularly South Asia and East Asia, faces a prominent problem of energy poverty, which means that a large proportion of its population do not have basic energy services. According to IEA estimates (2009), so far about 22% of the world population, or 1.5 billion people, cannot access clean, cheap, and reliable commercial energy and the majority of these people live in Asia. In South Asia, approximately more than 42% of the population, or 630 million people, rely on traditional biomass such as charcoal, firewood, crop waste and cattle manure in cooking and heating, and 700 million rural residents and 160 million urban residents do not have access to electricity (UNESCAP, 2008). In East Asia, 195 million people at present do not have commercial energy, although economic developments have enabled many to enjoy its benefits (IEA, 2009).

Having no access to commercial energy is one of the important factors that bear on employment, productivity, education and health (IEA, 2009). Asia is populous and is undergoing the process of modernization. It therefore has become a pressing and daunting task to enlarge the use of modern forms of energy among poor people in Asia. To enable more people to use commercial energy, input must be increased. This will not only improve the quality of life (QOL) among local people, but also liberate a large part of the working force, particularly women and children, from the traditional work of looking for firewood so that they can engage in other activities. Furthermore, teenagers will be able to learn at night and educational resources will be more fully utilized. Anyway, promoting the use of commercial energy among poor people will lead to the increase of total energy consumption.

(7) Energy environmental problems pose new challenges to energy supply and demand. Energy production and energy consumption in Asia has brought about serious energy environmental problems, which include environmental pollution and emissions of carbon dioxide. Coping with these problems, especially climate warming, poses tougher challenges to future use of energy.

As a major source of energy in Asia, coal has determined the whole production process, choice of technology and efficiency; meanwhile, it has brought about dire environmental pollution (Wang et al., 2008). In 2008, Asia's coal consumption accounted for 51% of its total energy consumption, oil 29.7%, and gas 11.0%, whereas the global average levels of these energy varieties were 29.2%, 34.8% and 24.1% (BP, 2009). The main causes for the aggravation of air pollution in many Asian cities are Asia's increasing energy demand, increased vehicle ownership and a coal-dominant energy structure in some countries. In China, coal consumption approximately accounts for 70% of its total energy consumption. Coal-smoke pollution brought about by China's coal-dominant energy structure is the main reason why SO_2 and TSP levels are so high in Chinese cities. In 2006, the Chinese government adopted a tough "energy conservation" policy and stepped up its efforts in developing renewable energy sources and low-carbon energy technology (CAS Sustainable Development Strategy Study Group, 2009).

With the rapid increase of fossil fuel consumption, CO_2 emissions in Asia grew dramatically. Since 1990, the average annual growth rate of CO_2 emissions in Asia has been more than doubling the world average; 88.1% of increased global carbon emissions is generated in Asia; and the increased carbon emissions in non-OECD Asian countries (including the Middle East) accounts for 79.1% of increased global emissions. In 2006, the percentage of Asia's total CO_2 emissions in the world total reached 42.8%, 13.4 percentage points higher than 1990. By then, Asia will have 4 of the world's 10 largest greenhouse-gas emitters—China, India, Japan and Rep. of Korea.

In the next two decades, Asia's CO_2 emissions will continue to rise substantially, thus making Asia the leading driver of increased global CO_2 emissions. According to IEA (2009) estimates, from 2007 to 2030, 88.5% of increased global CO_2 emissions will be brought about by increased emissions in non-OECD Asian countries. Even when the Middle East—which is highly dependent on oil resources—is excluded, CO_2 emissions in other countries and regions will still account for 78.7% of the increased global total. In 2030, CO_2 emissions generated by energy consumption in the Asia-pacific region is expected to account for 55% of the world total (UNESCAP, 2008).

The whole world is attempting to find a solution to the problem of climate change. The continued growth of CO_2 emissions in Asia and its share in the world total have put greater international pressure on the region to reduce carbon emissions. China and India fall in for the major share of the responsibilities. In view of the fact that Asia's energy development pattern lacks in sustainability, efforts must be made so that the transition to a sustainable low-carbon energy system could be achieved. This entails change, remolding and adjustment of the present relation between energy supply and demand. Improving efficiency and developing clean and renewable energy sources is of great significance for Asia's energy security and the efforts to counter climate change and environmental pollution. As agreed at the 2010 Boao Forum for Asia (BFA), low-carbon energy sources and green development are Asia's opportunities to push the world economy ahead (Xinhua News Agency, 2010).

2.2.6 Increasing Sensitivity and Vulnerability to Natural Disasters and Climate Change

Greenhouse gas emissions in Asia contributes to global climate change, which in turn, affects a wide range of areas in Asia such as the ecological system, health, production and life. According to the 4^{th} assessment report by IPCC, the rate at which Asia became warmer over the last century surpassed those of other continents. As the most populous and fastest developing continent where the natural environment has a weak basis, Asia is becoming the most vulnerable region to the threat of global warming. If the temperature continues to rise, Asia will have more droughts and floods and freshwater and food will be in short supply. Some densely populated river deltas, where agriculture is well developed, will be endangered. Undoubtedly, the poorest countries, regions and people will be affected the most. Due to regional and ecological differences, the problems and challenges posed by climate change in all Asian sub-regions are different in kind, range and degree (IPCC, 2007a).

On the whole, Asia's vulnerability and sensitivity to climate change is mainly manifested in the following respects:

(1) Extreme weather events mount in frequency and intensity. Climate change causes frequent meteorological disasters like flood, hurricane and draught through its influence on the global hydrothermal pattern. Since the 1990s, extreme weather events, which include heat wave, tropical storm, long-term draught, strong rainfall, cyclone, snowslide, thunderstorm and serious sandstorm, have been mounting in frequency and intensity (IPCC, 2007a) and threatened economic development and personal safety.

(2) Asia is vulnerable to the impact and destruction of natural disasters. Between 1975 and 2005, the number of natural disasters in Asia, one of the most disaster-prone regions, represented only 37% of the world total, but destruction and losses were enormous. The number of people affected took up 89% of the world total, the number of deaths 57% and economic losses 44% (CRED-EMDAT, 2005) (Figure 2.13).

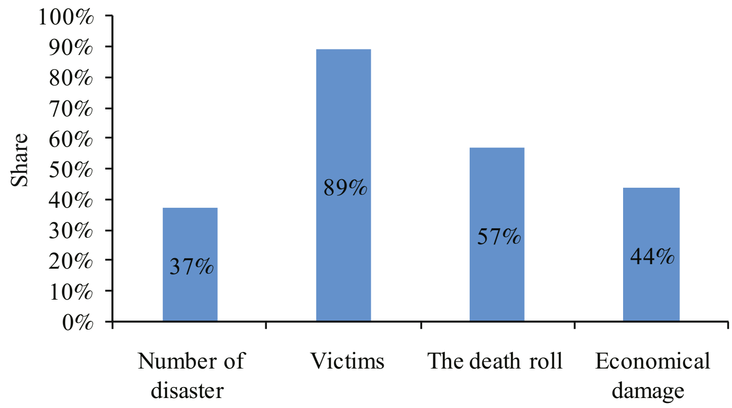

Figure 2.13 Share of global natural disaster damages in Asia (1975-2005)
(Source: CRED-EMDAT, 2005)

(3) Water resources security is seriously threatened. In most areas of Asia, the demand for water resources is greater than supply. Approximately over 1 billion people are likely to experience the negative effects of water resources change caused by climate change. Water resources are already in short supply. Over the long run, saline alkali land expansion caused by glacial ablation and sea level rise will make this situation even worse. The decrease of freshwater resources has a number of consequences—grain reduction, lowering of living standard, large-scale domestic and overseas migration, geopolitical pressure and instability—which will have a far-reaching influence on the security of Asia (UNESCAP, 2009).

(4) Food security faces a serious challenge. Temperature rise and the increase of extreme weather events caused by climate change are likely to have a negative effect on crops production and livestock farming, making it difficult to maintain a continued supply of food. In Asia's arid and semiarid regions, the intensity and frequency of draught is escalating and land deterioration is continuing. These have constituted a grave threat to food security in these areas. In 2050, grain production in Central Asia and South Asia is projected to drop by 30% (IPCC, 2007a) and the campaign aimed at eliminating famine for several hundred million people in these areas will be affected.

(5) Health risks are increasing. The incidence and mortality rate of heart diseases and respiratory tract diseases triggered by heat wave are mounting. The problem is most obvious among poor people in developing countries. Extreme weather events provide infection environments for malaria, dengue fever, cholera, encephalitis and other contagious diseases. As a result, more harm is indirectly done to people's health. Climate warming and air pollution have increased the probability of vector borne diseases, temperature-sensitive contagious diseases, anaphylactic diseases and pollution exposure diseases in Central Asia, East Asia, South Asia and Southeast Asia.

(6) Ecosystem degradation is worsening. Climate change has transformed the heat cycle and the hydrological cycle, exerting great stress onto the structure and function of Asia's ecosystems. The terrestrial ecosystems and the marine ecosystems are undergoing more marked transformations. As a result of climate change, glaciers and permafrost in East Asia and South Asia are shrinking at a fast speed. In the Himalayas, 67% of the glaciers are receding at an astonishing rate. As a result of sea level rise, coastal lowland is being flooded, sea water encroachment is expanding, and coast erosion is worsening. Asia's semiarid regions are in the process of becoming arid regions (Ma and Fu, 2005). Land is deteriorating, sandstorms are getting stronger, productivity of land is going down, and wetland and oasis are declining. If global warming worsens, the ecosystems in areas sensitive to climate change will be in grave danger: there will be more and stronger extreme weather events, biodiversity loss and ecological degradation.

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3 Drivers of Environmental Changes in Asia

3.1 Environmental changes and drivers in Asia

Environmental changes are often related to natural and human-induced factors. Under the context of fast growth in Asia, the human-induced factors play a crucial role in understanding and addressing the environmental problems in the region. Human-induced factors include both direct and indirect ones. The direct factors consist of land use, resources exploitation, pollutant discharge, while the indirect ones are composed of population growth, economic development model, technology change, social institutions and social-political frameworks, and value systems, among others. The trend of environmental changes often depends on these indirect factors. As a result, assessing the changes of these factors can not only help predict the future trend of environmental changes, but also affect their future trend by changing these factors.

For this reason, most of the drivers are indirect and underlying ones, whose change will also reflect the socio-economic process that affects the environmental conditions. It should be noted, however, the features and importance of these drivers vary within and among the countries and regions (UNEP, 2007), especially between the developed and developing countries.

Zbicz et al. (2009), in *Asia's Future: Critical Thinking for a Changing Environment*, defined six primary drivers identified as most affecting Asia's future environment in immediate future and in the next 10-20 years, i.e., rapid economic development and rising living standard, globalization of trade and demand for Asian natural resources , rise of Asian science and technology, exploding energy demand in Asia and globally, projected effects of climate change and Post-Kyoto Protocol mitigation approaches, continued population growth and urbanization. This research reflected the fundamental trend of socio-economic development and environmental changes in Asia.

Assessing the major drivers of environmental changes in Asia provides basis for policy design, and for addressing environmental problems in the region. Many studies have already been undertaken on the drivers of environmental impact, one of which is the IPAT Equation, a Simple Conceptual Model that explains the impact of human activities onto the environment (Ehrlich et al., 1971; Commoner, 1972). The Equation describes the human impact on the environment as a combined result of population growth, economic growth and technical change. Although it has been widely used, it still fails to cover all the possible drivers, some more specific drivers and new drivers such as climate change.

To give a broader picture on the basic trend and its major drivers of environmental change in Asia, the report, in addition to the above-mentioned drivers, also takes into account other factors, such as population structure, urbanization process, the transformation of consumption model and living style, investment demand and orientation, international trade and globalization process, industrialization or economic restructuring, as well as policy and institutional changes.

3.2 Analysis of drivers of environmental changes in Asia

3.2.1 Population growth

Population growth is known as a key driver of environmental changes. In general, when other conditions remain unchanged, the expanding population will often increase the human needs for food, water resources and energy and lead to more wastes, which, in turn, produce a greater pressure on natural resources and the environment.

With the largest population size and percentage, Asia is also the most densely populated region in the world, with its population density well above the world average level. Presently, more than 4 billion people live in Asia, accounting for over 60% of the total population worldwide. Since the middle period of last century, the population in the region has been growing at a fast speed. The statistics of UN (2008) indicate that, from 1950 to 2005, the population in Asia rose sharply from 1.4 billion to 3.9 billion, with an annual growth rate of 1.9%, high than the world average level of 1.7%. It is predicated that although its population growth rate may slow down in Asia in the next four decades, its total population in the region may reach up to 5.2 billion by 2050 (medium variant), up 33% compared to 2005, and representing 57% of the world population (UN, 2008) (Figure 3.1 and Table 3.1).

The huge population size and its continuous growth is putting the resources and environment in Asia under increasingly heavy and lasting stress. On one hand, the per capita share of some key resources in Asia, e.g., farmland, freshwater and non-ferrous metals, is well below the world average level. It is most likely that this figure tends to decline with the further growth of population in the region. On the other hand, with the rising living standards, the per capita consumption of various resources and energy in Asia will continue to grow, although at a low level at present, thus aggravating the tight supply of resources in the region. This situation will be made worse as a large number of poor people in the region will compete for the limited resources to make a living.

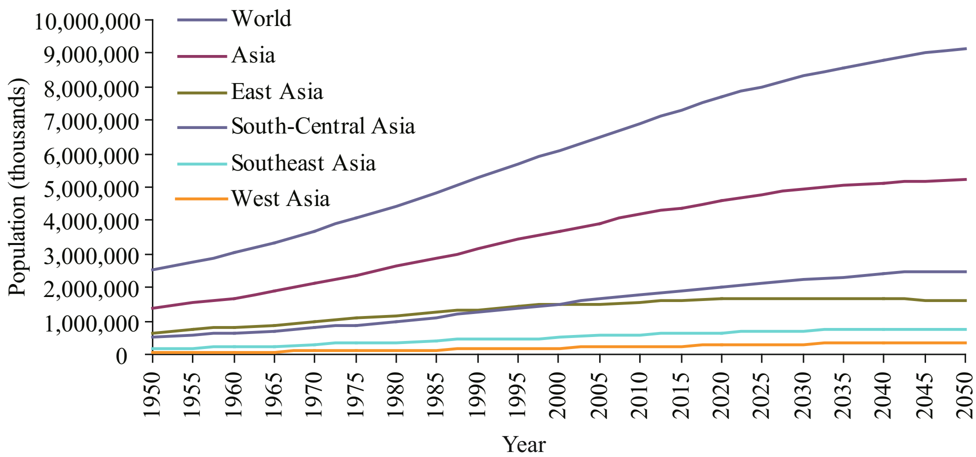

Figure 3.1 The trends of population in Asia and the world

(Source: UN, 2008)

Table 3.1 The trends of population growth rate in Asia and the world (Unit: percent)

Region	1950-2005	2005-2050
East Asia	1.5	0.1
South-Central Asia	2.1	0.9
Southeast Asia	2.1	0.7
West Asia	2.6	1.3
Asia	1.9	0.6
World	1.7	0.8

Note:

According to the Categorization System of UN (2008), East Asia only refers to Northeast Asia, while South-Central Asia includes South Asia and Central Asia, and Russia is excluded from Asia.

Source:

UN, 2008

The features of population growth and their contribution to the environmental change in each sub-region vary within the Asian region. As for the relatively poor countries and areas, too fast population growth may place greater pressure on the environment and accelerate the environmental degradation in the region.

3.2.2 Urbanization

Most of the developing countries in Asia, represented by China and India, are currently on a large-scaled and fast track of urbanization. From 1950 to 2005, the population living in the urban areas in Asia grew 3.6% annually, higher than the world average of 2.7%, and only next to Africa. At present, more than 40% of the population in Asia live in the urban areas, although still at a lower level compared to other continents (Figure 3.2).

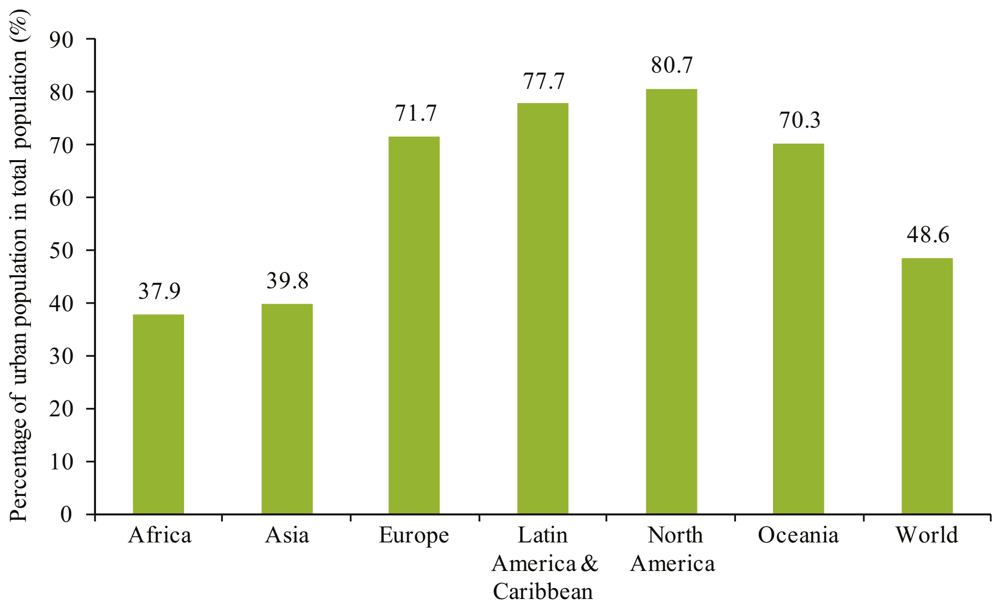

Figure 3.2 Comparison of urbanization between Asia and other continents in 2005
(Source: UN, 2008)

It is predicated that in the next four decades the population living in the urban areas worldwide will increase by 3.1 billion, of which, 1.8 billion will come from Asia, accounting for 58%. By 2050, the urbanization rate in Asia is expected to reach approximately 65%. By sub-region in Asia, the speed of urbanization varies significantly. In 2005, West Asia ranked first with an urbanization rate of 65%, which was followed by East Asia, with a figure of 46%. Except West Asia, the average urbanization rate of other sub-regions in Asia is lower than the world average level (49%). It is forecasted that by 2050 the urbanization rate in East Asia, West Asia and Southeast Asia will reach up to 74%, 80% and 65%, respectively (UN, 2008) (Figure 3.3).

While the large-scaled, fast expanding urbanization in Asia can improve the living and working conditions of the urban population, it may also bring about strong impacts on the environment in these areas. The large concentration of population in urban areas often results in large consumption of water resources and energy and other living materials, as well as the heavy discharge of pollutants, which, in turn, significantly increases the demand for various infrastructure in the urban areas. The water consumption of a typical urbanite generally triples that of a resident living in the rural areas (UNESCAP, 2006). Due to the too rapid growth of urban population, in case no sufficient investment on urban infrastructure development has been made and strong actions on pollution prevention and control have been undertaken, many problems may emerge in the urban areas, such as the over-exploitation of underground water, reduced air quality and energy-related problems including carbon emissions.

Similarly, the sprawl of many cities in Asia has not only occupied and wasted a large number of land and farmland, exacerbated the short supply of farmland resources, but may lead to a series of ecological problems such as the reduced capacity of fighting against natural disasters (e.g., flood) and loss of biodiversity. This has already become true in many Asian countries.

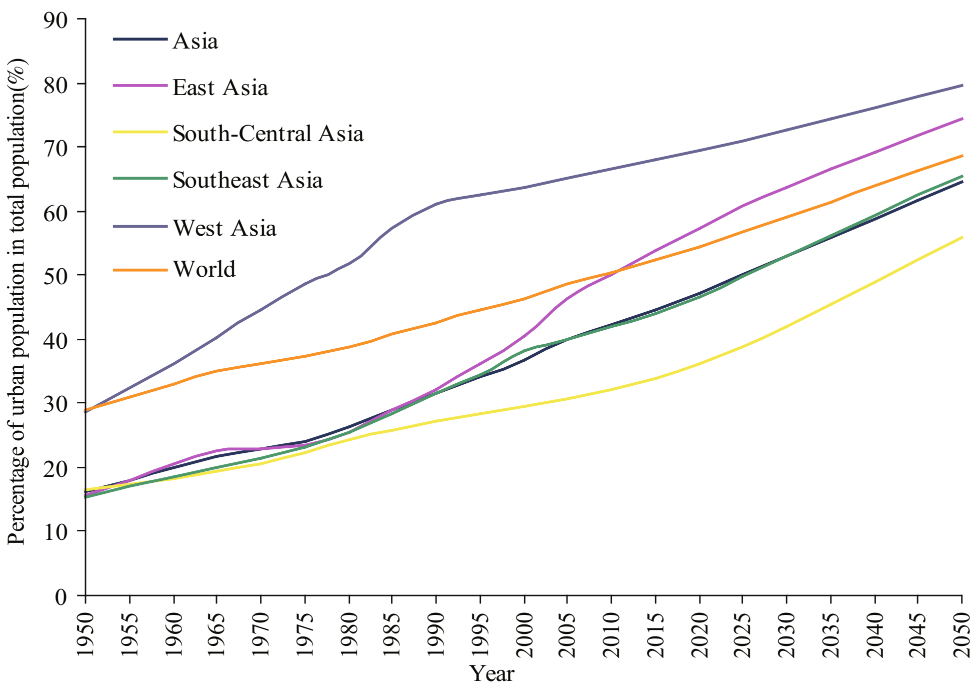

Figure 3.3 The trends of urbanization in Asia and the world

(Source: UN, 2008).

3.2.3 Consumption

With the fast economic growth, the consumption level and living standards of various countries in Asia have been steadily improved. Between 1960 and 2007, the household final consumption expenditure per capita in East Asia & Pacific region grew 4.5% annually, more than doubling that of the world average of 1.9%. However, the figure in South Asia was only 1.5%, lower than the world average (World Bank, 2010) (Figure 3.4).

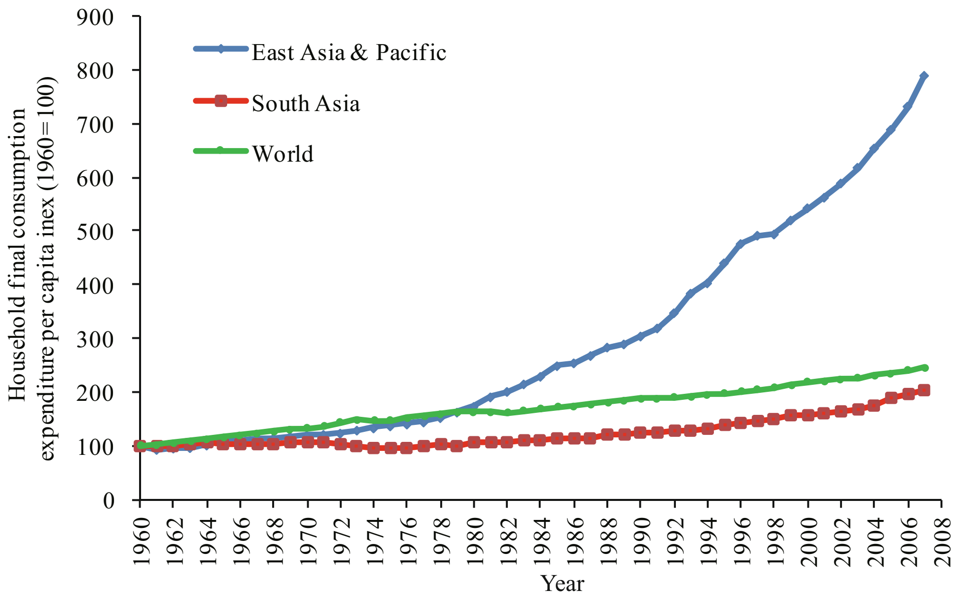

Figure 3.4 Household final consumption expenditure per capita (Source: World Bank, 2010).

Although the consumption level in Asia has been significantly enhanced, it is still well below the world average. In 1960, the household final consumption expenditure per capita in East Asia & Pacific region was only approximately 1/17 of the world average level. That figure was narrowed to 1/5 in 2007. During the same period, however, the gap between South Asia and the world average level had been expanding. In 1960, the household final consumption expenditure per capita in South Asia accounted for 1/8 of the world average level, but that figure was widened to 1/9 in 2007.

With the steady improvement of the consumption level and living standards, the pollutants discharged by the urban and rural residents have increased significantly, while the upgrading of consumption structure has also placed greater pressure on the environment. In terms of food structure, the rising demands of the Asian people for meat, eggs and dairy products have already transformed the traditional food structure that focused on grain and starch, which, in turn, puts the land use under greater stress, leading to some environmental problems such as deforestation, water and soil erosion, and biodiversity loss. By consumption structure, the substantially growing needs of the Asian inhabitants for electric appliances, housing and autos have stimulated the demands for energy and promoted further development of related heavy and chemical industries, which brings more pressures on the environment. For instance, the passenger car per 1,000 people in East Asia & Pacific region increased sharply from 13.5 units in 2002 to 23.4 units in 2007 (World Bank, 2010). In addition, the unsustainable consumption practice in the western countries has not only had a negative impact on the traditional, thrift-based consumption model in Asia, but on environment in the region.

As the per capita consumption in many Asian countries is lower than the world average level, the consumption growth to improve the living standards is understandable. However, if the existing consumption model in Asia is not transformed into a sustainable one, its limited resources, energy and environmental capacities may not meet the growing material needs of the people in the future.

3.2.4 Economic growth

As one of the most economically dynamic regions worldwide, Asia has been maintaining a relatively fast growth rate. Between 1990 and 2007, Asian economy grew 3.5 annually, higher than the world average of 2.9%. This also increased the percentage of Asian GDP in the world from 25.6% in 1990 to 27.7% in 2007. Of particular note are China and India, the two countries with the largest populations in Asia, whose GDP expanded by 10.4% and 9.6% respectively during the same period. Since 2008 when the world economy was severely hit by global financial crisis, Asia has become a major force in leading the global economic recovery with its strong growth.

As many countries and areas in Asia base their growth on expanding inputs on production factors and mainly depend on exports, this kind of growth is, to some extent, achieved at the cost of increased resources consumption and environmental degradation. For example, in 2007, Asia's GDP accounted for 27.7% of the world level, while consuming 46.7% of the primary energy, 64.3% of the finished steel, 53.9% of non-ferrous common metals, 66.0% of cement (2008), 66.2% of fresh water resources, 76.3% of ozone-depleting substances, and contributing 50.7% of CO_2 emissions from fuel combustion and 39.0% of consumption ecological footprint of the world level (Table 3.2).

Table 3.2 The resources consumption and pollutant discharge between Asia and the world

Items	Asia	World	Percentage of the world (%)
GDP in 2007 (Million USD)[1]	15,290,606	55,117,261	27.7
Energy use in 2007 (kt of oil equivalent)[1]	5,447,107	11,664,302	46.7
Apparent consumption of finished steel in 2007 (Thousand metric tons)[2]	784,772	1,221,014	64.3
Consumption of non-ferrous common metals in 2007 (Ten thousand metric tons)[3]	4,123.6	7,650.5	53.9
Cement consumption in 2008(million tonnes)[4]	1,885	2,857	66.0

Continued

Items	Asia	World	Percentage of the world (%)
Annual freshwater withdrawal in 2007[5] (billion m^3)	2,494.1	3,765.3	66.2
Consumption of ozone-depleting substances (ODS)[6](ODP Tones)in 2007[*]	47,147.9	61,786.8	76.3
Carbon dioxide emissions from the consumption of energy in 2007[7] (million metric tons)	15,155.3	29,873.3	50.7
Total ecological footprint (million global hectares) in 2006[8]	6,667.7	17,090.7	39.0
N_2O emissions in 2000 (Gig grams)[9]	4,607.7	12,188	37.8
SO_2 emissions in 2000 (Gig grams)[9]	76,169.9	147,997.4	51.5

Source:

1. World Bank. World development indicators & global development finance database, 2010. http://data.worldbank.org/data-catalog
2. World Steel Association. Steel Statistical Yearbook 2008, Brussels, 2009
3. China Nonferrous Metals Industry Association, Editorial Board of China Nonferrous Metals Industry Yearbooks. China Nonferrous Metals Industry Yearbook 2008, 2009
4. Cement Industry in India: Trade Perspectives. http://newsletters.cii.in/newsletters/mailer/trade_talk/pdf/Cement%20Industry%20in%20India-%20Trade%20Perspectives.pdf
5. World Bank. 2010 World development indicators. Washington, DC, 2010
6. UNEP Ozone Secretariat. Data Access Centre. http://ozone.unep.org/Data_Reporting/Data_Access/.* Major ozone-depleting substances including CFCs, halons, carbon tetrachloride, methyl chloroform, HCFCs, HBFCs, bromine chloride, bromide, and other fully halogenated CFCs. ODP is the value of ozone depletion potential
7. EIA (U.S. Energy Information Administration). International Energy Statistics, 2010. http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8
8. Global footprint network (GFN). The Ecological Footprint Atlas 2009, 2009. www.footprintnetwork.org/atlas
9. UNEP Global Environment Outlook. GEO Data Portal. http://geodata.grid.unep.ch

Despite this, as the per capita resources consumption and pollutant discharge in Asia is far below that in other developing countries, and as the basic needs of a large number of poor people have yet to be met, improving people's living standards and promoting the economic growth should still be the policy objectives and priorities for the governments of many developing countries in Asia in the future. With the rising of emerging economies in Asia (e.g., China, India, Indonesia, and Saudi Arabia), the global production and consumption model is undergoing changes and transforming the global environmental and geopolitical patterns. For this reason, in the foreseeable future, on one hand, Asian economy will keep growing at a fast speed, placing greater pressure on the environment; on the other hand, the environmental improvement will bring new opportunities with the gradual transformation of the growth model in Asia.

3.2.5 Investment

The size and orientation of investment, as a major driver of economic growth, will also have far-reaching impact on the environment. Since the 1960s, the rising Asian economy has largely been driven by material or physical capital investment. The tradition of being thrifty in Asia, in particular East Asia, has brought high savings and investment ratios, which is considered a key source of promoting the ongoing, high-speed economic growth in the region. As Figure 3.5 shows, the contribution of investment is the highest for all the economies in Asia, generally at a percentage of over 40%, while the contribution of TFP (total factor productivity) is obviously low, which is also considered a major cause for low quality of economic growth, large resources consumption and serious environmental pollution in the region.

Currently, most countries in Asia are in the process of urbanization. Driven by the ongoing adjustment and upgrading of consumption structure, as well as the increasing domestic and international demands, investment in the industries of high consumption and high pollution (e.g., steel, chemical industry, non-ferrous metals and building material) has been expanding at a large scale in many countries. This has resulted in the fast growth of these industries and significantly enhanced production capacity, thus placing greater pressure on the environment of these countries. Moreover, as the demands for resources and energy are sharply rising due to the rapid economic development in Asia, many countries have increased their investment and production capacity in some basic industries such as energy and mineral resources, leading to a series of problems such as land degradation, deforestation, biodiversity loss and environmental pollution. This has undoubtedly put the environment in Asia under greater stress.

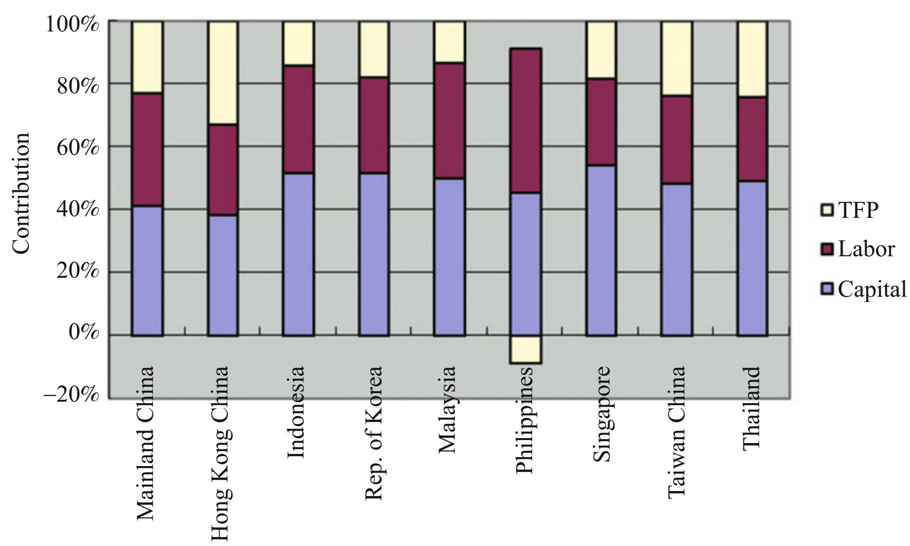

Figure 3.5 The contribution of investment, labor and TFP to economic growth in Asian economies (1960-1994)

(Source: Based on Crafts, 1998)

In addition, to address the financial crisis and stimulate their economic development, many countries and areas in Asia have been expanding their investment in traditional industries and large-scaled infrastructure while boosting their domestic demands, which brings larger costs and makes it more difficult for these countries and areas to transform towards a green economy in the future (Cai, 2009).

3.2.6 Economic globalization

Economic globalization is generally recognized as a fundamental trend of world economic development. The process of global economic integration can be promoted by enhancing trade and financial flow. The fact that various economies in Asia, in particular in East Asia, implement an export-oriented development strategy makes it possible for them to be quickly integrated into the globalization process, and to play an increasingly important role in world economy. For example, in East Asia & Pacific region, the percentage of merchandise trade in GDP in the region rose from 13.3% in 1960 to 68.0% in 2008, well above the world average level of 52.5% (Figure3.6).

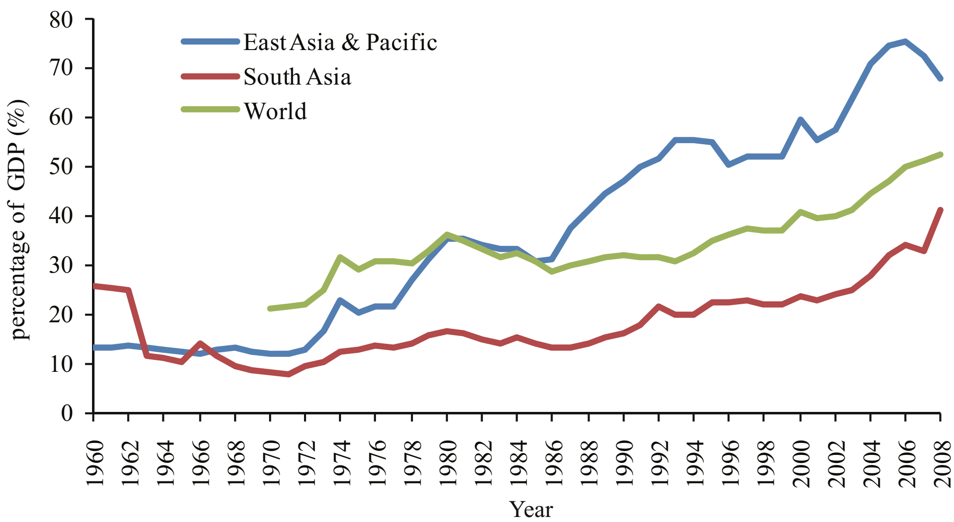

Figure 3.6 The trends of merchandise trade between Asia and the world (1960-2008)
(Source: World Bank, 2010)

While economic globalization has given an impetus to and provided opportunities for the economic growth in Asia, it has also brought potential pressures and challenges to the environment in the region. As the international trade has led to the global distribution of resources and specialized division of labor at the global scale, some countries and areas in Asia have been turned into the World's Factory due to the limit in terms of factor or resource endowment and technical conditions, providing low-cost and high-energy-consuming products and raw materials for the global market. This pattern has stimulated the development of high energy and raw materials consuming, and highly-polluted industries while bringing serious damage to regional environment.

Despite large trade surplus, these countries and areas in Asia have to suffer from large "ecological deficit" and fail to be compensated in additional funding and technical support.

In addition to international trade, foreign direct investment (FDI) has also placed great pressure on the environment in Asia. It is known as one of the regions worldwide that are mostly attractive to FDI. However, due to relatively loose criteria of environmental protection, incomplete supporting policies and poor regulation of the developing countries in Asia, the FDI in these countries is generally characterized by inappropriate structure and 'focusing more on quantity than quality' in the process of attracting FDI and undertaking industry transfer from the developed countries. This has not only transferred the environmental risks to the developing countries in Asia, but exacerbated the already tight supply of resources in these countries. Furthermore, with the adjustment and transfer of international industry structure, it has become very serious for the transfer of hazardous wastes from the western developed countries to developing countries in Asia through direct trading or smuggling, which also poses a major challenge to the environment in the region.

Overall, Asia's role as a global production center is a result of these countries' implementation of an export-oriented development strategy for a long time. Although this role has been weakened due to the sluggish demands from the international markets following the global financial crisis, it will remain unchanged in the long run. This also means that the pressure of economic globalization on Asia's environment will persist, which calls for these countries and areas in Asia to adjust themselves in order to adapt to the new situations of rising international trade protectionism and low-carbon growth at the global scale.

3.2.7 Industrialization or economic restructuring

The types of goods and services as a component of the industry structure vary at different economic development stages, which, in turn, results in the great difference of resources input and wastes generation. As for the industrialization process of the major developed countries in the world, their industrial systems successively underwent such stages as light industry, heavy and chemical industries, high-tech and service industries, and post-industrialization, with the industry structure being upgraded gradually. The stage of heavy and chemical industrialization, as a mid-stage in the process of industrialization, is considered indispensable (Liu et al., 2006).

In the early and middle stages of industrialization, the industrial sector is generally featured with large production, processing and consumption of raw materials and energy. It often has to experience a stage of resource and energy use and pollutants discharge concentration. With only a few exceptions (e.g., Japan, Singapore, Rep. of Korea, Hong Kong China and Taiwan China), most countries and areas in Asia are currently in the process of promoting industrialization, evidenced by the rapidly expanding production capacity, rising percentage of industrial value added in GDP, and the leading role of industrial sector in the national economic development (Figure 3.7 and 3.8). Some countries like China are in the process of heavy and chemical industrialization. The economic restructuring has, therefore, largely determined the basic characteristic of these Asian countries, i.e., the high concentration of resources and energy use and pollutants discharge in the process of economic development.

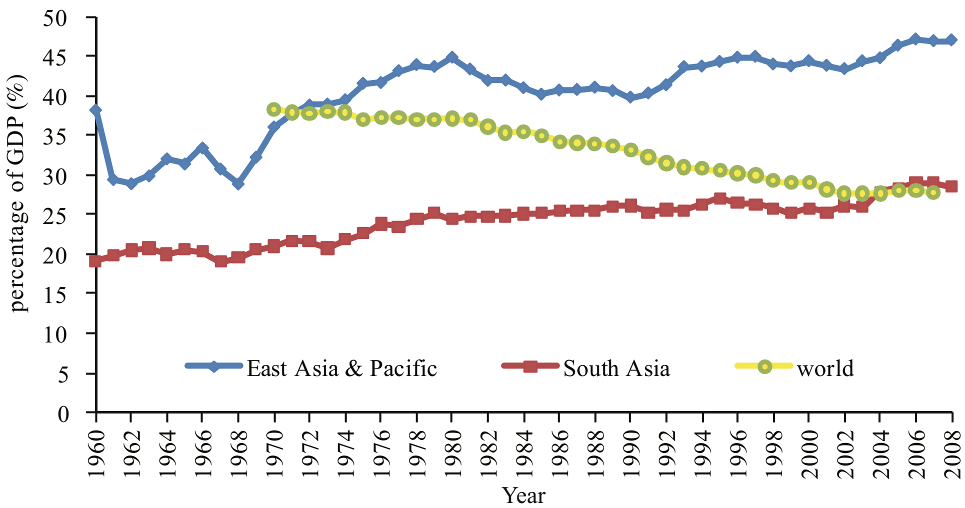

Figure 3.7 The percentage of industrial value added in GDP between Asia and the world (1960-2008)

(Source: World Bank, 2010)

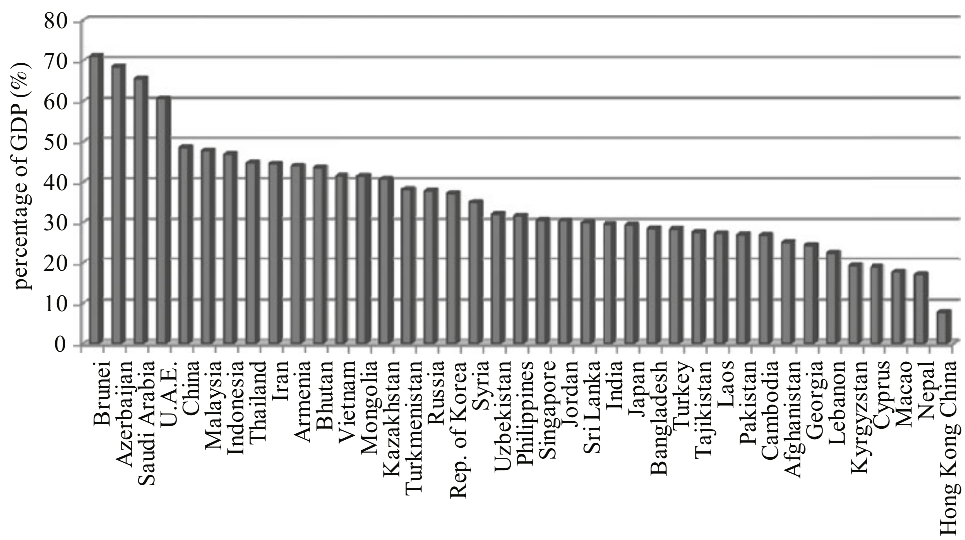

Figure 3.8 The percentage of industrial value added in GDP in Asian economies in 2007

(Source: World Bank, 2010)

Asia is known as a region mainly composed of developing countries. On one hand, it still has a long way to go to achieve its objective of industrialization and urbanization. On the other hand, these countries are required to make systematic and unremitting efforts to explore an innovative pathway according to their own domestic conditions so as to fulfill their objectives of industrial and economic transitions.

3.2.8 Institutional arrangement and transitions

Institutional arrangement can adjust and change the producers and consumers' behaviors, and, in turn, exert impacts on the socio-economic development and environmental protection. The political systems and institutional arrangement in different countries often have distinct effects on environmental change. Economically speaking, the environment problems are a result of the market failure. One of the measures to correct market failure is to enhance the government regulation and intervention. However, when the government intervention still fails to correct such a failure, it may even exacerbate the market failure and lead to the so-called "government failure", which also cannot help improve the environment. In this sense, the trend of environmental change in Asia is closely associated with the institutional arrangement of different countries in the region.

So far, significant progress has been made by the governments in Asia in improving their legislative and administrative systems to enhance their environmental performance (UNESCAP, 2006). These governments have not only developed and promulgated various national and local laws, regulations and standards on environmental protection, as well as the national environmental strategies or sustainable development strategies and action plans, but established environmental management organizations at national and local levels, and made available regional or global environmental collaborative mechanism. In addition, they have been actively involved in international actions through bilateral or multi-lateral environmental conventions (UNEP, 2007). Over the recent years, the cooperation within Asia region focusing on the shared environmental resources, enhanced environmental management and political security is on the rise, such as the dialogue and collaboration in Mekong river sub-region, ASEAN Agreement on Transboundary Haze Pollution, and the Coral Triangle Initiative (CTI) for the six coastal countries in Southeast Asia, to name just a few (Zbicz et al., 2009).

Despite this, many gaps still exist for most Asian countries in terms of resources and environmental management. These factors include lack of integrated policy-making mechanism on the environment and development, sector-based management and inefficient coordination between/among various economic and environmental agencies; poor capacity and influence of environmental authorities, including lack of expertise, tools, capacities of enforcement, coordination and monitoring; incomplete legal and policy tools; poor public participation, public awareness and education on environmental protection; insufficient supervision leading to corruption and other problems in environmental management (Zbicz et al., 2009). As for the transboundary, regional or global environmental issues, although cooperation in this area has been promoted, it is still featured with poor regional environmental management, and a strong mechanism on coordinating and addressing the cross-border environmental problems and conflicts. All these problems have posed severe challenge to the Asian countries in mitigating the pressures in terms of environmental quality and ecosystem health.

3.2.9 Technology change

In the long run, technology change often plays a decisive role in environmental evolution. As a double-edged sword, technology can liberate the human productivity while accelerating the depletion of natural resources and causing irreversible damages to the global environment. To achieve sustainable development, the next challenge is to wisely use the power of technology to "liberate" the environment from human interference (Grübler, 2003).

To some extent, the technological level determines the types and approaches of accessing natural resources, the production process, efficiency of processing and converting resources, the approaches of wastes generation in the process of production and consumption and their impact onto the environment, as well as the human management and regulation levels (Huang et al., 1997). Different technologies or technological clusters at different economic development stages often result in different environmental impacts.

As for the environment-friendly technologies, they have undergone such stages as high energy consumption and emission technologies and terminal treatment technology, clean production technologies focusing on process control and high environmental performance, ecologically-based product design and recycling technologies. Technology change is not exactly positively correlated with resource and environmental performance, i.e., the resource consumption or pollutant discharge per unit of GDP. Only with the guidance of favorable stimulative policies can the environmental performance be improved together with the technology change.

The technical change also depends on drivers of economic growth. For a long time, the overall economic and technological level in Asia has been kept low, and its economic growth has mainly been achieved on a basis of low-cost environmental input, large-scaled surplus labor supply, and failure of sharing the exterior environmental costs. As a consequence, Asian economy is characterized by extensive growth model and low productivity, leading to heavy resources waste and serious environmental pollution. With the rising economic development, the gradual loss of comparative advantages such as cheap labor force, and the increasing regulation of environmental policies, technical innovation is becoming a major driver of economic growth while transforming towards Energy Conservation and Pollution Reduction.

Over the last decade, many countries in Asia have increased their investment in R&D. Therefore, significant progress has been made in the technical R&D and application in terms of ICT, biotechnology, nanotechnology, Energy Conservation and Pollution Reduction. Some technologies on environmental protection, renewable energy and low-carbon, including wind power, geothermal energy, and solar energy, have been widely used in such countries as China, India and the Philippines. Thanks to the technology change, economic restructuring and policy improvement, the environmental performance in Asia has been enhanced to some degree, with the resources consumption and pollutant discharge per unit of GDP on the decline (Table 3.3). As shown in the table, the energy intensity, ODS consumption intensity, SO_2 intensity and ecological footprint intensity in Asia tend to fall, while that of the CO_2 emissions from fuel consumption and that of finished steel and non-ferrous common metals consumption are on the rise.

Comparatively speaking, the environmental performance level in Asia is significantly low, with its intensity of major resources consumption and pollutant discharge well above that of the developed countries and the world average (Table 3.4). The intensity of energy use, crude steel consumption, non-ferrous common metals, freshwater withdrawals, CO_2 emissions and ecological footprint in Asia is recorded to be 1.7, 2.3, 1.9, 2.4, 1.8 and 1.4 times that of the world average, respectively, indicating the extensive economic growth model in the region. Within Asia, the indicators in most of the countries in the region exceed those of world average, with a large gap between the developed countries.

To conclude, the environmental problems in Asia are mainly ascribed to its under-developed economic and technical condition, extensive economic growth model, and poor environmental performance. It is expected that the resources and environmental pressures in Asia will continue to grow in the future under the joint effects of the above-mentioned drivers. On one hand, addressing these challenges and promoting the transformation of its economic growth model into an innovation and green-based one provide new opportunities for Asia to achieve its sustainable growth. On the other hand, although the public awareness on environmental protection, scientific and technological level and governments' environmental management capacity in Asian countries have been steadily improved, it still takes a long time for Asia to significantly enhance its technological innovation, transformation and environmental performance. The only right pathway for the countries in Asia is believed to explore a win-win strategy to balance economic development and environmental protection while maintaining fast economic growth and attempting to achieve its goal of transforming its old growth model.

Table 3.3 The trends of intensity of main resources consumption and pollutant discharge in Asia (1994-2007) (1994=100)

Items	1994	1995	1998	2000	2002	2004	2006	2007
Energy use per unit of GDP	100.0	99.4	95.7	93.8	93.6	97.1	96.9	95.5
Carbon dioxide emissions from fuel combustion per unit of GDP	100.0	98.1	94.1	91.8	94.8	104.3	103.6	102.6
Non-ferrous common metals consumption per unit of GDP	100.0	112.3	106.6	125.5	136.9	157.0	167.3	180.0
Finished steel consumption per unit of GDP	100.0	99.3	91.2	100.4	118.3	148.1	150.6	159.1
Consumption of ozone-depleting substances per unit of GDP*	100.0	103.0	96.7	68.2	38.7	25.8	16.1	12.2
Sulfur dioxide emissions per unit of GDP	/	100.0	/	95.2	/	/	/	/
Footprint of consumption per unit of GDP	100.0	97.9	91.8	90.9	87.3	90.9	85.1	/

Source:

1. World Bank. World development indicators & global development finance database. 2010. http://data.worldbank.org/data-catalog
2. World Steel Association. Steel Statistical Yearbook 2008. 2009. Brussels
3. China Nonferrous Metals Industry Association, Editorial Board of China Nonferrous Metals Industry Yearbooks. China Nonferrous Metals Industry Yearbook 2008. 2009
4. UNEP Ozone Secretariat. Data Access Centre. http://ozone.unep.org/Data_Reporting/Data_Access/.* Major ozone-depleting substances include CFCs, halons, carbon tetrachloride, methyl chloroform, HCFCs, HBFCs, bromine chloride, bromide, and other fully halogenated CFCs. ODP is the value of ozone depletion potential
5. EIA (U.S. Energy Information Administration). International Energy Statistics, 2010. http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8
6. Global footprint network (GFN). The Ecological Footprint Atlas 2009. 2009. www.footprintnetwork.org/atlas
7. UNEP Global Environment Outlook. GEO Data Portal. http://geodata.grid.unep.ch

Table 3.4 The main resources consumption and pollutant discharge intensity of Asian economies and the world in 2007

Country/Region	Crude steel consumption/GDP (kg/thousand current USD)	Non-ferrous common metal consumption /GDP (kg/thousand current USD)	Energy consumption /GDP (kg/thousand current USD)	Carbon emissions/ GDP (kg/thousand current USD)	Annual freshwater withdrawals/GDP (m^3 / thousand current USD)	Ecological Footprint /GDP (global hectare/ thousand current USD)(2006)
Brunei	/	/	/	/	/	/
Cambodia	/	/	594.9	454.7	475.1	1.753
China	126.1	702.5	578.2	1846.9	186.4	0.924
Indonesia	18.7	149	441.4	931.4	191.7	/
Japan	19.6	103.9	117.2	288.2	20.2	0.121
Hong Kong China	19.1	22.7	66.4	400.5		/
Macao	/	/	/	126.5	/	/
Malaysia	59.3	335.1	388.8	842.1	48.2	/
Mongolia	/	/	785.5	2376.1	101.8	/
Myanmar	/	/	/	/		/
DPR of Korea	/	/	/	/	/	/
Laos	/	/	/	284.5	697.0	1.69
Philippines	27.6	77.3	277.6	539.6	197.9	/
Singapore	22.8	63	160.3	923.5	/	0.142
Rep. of Korea	54.7	193.5	211.8	491.9	17.7	0.189
Taiwan China	/	/	/	/	/	/

Continued

Country/Region	Crude steel consumption/GDP (kg/thousand current USD)	Non-ferrous common metal consumption /GDP (kg/thousand current USD)	Energy consumption /GDP (kg/thousand current USD)	Carbon emissions/GDP (kg/thousand current USD)	Annual freshwater withdrawals/GDP (m^3 / thousand current USD)	Ecological Footprint /GDP (global hectare/thousand current USD)(2006)
Thailand	57.2	348.9	420.8	1003.8	352.5	0.527
Timor-Leste	/	/	/	845.5	/	/
Vietnam	157.6	319	812.9	1177.5	1040.4	1.462
Afghanistan	/	/	/	82.2	2294.8	/
Bangladesh	13.2	73.1	376.5	666	1160.6	/
Bhutan	/	/	/	312.4	/	/
India	46.8	181.2	505.5	1177.5	548.7	0.968
Maldives	/	/	/	767.8	/	/
Nepal	/	/	929.1	316.5	992.0	/
Pakistan	21.2	39.5	581.5	982.7	1182.9	0.942
Sri Lanka	15.8	/	286.9	401.1	389.3	0.633
Kazakhstan	34.6	116.8	633.9	1708.7	333.8	0.835
Kyrgyzstan	/	/	766.1	1469.8	2656.4	2.371
Tajikistan	/	/	1050.6	1854.6	3232.5	2.045
Turkmenistan	/	/	1907.7	5607.7	2607.2	0.876
Uzbekistan	62.4	163.2	2182.2	5482.6	2613.4	2.742

Continued

Country/Region	Crude steel consumption/GDP (kg/thousand current USD)	Non-ferrous common metal consumption /GDP (kg/thousand current USD)	Energy consumption /GDP (kg/thousand current USD)	Carbon emissions/ GDP (kg/thousand current USD)	Annual freshwater withdrawals/GDP (m^3 / thousand current USD)	Ecological Footprint /GDP (global hectare/ thousand current USD)(2006)
Armenia	/	/	308.9	1219.1	325.9	0.773
Azerbaijan	21.2	/	360.4	1070.4	369.1	0.917
Bahrain	8	1747.4	475	1575.6	/	/
Cyprus	24.9	/	113.6	439.7	/	/
Georgia	27.8	/	328.6	539.3	157.3	/
Iran	78	175	646.5	1716.7	326.2	0.837
Iraq	/	/	/	/	/	/
Israel	8.8	57.5	131.5	422.5	12.0	0.251
Jordan	62.2	/	423.5	1239.3	52.9	0.786
Kuwait	5.5	9.2	219.6	684	7.8	0.216
Lebanon	12.9	/	159.4	554.3	51.9	0.385
Oman	12.4	/	371.7	872.9	31.2	0.245
Palestine	/	/	/	/	/	/
Qatar	25	/	312.3	809.5	5.6	0.14
Saudi Arabia	23.8	82.9	391.4	1,129.8	61.7	0.236
Syria	62.5	/	484.3	1,282.7	411.9	0.938

Continued

Country/Region	Crude steel consumption/GDP (kg/thousand current USD)	Non-ferrous common metal consumption /GDP (kg/thousand current USD)	Energy consumption /GDP (kg/thousand current USD)	Carbon emissions/ GDP (kg/thousand current USD)	Annual freshwater withdrawals/GDP (m^3 / thousand current USD)	Ecological Footprint /GDP (global hectare/ thousand current USD)(2006)
Turkey	43.4	165	154.4	434.2	61.9	0.396
United Arab Emirates	36.3	47.6	259.9	860.2	20.1	0.268
Yemen	/	/	333	900.8	157.0	1.117
Russia	36.3	155.3	519.1	1,273.6	59.2	/
Asia	54.7	269.7	356.2	991.1	163.1	0.502
World	23.9	138.8	211.6	542.0	68.3	0.349

Source:

1. World Bank. World development indicators & global development finance database. 2010. http://data.worldbank.org/data-catalog
2. World Steel Association. Steel Statistical Yearbook 2008. 2009. Brussels
3. China Nonferrous Metals Industry Association, Editorial Board of China Nonferrous Metals Industry Yearbooks. China Nonferrous Metals Industry Yearbook 2008, 2009
4. World Bank. 2010 World development indicators. Washington, D C, 2010
5. EIA (U.S.Energy Information Administration). International Energy Statistics, 2010. http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8
6. Global footprint network (GFN). The Ecological Footprint Atlas 2009, 2009. www.footprintnetwork.org/atlas

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4 Empirical Analysis of the Relations between Environment and Development in Asia

The complex relations between environment and development is a constant issue that must be addressed in implementing the concept of sustainable development, which derives from the conflicts between the two and tries to ensure a dynamic balance between them. It is the primary objective of sustainable development to enhance the abilities of the environment to support human development and satisfy the needs of future generations.

4.1 Analytical framework for the relations between environment and development

The academia normally uses the Environmental Kuznets Curve (EKC) Hypothesis to describe the dynamic evolutionary relations between environment and economic development. The purpose is to find a way to decouple economic development and environmental degradation. According to research, evidence acquired by means of diverse methods and data analysis in most cases does not lead to the conclusion that EKC is widespread (Dinda, 2004, 2005; Hettige, 2006; Verbeke, 2006; Auci et al., 2006; Soytas et al., 2007; Vehmas et al., 2007). For various reasons, especially cross-country differences, differences in types of resources and pollutants, and differences in stages of social development, cross-country or cross-sectional longitudinal data generally do not produce EKC functional relations between income and environment (Chimeli, 2007). In view of this, we will put much emphasis on a time series investigation into the evolutionary trajectory of Asia's environment as a result of economic development.

According to the IPAT equation[1], the overall impact of human economic activities on the environment is determined by population, affluence and technology. We will, on the basis of this, go further and discuss the evolutionary trend of the environment and resources under the interaction among three factors—population growth, economic growth and technology change. Our deduction will be: generally, with the development of economy or the elapse of time, environmental impacts present three successive inverted U-shaped curves, i.e., environmental impact intensity (environmental impacts per unit of GDP) inverted U-shaped curve, per capita environmental impacts inverted U-shaped curve, and total environmental impacts inverted U-shaped curve (CAS Sustainable Development Strategy Study Group, 2009, 2010) (Figure 4.1). In other words, socio-economic development necessarily undergoes "three peaks"—peak of environmental impact intensity, peak of per capita environmental impacts, and peak of total environmental impacts, which integrate such concepts and hypothese as Intensity-of-Use Hypothesis, EKC Hypothesis, Decoupling and Dematerialization.

The peak values on the three inverted U-shaped curves have divided the evolution of environmental and resources impacts into four stages: environmental impact intensity pre-peak stage or materialization stage (Stage S_1), stage between peak of environmental impact intensity and peak per capita environmental impacts (Stage S_2), stage between peak of per capita environmental impacts and peak total environmental impacts (Stage S_3) and stage of steady declining of total environmental impacts (Stage S_4).

The substance-reduction theory proposes absolute or relative reduction in the quantity of materials used and/or the quantity of waste generated in the production of a unit of economic output(Cleveland et al., 1999). This sheds light on the division of the above process, which can be divided into Stage D_1 (substance-reduction stage), Stage D_2 (relative substance-reduction stage which covers Stage S_2 and Stage S_3), and Stage D_3 (absolute substance-reduction stage).

According to the decoupling theory, economic growth is decoupled from environmental impact when the growth rate of the latter is lower than that of the former. In terms of this theory, the above process can be divided into Stage B_1 (decoupling stage), Stage B_2 (relative decoupling stage) and Stage B_3 (absolute decoupling stage).

Different drivers are at work during different stages of environmental evolution. In stage S_1, although population growth, economic growth and technology change contribute to resource consumption or pollutant discharge,

1 In a series of papers in the early 1970s, Paul Ehrlich and John Holdren proposed the following equation to describe the overall impact of human economic activities on the evironment: I(Impact)=P(Population)×A (Affluence)×T(Technology). See Ehrlich P R, Holdren J P, 1971. Impact of Population Growth. *Science*, 171: 1212-1217

the intensity of resource consumption or pollutant discharge brought about by technology change grows at a higher rate than that brought about by the other two factors. The growth of resource consumption or pollutant discharge is driven more by the proliferation and application of technology that increases resource consumption or pollutant discharge. In stage S_2, although technology change can to some extent check the growth of resource consumption or pollutant discharge, the effect is not obvious because population growth and economic growth are causing resource consumption or pollutant discharge at a much faster rate. In this stage, economic growth plays a leading role. In stage S_3 and stage S_4, technological progress in resource conservation or pollution reduction plays a significant role in reducing resource consumption or pollutant discharge.

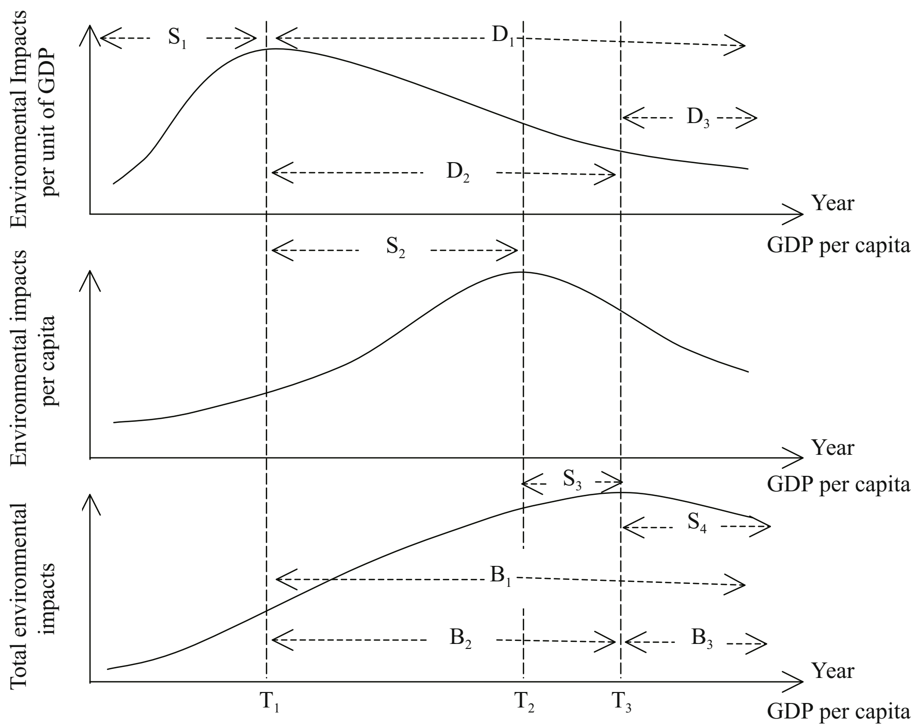

Figure 4.1 The evolutionary trend of three inverted U shape of environmental impacts

To sum it up, the human being must chiefly rely on technology change and economic restructuring to surpass the peak of environmental impact intensity, on stringent policy constraints and consumption mode transformation to surpass the peak of per capita environmental impacts, and on zero population growth, development mode transformation, etc. to surpass the peak of total environmental impacts.

It needs to be noted that the deduction of the three inverted U-shaped curves implies an assumption that technology change is continuous. However, due to the effect of economic fluctuations, restructuring, changes in policies and systems, potential technical or economic upper limits (Vehmas et al., 2007), uncertainties, etc., the intensity of environmental impacts may fluctuate or even rebound in some years or short periods. It does not always maintain a continuous upward or downward trend.

The policy implications of the regular patterns of the three inverted U-shaped curves are environmental and resources costs should be kept at a minimum in promoting economic development and satisfying moderate consumer demand and measures including institutional arrangement, restructuring, technology innovations, social behavior adjustment, etc. should be taken to leapfrog peak resource consumption and pollutant discharge as soon as possible. This is essentially consistent with the theory of "tunneling through the EKC" (Munashinghe, 1999; Perkins, 2003), which proposes that developing countries do not need to follow the emission path of the industrialized countries in the process of catching up with them and that they can draw on their experiences and leapfrog their EKC peak values at a much lower level of environmental pressure than the developed countries.

The World Bank well illustrates this in a recent scenario study on sustainable energy future in East Asia. Under sustainable energy development scenarios, or, when energy efficiency and low-carbon technology is extensively employed, CO_2 emissions in East Asia will be kept at a stable level of 9.2Gt in 2025. The environment will be improved markedly, energy security will be enhanced, and economic growth will remain unaffected (World Bank, 2010).

4.2 Empirical analysis of the evolution of the relations between Asia's environment and development

What the deduction of the three inverted U-shaped curves in the evolution of the relations between environment and development describes is a set of ideal circumstances. In practice, due to the limitations of time-series data, it is sometimes difficult to obtain a complete picture of all the changes in a short period. Nevertheless, the deduction of the three inverted U shape curves is still useful in describing the trend of environmental impacts along the time axis and its trend as a result of economic development. In our empirical study, the focus is on the trend of environmental impacts along the time axis.

In order to verify the deduction of the three inverted U-shaped curves in the evolution of environmental impacts in Asia and its economies and locate the present evolutionary stage of the relations between environment and development, we have, on the basis of data availability, selected the following different environmental impact indicators (including resource consumption indicator and pollutant discharge indicator) in this empirical study.

4.2.1 Trend of primary energy use in Asia

Energy use is usually regarded as an important indicator of environmental impacts. At present, the results of research into the relations between energy use and economic development, like those of the EKC research, are mixed (Akbostanci et al., 2009; Luzzati et al., 2009; Soytas et al., 2007; Auci et al., 2006; Richmond et al., 2006). Mr. Liu and others carried out an empirical analysis of the relations between per capita GDP and per capita and total energy use in 28 developed economies from 1970 to 2004(Liu et al., 2008). The analysis shows that per capita energy use in 10 economies was once around the inflexion point and that total energy use in 7 of the 10 economies was once around the inflexion point.

Since 1990, primary energy use intensity in Asia on the whole has been on the decline, dropping by 0.7% annually (Figure 4.2), but both per capita energy use and total energy use have been on the rise (Figure 4.3 and Figure 4.4), increasing by 1.5% and 2.8% annually.

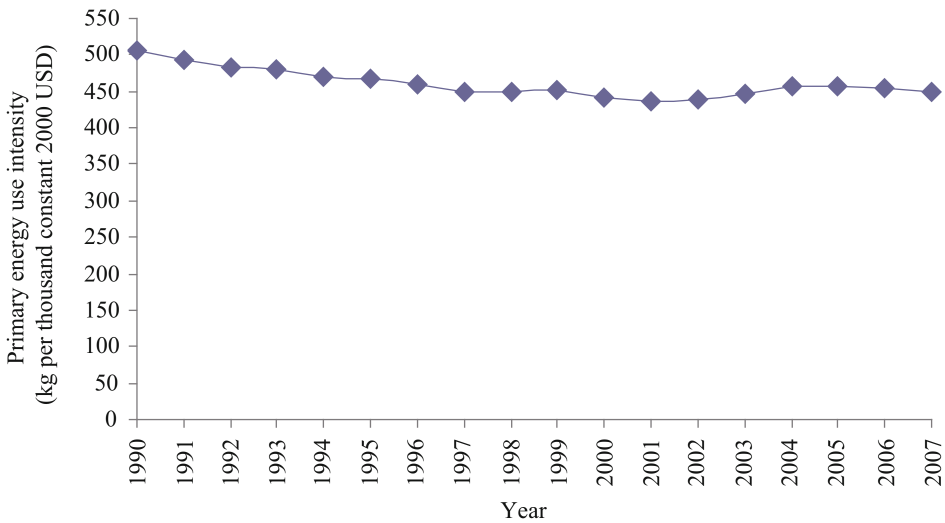

Figure 4.2 Trend of primary energy use intensity in Asia (1990-2007)
(Source: World Bank, 2010)

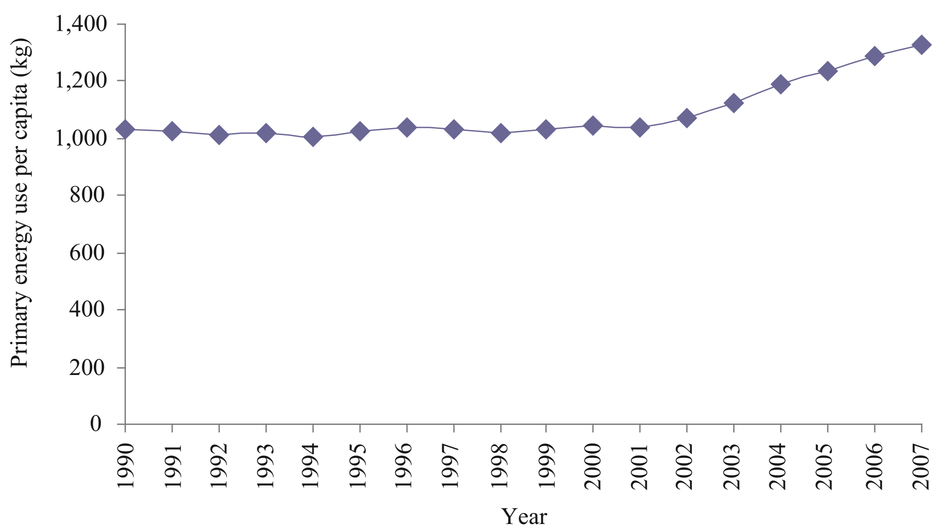

Figure 4.3 Trend of primary energy use per capita in Asia (1990-2007)
(Source: World Bank, 2010)

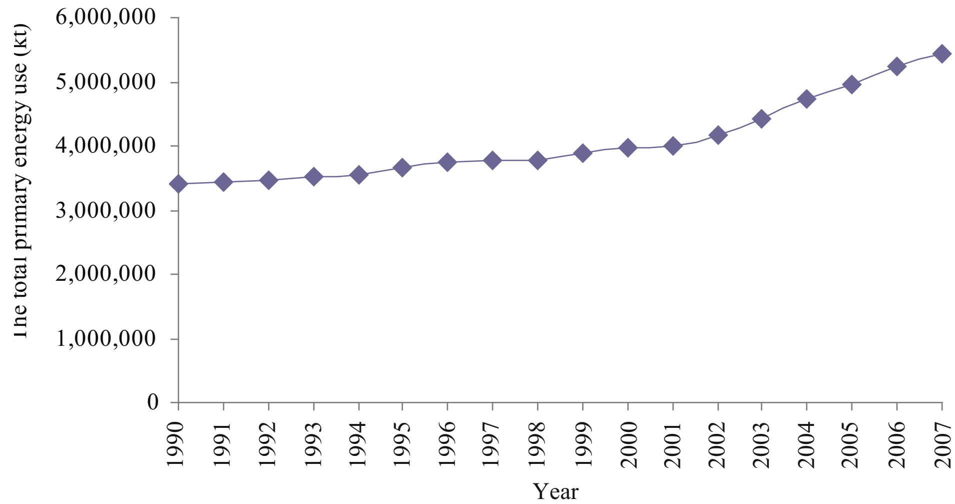

Figure 4.4 Trend of the total primary energy use in Asia (1990-2007)
(Source: World Bank, 2010)

Table 4.1 shows the trend of energy use in major Asian economies. Since 1971, with the exception of Iran, Oman, Saudi Arabia, and Yemen where energy use intensity is rising, the economies have basically transcended the peak point, or, their energy use intensity is dropping. However, per capita energy use and total energy use in most economies are growing.

Table 4.1 Trend of primary energy use in Asian Economies

Country /Region	Periods	Primary energy use per unit of GDP		Primary energy use per capita		Total primary energy use	
		Trend	Peaking year	Trend	Peaking year	Trend	Peaking year
Brunei	1971-2007	Wave-motion upward	/	Wave-motion stabilizing	/	Wave-motion upward	/
Cambodia	1995-2007	Downward	/	Upward	/	Upward	/
China	1971-2007	Inverted U shape	1977	Upward	/	Upward	/
Indonesia	1971-2007	Downward	/	Upward	/	Upward	/
Japan	1971-2007	Downward	/	Stabilizing	/	Stabilizing	/
Hong Kong, China	1971-2007	Wave-motion downward	/	Wave-motion stabilizing	/	Stabilizing	/
Malaysia	1971-2007	Wave-motion upward	/	Upward	/	Upward	/
Mongolia	1981-2007	Inverted U shape	1991	N shape	1988(first peak value)	N shape	1991(first peak value)
Myanmar	1971-2007	/	/	U shape	/	Upward	/
DPR of Korea	1971-2007	/	/	Inverted U shape	1985	Inverted U shape	1985

Continued

Country /Region	Periods	Primary energy use per unit of GDP		Primary energy use per capita		Total primary energy use	
		Trend	Peaking year	Trend	Peaking year	Trend	Peaking year
Philippines	1971-2007	Anti-N shape	1998(first peak value)	Hump shape	1983/2000	Stabilizing	/
Singapore	1971-2007	Inverted U shape	1994	Hump shape	1994/2005	Upward	/
Rep. of Korea	1971-2007	Inverted U shape	1997	Upward	/	Upward	/
Thailand	1971-2007	U shape	/	Upward	/	Upward	/
Vietnam	1971-2007	Downward	/	Upward	/	Upward	/
Bangladesh	1971-2007	Wave-motion stabilizing	/	Upward	/	Upward	/
India	1971-2007	Downward	/	Upward	/	Upward	/
Nepal	1971-2007	Downward	/	Upward	/	Upward	/
Pakistan	1971-2007	Downward	/	Upward	/	Upward	/
Sri Lanka	1971-2007	Downward	/	Upward	/	Upward	/
Kazakhstan	1990-2007	Inverted U shape	1992	N shape	1992(first peak value)	N shape	1992(first peak value)
Kyrgyzstan	1990-2007	Downward	/	U shape	/	U shape	/
Tajikistan	1990-2007	Inverted U shape	1996	U shape	/	U shape	/
Turkmeni-stan	1990-2007	Anti-N shape	1997(first peak value)	U shape	/	U shape	/
Uzbekistan	1990-2007	Inverted U shape	1994	Downward	/	Anti-N shape	2002(first peak value)
Armenia	1990-2007	Downward	/	U shape	/	U shape	/
Azerbaijan	1990-2007	Inverted U shape	1994	U shape	/	U shape	/
Bahrain	1971-2007	Inverted U shape	1985	Wave-motion upward	/	Upward	/
Cyprus	1971-2007	Downward	/	Upward	/	Upward	/
Georgia	1990-2007	Inverted U shape	1993	U shape	/	U shape	/
Iran	1971-2007	Upward	/	Upward	/	Upward	/

Continued

Country /Region	Periods	Primary energy use per unit of GDP		Primary energy use per capita		Total primary energy use	
		Trend	Peaking year	Trend	Peaking year	Trend	Peaking year
Iraq	1971-2007	Anti-N shape	2003(first peak value)	Wave-motion upward	/	Upward	/
Israel	1971-2007	Wave-motion downward	/	Wave-motion upward	/	Upward	/
Jordan	1971-2007	Inverted U shape	1991	Upward	/	Upward	/
Kuwait	1971-2007	Inverted U shape	1999	Wave-motion stabilizing	/	Wave-motion upward	/
Lebanon	1971-2007	Hump shape	1989/1997	Hump shape	1997/2003	Inverted U shape	2003
Oman	1971-2007	Upward	/	Upward	/	Upward	/
Qatar	1971-2007	Hump shape	2001/2003	Wave-motion upward	/	Upward	/
Saudi Arabia	1971-2007	Upward	/	Upward	/	Upward	/
Syria	1971-2007	Inverted U shape	1991	Wave-motion upward	/	Upward	/
Turkey	1971-2007	Wave-motion	/	Upward	/	Upward	/
United Arab Emirates	1971-2007	Wave-motion stabilizing	/	Wave-motion stabilizing	/	Upward	/
Yemen	1971-2007	Anti-N shape	1992(first peak value)	Upward	/	Upward	/
Russia	1990-2007	Inverted U shape	1996	U shape	/	U shape	/

Note:
"/" indicates that no clear trend is displayed or data is unavailable
Source:
World Bank, 2010

4.2.2 Trend of finished steel use in Asia

Since 1994, steel use intensity, per capita steel use and total steel use in Asia display a noticeable upward trend. The average annual growth rates are 3.64%, 6.28% and 7.51%, respectively. This indicates that steel use in Asia is in its materialization stage.

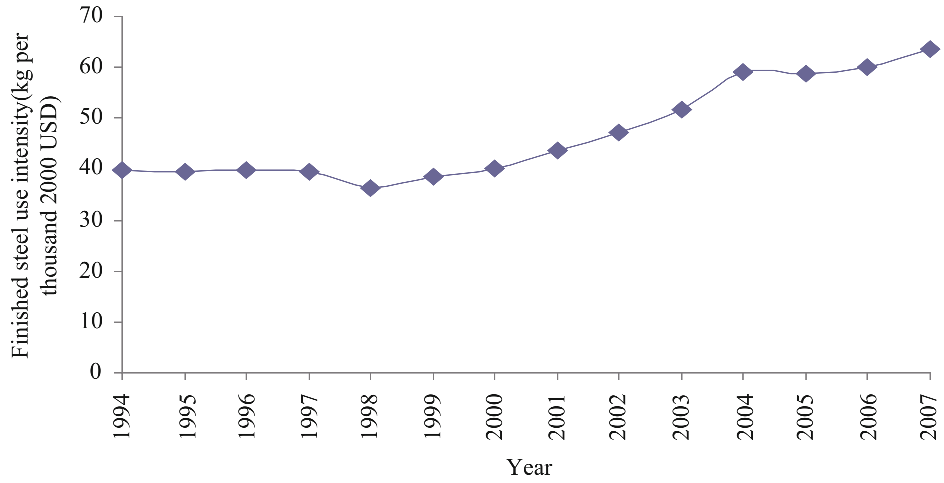

Figure 4.5 Trend of the total finished steel use intensity in Asia (1994-2007)
(Source: World Steel Association, 2009).

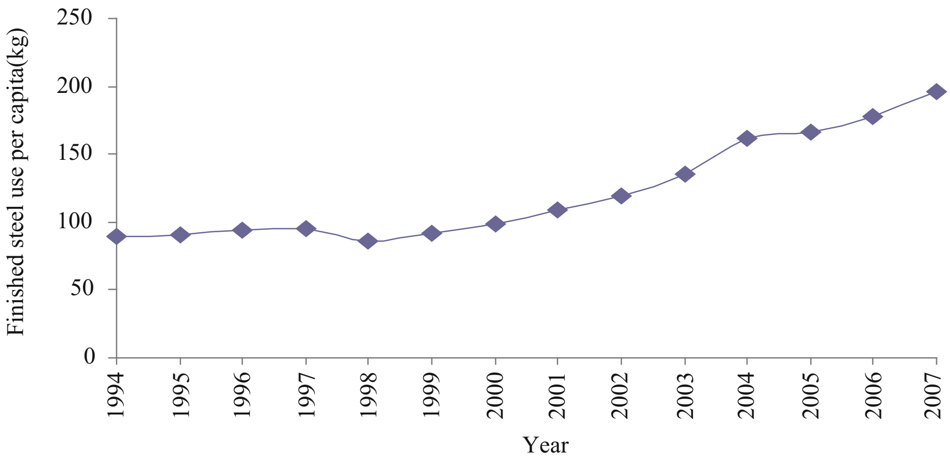

Figure 4.6 Trend of the total finished steel use per capita in Asia (1994-2007)
(Source: World Steel Association, 2009)

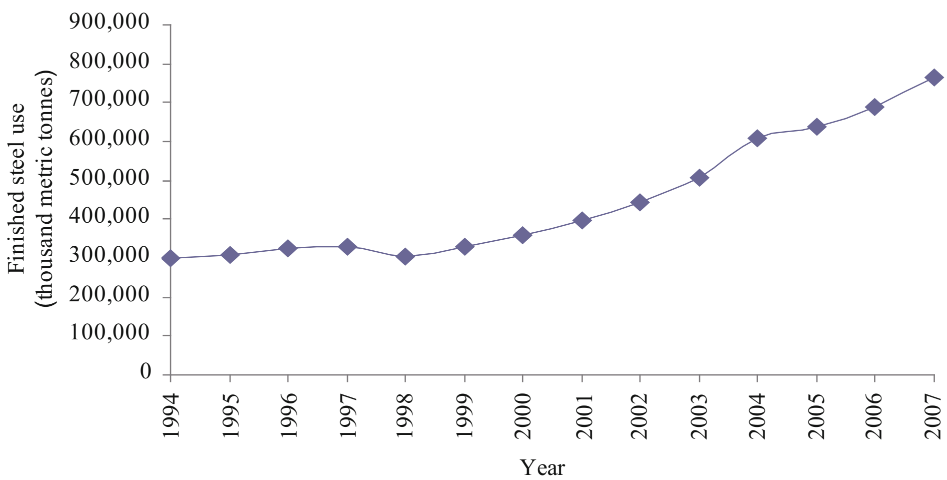

Figure 4.7 Trend of the total finished steel use in Asia (1994-2007)
(Source: World Steel Association, 2009).

Table 4.2 shows the trend of steel use in Asian economies. It can be seen that finished steel use intensity has been dropping in only 13 of the 33 economies for which data is available and that it has been growing in most Asian economies. With the exception of a few economies including Hong Kong China and Singapore, per capita steel use and total steel use in other economies have been increasing.

Table 4.2 Trend of finished steel use in Asian economies (1994-2007)

Country /Region	Finished steel use intensity (kg per thousand 2000 USD)			Finished steel use per capita (kg)			Total finished steel use (thousand tonne)		
	1994	2000	2007	1994	2000	2007	1994	2000	2007
Azerbaijan	11.8	34.1	47.4	6.6	22.4	92.2	50.0	180.0	791.0
Bahrain	8.9	5.3	11.1	97.9	64.6	180.4	55.0	42.0	137.0
Bangladesh	10.4	13.5	12.1	2.9	4.5	5.3	361.0	638.0	840.0
China	147.4	103.7	173.3	88.4	98.4	313.9	105,370.0	124,278.0	413,722.0
Cyprus	51.4	23.5	41.8	519.1	278.4	580.9	374.0	219.0	496.0
Georgia		10.5	48.9		6.7	60.1		32.0	262.0
Hong Kong, China	27.4	28.4	15.5	659.1	720.0	528.7	3,978.0	4,799.0	3,662.0
India	57.7	60.1	64.2	20.3	27.2	44.0	18,600.0	27,647.0	49,520.0
Indonesia	35.7	29.4	31.1	27.8	23.7	32.2	5,244.0	4,858.0	7,245.0
Iran	62.6	94.8	137.4	87.3	150.1	293.7	5,065.0	9,597.0	2,0862.0
Israel	14.7	13.2	8.9	249.7	261.7	191.1	1,348.0	1,646.0	1,372.0
Japan	17.2	16.3	15.3	599.1	599.8	623.0	74,867.0	76,100.0	79,600.0
Jordan	79.5	46.4	72.9	133.2	81.9	172.8	541.0	393.0	988.0
Kazakhstan	97.7	49.3	83.0	107.0	60.5	193.5	1,722.0	901.0	2,996.0
Kuwait	15.0	8.8	9.5		151.6	218.6	492.0	332.0	582.0
Lebanon	8.0	25.9	13.3	35.4	118.5	71.8	120.0	447.0	299.0
Malaysia	73.5	66.2	75.0	247.5	267.0	375.5	4,970.0	6,213.0	9,971.0
Oman	16.3	8.5	17.6	123.6	69.9	175.7	261.0	168.0	479.0
Pakistan	21.4	19.3	25.2	10.8	10.3	16.4	1,287.0	1,426.0	2,663.0
Philippines	41.1	40.1	33.5	35.9	39.1	40.3	2,457.0	3,041.0	3,575.0
Qatar		6.0		126.2	171.8	1,461.9	65.0	106.0	1,663.0
Russia	65.7	93.8	99.1	110.8	166.5	284.2	16,431.0	24,355.0	40,379.0
Saudi Arabia	19.4	20.6	35.3	180.1	187.8	353.7	3,209.0	3,877.0	8,545.0
Singapore	53.1	32.1	21.7	979.5	739.8	632.0	3,349.0	2,980.0	2,900.0

Continued

Country /Region	Finished steel use intensity (kg per thousand 2000 USD)			Finished steel use per capita (kg)			Total finished steel use (thousand tonne)		
	1994	2000	2007	1994	2000	2007	1994	2000	2007
Rep. of Korea	76.9	71.8	75.2	682.6	814.8	1,139.3	30,344.0	38,300.0	55,204.0
Sri Lanka	29.6	11.7	20.9	20.0	10.2	23.8	358.0	191.0	477.0
Syria	61.3	58.5	90.7	70.2	68.5	117.5	1,000.0	1,131.0	2,360.0
Thailand	72.7	53.7	73.3	134.1	105.8	189.9	7,985.0	6,595.0	12,720.0
Turkey	33.8	47.6	63.1	114.2	191.5	322.7	6,870.0	12,730.0	23,559.0
United Arab Emirates	22.3	25.7	59.0	491.8	559.6	1,537.2	1,131.0	1,812.0	6,708.0
Uzbekistan	33.5	35.0	61.6	17.2	19.6	48.2	385.0	482.0	1,296.0
Vietnam	22.4	86.5	191.4	6.3	34.7	118.1	455.0	2,695.0	10,058.0
Yemen	32.8	21.2		14.2	11.0		212.0	200.0	

Source:
World Steel Association, 2009

4.2.3 Trend of non-ferrous common metals use in Asia

Since 1992, similar to the trend of steel use, non-ferrous metals use intensity, per capita non-ferrous metals use and total non-ferrous metals use in Asia have maintained rapid growth momentum and entered their materialization stages, registering an average annual growth of 3.32%, 5.71% and 6.99%, respectively.

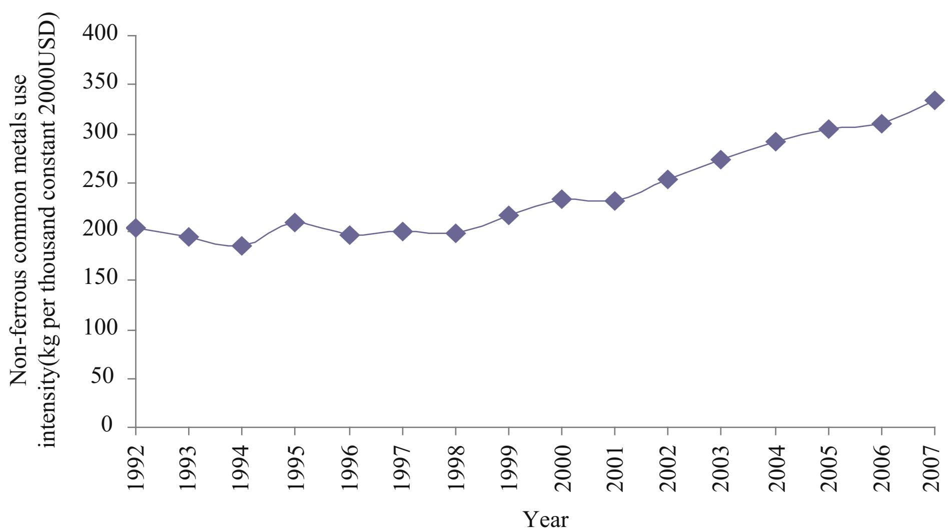

Figure 4.8 Trend of non-ferrous common metals use intensity in Asia (1992-2007)
(Source: China Nonferrous Metals Industry Association, etc., 2009)

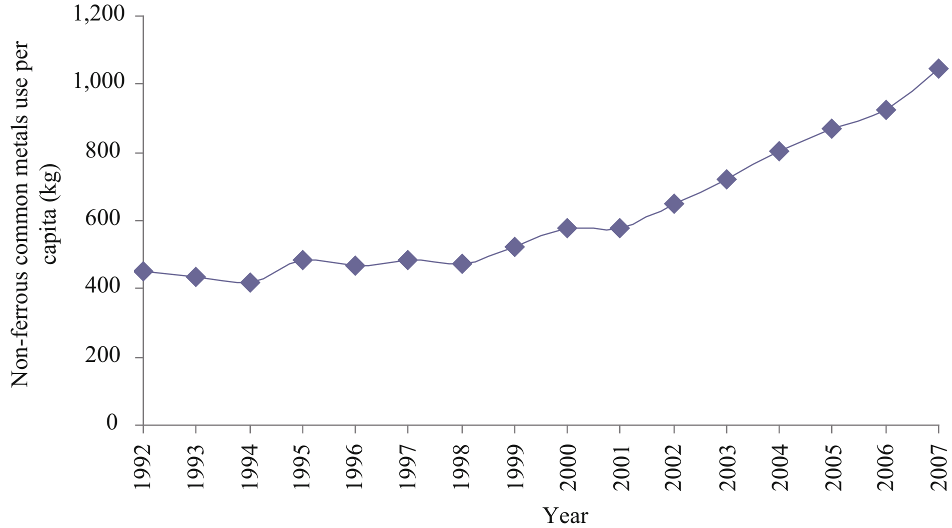

Figure 4.9 Trend of non-ferrous common metals use per capita in Asia (1992-2007)
(Source: China Nonferrous Metals Industry Association, etc., 2009)

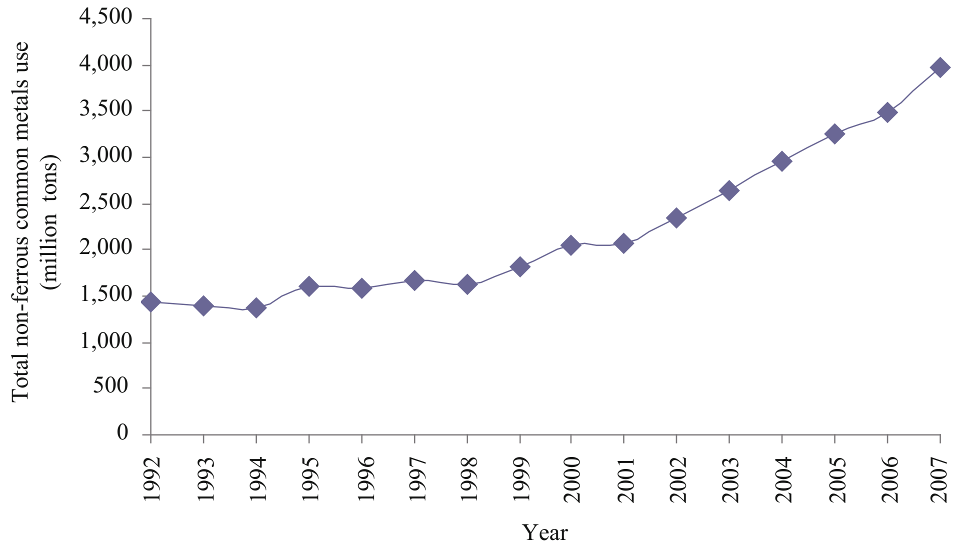

Figure 4.10 Trend of the total non-ferrous common metals use in Asia (1992-2007)
(Source: China Nonferrous Metals Industry Association, etc., 2009)

Table 4.3 shows the trend of non-ferrous metals use in Asian economies. In Hong Kong China, Japan, Rep. of Korea and the Philippines , non-ferrous metals use intensity, per capita non-ferrous metals use and total non-ferrous metals use all display an inverted U shape. In 7 economies, non-ferrous metals use intensity has transcended its peak and in 5 of them, per capita non-ferrous metals use has transcended its peak. In other economies, non-ferrous metals use intensity, per capita non-ferrous metals use and total non-ferrous metals use are growing in varying degrees.

Table 4.3 Trend of non-ferrous common metals use in Asian economies

Country /Region	Periods	Use intensity of non-ferrous metals		Per capita use intensity of non-ferrous metals		Total use of non-ferrous metals	
		Trend	Peaking year	Trend	Peaking year	Trend	Peaking year
Bahrain	1998-2007	Wave-motion upward	/	Wave-motion upward	/	Wave-motion upward	/
Bangladesh	1999-2007	Hump shape	2000/2006	Hump shape	2000/2006	Hump shape	2000/2006
China	1980-2007	U shape	/	Upward	/	Upward	/
Hong Kong, China	1986-2007	Inverted U shape	1995	Inverted U shape	1995	Inverted U shape	1995
India	1980-2007	Stabilizing	/	Upward	/	Upward	/
Indonesia	1986-2007	N shape	1997(first peak point)	N shape	1997(first peak point)	N shape	1997(first peak point)
Iran	1986-2007	Wave-motion upward	/	Upward	/	Upward	/
Israel	1999-2007	Anti-N shape	2003	Stabilizing	/	Upward	/
Japan	1980-2007	Downward	/	Inverted U shape	1991	Inverted U shape	1991
Kazakhstan	1992-2007	Wave-motion downward	/	U shape	/	U shape	/
Rep. of Korea	1980-2007	Inverted U shape	1999	Inverted U shape	2005	Inverted U shape	2005
Kuwait	2002-2007	Inverted U shape	2003	Inverted U shape	2003	Stabilizing	/
Malaysia	1988-2007	Stabilizing	/	Wave-motion upward	/	Wave-motion upward	/
Pakistan	1988-2007	Fluctuating	/	Wave-motion upward	/	Wave-motion upward	/
Philippines	1986-2007	Inverted U shape	1995	Inverted U shape	1995	Inverted U shape	1995
Russia	1992-2007	U shape	/	U shape	/	U shape	/
Saudi Arabia	1988-2007	Upward stabilizing	/	Upward	/	Upward	/
Singapore	1999-2007	Inverted U shape	1993	Upward	/	N shape	1994(first peak point)
Thailand	1986-2007	Inverted U shape	2004	N shape	1996(first peak point)	N shape	1996(first peak point)
Turkey	1980-2007	Upward	/	Upward	/	Upward	/
United Arab Emirates	1999-2007	Upward	/	Wave-motion upward	/	Wave-motion upward	/
Uzbekistan	1992-2007	U shape	/	U shape	/	U shape	/
Vietnam	1999-2007	Stabilizing	/	Upward	/	Upward	/

Source:

China Nonferrous Metals Industry Association, etc., 2009

4.2.4 Trend of ODS (Ozone-Depleting Substances) consumption in Asia

The *Montreal Protocol on Substances that Deplete the Ozone Layer*, signed in 1978, is so far the most successful international agreement. Full and smooth implementation of the Protocol has substantially reduced the consumption of ODS in major developed countries and developing countries—Asia is no exception.

Since the Montreal Protocol came into effect in 1989, per unit GDP ODS consumption, per capita ODS consumption and total ODS consumption in Asia have declined (Figure 4.11-4.13), dropping at an average annual rate of 16.8%, 14.9% and 13.8%, respectively. This has contributed to absolute decoupling of Asia's economic development from ODS consumption.

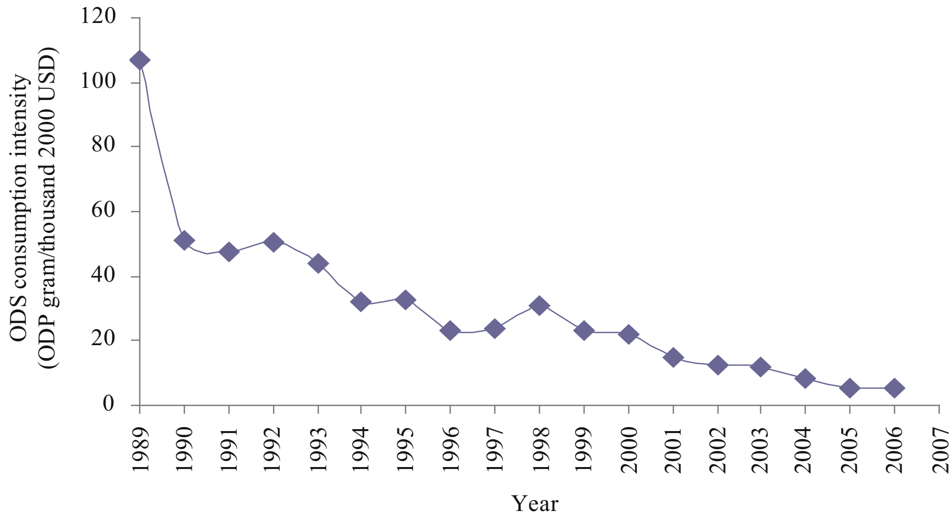

Figure 4.11 Trend of ODS consumption intensity in Asia (1989 -2007)
(Source: UNEP Ozone Secretariat, 2010)

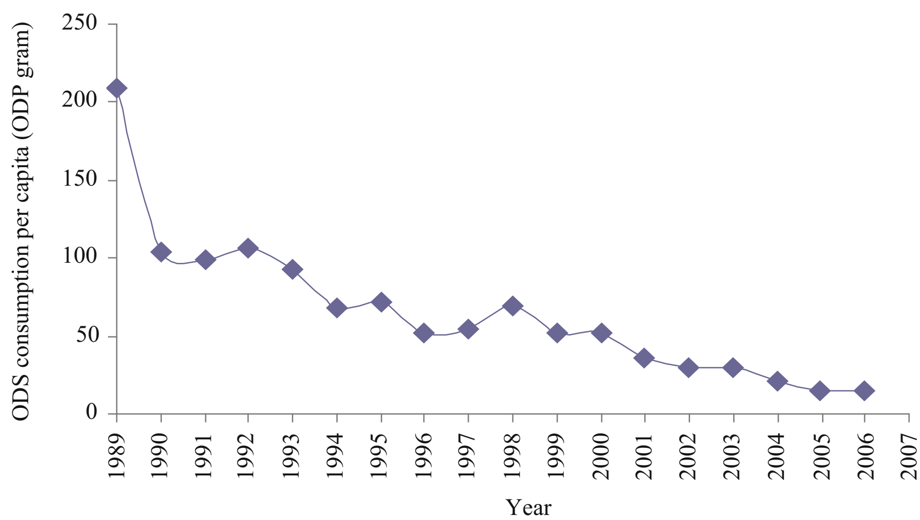

Figure 4. 12 Trend of ODS consumption per capita in Asia (1989-2007)
(Source: UNEP Ozone Secretariat, 2010)

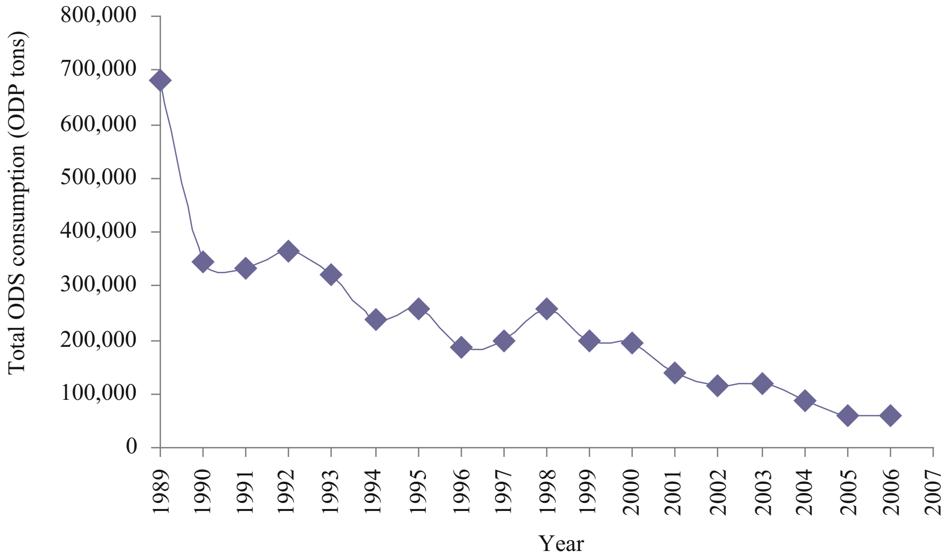

Figure 4. 13 Trend of total ODS consumption in Asia (1989-2007)
(Source: UNEP Ozone Secretariat, 2010)

Relative to the base year, ODS consumption in other economies, with the exception of a few countries including Cambodia, Burma, Laos, Afghanistan, Maldives, Sri Lanka, Kyrgyzstan, Iraq and Yemen, has been decreasing in varying degrees (Table 4.4).

Table 4. 4 Trend of total ODS consumption in Asian economies (1989-2007)

Country /Region	1989	1995	2000	2006	2007	Change of 2007 over 1989 (%)
Brunei	100.0	101.1	71.8	42.9	15.6	–84.4
Cambodia	100.0	3,464.3	3,464.3	1,235.7	710.7	610.7
China	100.0	130.0	107.0	35.3	29.6	–70.4
Indonesia	100.0	631.4	374.1	38.0	34.3	–65.7
Japan	100.0	13.0	2.2	0.4	0.4	–99.6
Malaysia	100.0	81.2	50.1	19.9	13.7	–86.3
Mongolia	100.0	100.0	152.0	34.7	22.7	–77.3
Myanmar	100.0	7,314.3	3,800.0	185.7	342.9	242.9
DPR of Korea	100.0	78.4	66.5	1.4	7.4	–92.6
Laos	100.0	14,433.3	15,066.7	6,466.7	2,666.7	2,566.7
Philippines	100.0	97.2	80.3	21.2	8.5	–91.5
Singapore	100.0	51.6	8.7	17.2	8.0	–92.0

Continued

Country /Region	1989	1995	2000	2006	2007	Change of 2007 over 1989 (%)
Rep. of Korea	100.0	41.2	37.8	17.8	12.5	–87.5
Thailand	100.0	168.0	92.1	26.4	23.7	–76.3
Vietnam	100.0	209.5	110.5	120.0	89.2	–10.8
Afghani-stan	100.0	42,433.3	100.0	11,044.4	6,811.1	6,711.1
Bangladesh	100.0	140.1	392.7	104.6	92.7	–7.3
India	100.0	110.8	201.5	56.9	32.0	–68.0
Maldives	100.0	268.2	209.1	245.5	200.0	100.0
Nepal	100.0	110.7	364.7	4.4	4.4	–95.6
Pakistan	100.0	266.0	249.6	70.4	34.0	–66.0
Sri Lanka	100.0	34,512.5	15,750.0	7,356.3	4,850.0	4,750.0
Kazakhstan	100.0		23.6	3.1	4.8	–95.2
Kyrgyzstan	100.0	4,638.1	2,561.9	419.0	276.2	176.2
Tajikistan	100.0	17.2	15.1	1.9	2.0	–98.0
Turkmeni-stan	100.0	31.9	13.3	12.6	4.7	–95.3
Uzbekistan	100.0	12.0	1.7	0.1	0.0	–100.0
Azerbaijan	100.0		18.3	0.2	0.2	–99.8
Bahrain	100.0	136.7	116.3	39.9	28.3	–71.7
Cyprus	100.0	64.6	78.9			–100.0
Georgia	100.0	9.9	8.4	1.9	0.8	–99.2
Iran	100.0	205.1	248.9	50.0	32.6	–67.4
Iraq	100.0	2,390.4	39.0	2,334.7	2,712.4	2,612.4
Israel	100.0	19.7	30.3	10.4	9.0	–91.0
Jordan	100.0	112.0	87.2	17.6	14.0	–86.0
Kuwait	100.0	25.5	24.6	16.3	17.7	–82.3
Lebanon	100.0	231.5	175.6	65.5	25.4	–74.6
Oman	100.0	36.7	44.1	8.1	4.1	–95.9
Qatar	100.0	111.8	136.7	50.3	39.6	–60.4

Continued

Country /Region	1989	1995	2000	2006	2007	Change of 2007 over 1989 (%)
Saudi Arabia	100.0	120.5	52.7	43.7	43.8	–56.2
Syria	100.0	237.2	132.8	55.1	28.9	–71.1
Turkey	100.0	131.9	45.6	25.8	26.8	–73.2
United Arab Emirates	100.0	85.7	74.7	64.6	61.2	–38.8
Yemen	100.0	12,267.0	5,997.1	2,561.2	2,045.5	1,945.5
Russia	100.0	10.7	11.7	0.5	0.6	–99.4
Asia	100.0	37.7	28.7	8.6	6.9	–93.1
World	100.0	24.5	15.8	5.2	3.7	–96.3

Source:
UNEP Ozone Secretariat, 2010

4.2.5 Trend of CO_2 emissions from fuel combustion in Asia

4.2.5.1 Status quo and problems in the research into the relations between CO_2 emissions and economic development

Since the *United Nations Framework Convention on Climate Change* (UNFCCC) and the *Kyoto Protocol* were approved, CO_2 emissions have become the focus of international attention (Huang et al., 2008) and research has been increasing as to whether or not the relations between CO_2 emissions and per capita income conform to the EKC hypothesis (Lantz et al., 2006; Galeotti, 2006; Richmond, 2006; Huang et al., 2008).

Although a considerable number of research results tend to support the idea that Environmental Kuznets Curves can be observed in CO_2 emissions, research into the relations between CO_2 emissions and economic development faces a common problem that is also widespread in EKC research—indeterminacy. For example, the choice of different indicators—some choose CO_2 emissions intensity, some choose per capita CO_2 emissions while others choose total CO_2 emissions—can lead to radical differences in research results.

The CAS Sustainable Development Strategy Study Group (2009) studied the evolution of the relations between economic development and carbon emissions in 26 major developed economies and 3 representative developing countries (China, India, Brazil) and partly verified the existence of three inverted U-shaped curves in developed economies. The major developed economies and the 3 representative developing countries have basically transcended the peak of carbon emissions intensity on the inverted U-shaped curve. Most of the developed economies in Europe and America (16) have transcended the peak of per capita carbon emissions and 11 of them have generally transcended the peak of total carbon emissions. This is attributable to developed countries which fulfilled their commitment to the *Kyoto Protocol*.

4.2.5.2 Trend of CO_2 emissions in Asia

Since the beginning of the 1990s, CO_2 emissions intensity in the whole Asia has exhibited a downward-upward trend, increasing at an average annual growth rate of 0.34% (Figures 4.14-4.16), whereas per capita CO_2 emissions and total CO_2 emissions have exhibited a trend of rapid growth, growing at a steady rate of 2.42% and 3.69%, respectively.

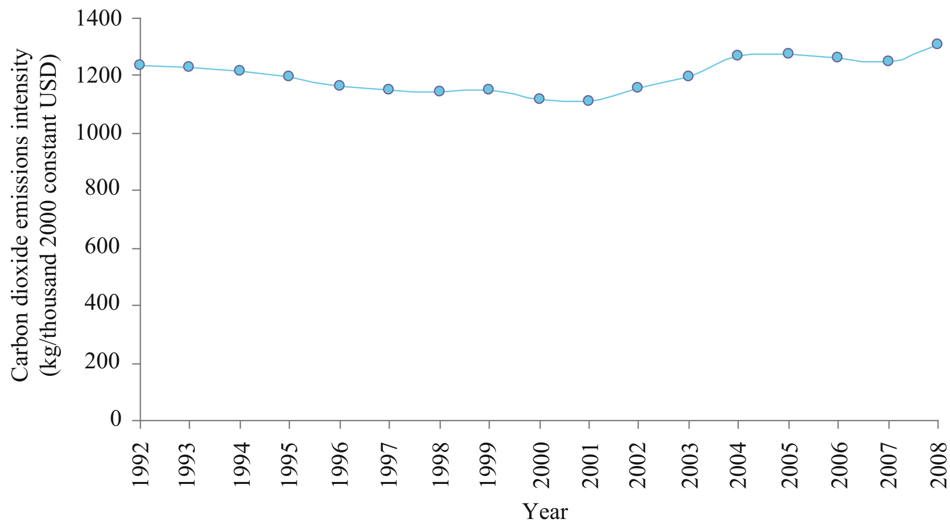

Figure 4.14 Trend of carbon dioxide emissions intensity in Asia (1992-2008)
(Source: EIA, 2010)

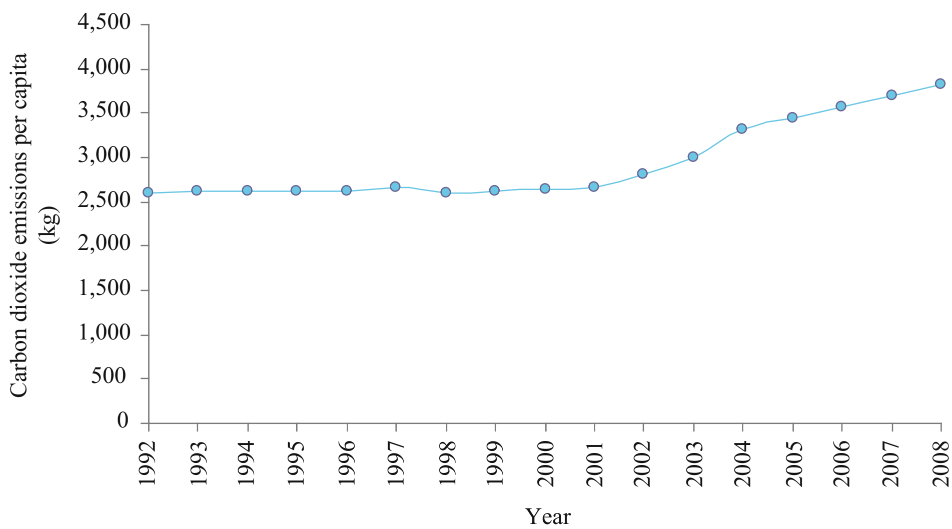

Figure 4.15 Trend of carbon dioxide emissions per capita in Asia (1992-2008)
(Source: EIA, 2010)

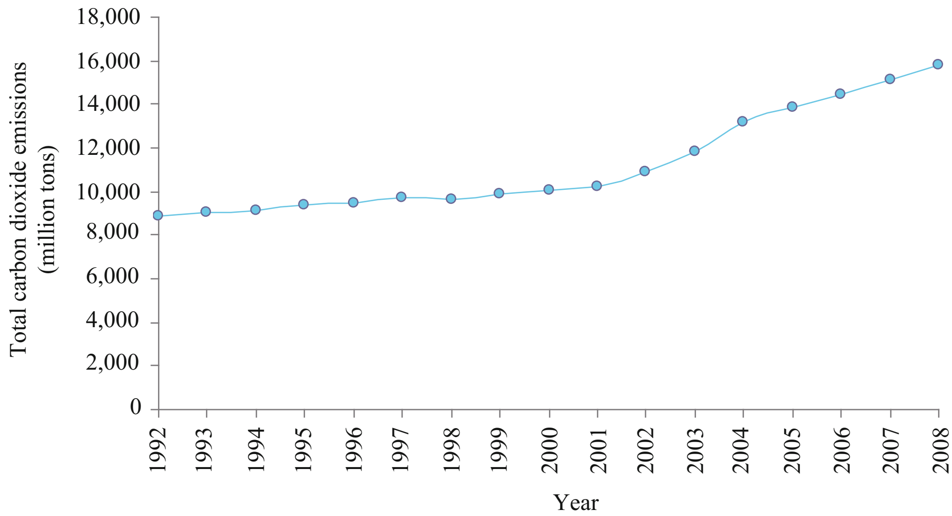

Figure 4.16 Trend of total carbon dioxide emissions in Asia (1992-2008)
(Source: EIA, 2010)

To reflect the evolutionary trend of the relations between economic development and carbon emissions in Asian economies, we employed historical data and carried out our analysis over a longer time scale. Data on carbon emissions, population and aggregate GDP are collected from CDIAC (2010) and Maddison (2009).

Table 4.5 Trend of carbon emissions in Asian economies

Country /Region	Periods	Carbon emissions intensity		Carbon emissions per capita		Total carbon emissions	
		Trend	Peaking year	Trend	Peaking year	Trend	Peak-ing year
Afghanistan	1950-2006	Hump shape	1977/1987	Inverted U shape	1985	Inverted U shape	1985
United Arab Emirates	1959-2006	U shape	/	Downward	/	Upward	/
Oman	1964-2006	N shape	1977(first peak point)	N SHAPE	1976(first peak point)	Upward	/
Azerbaijan	1992-2006	Inverted U shape	1994	U SHAPE	/	U shape	/
Pakistan	1972-2006	Upward	/	Upward	/	Upward	/
Bahrain	1950-2006	Anti-N shape	1997(first peak point)	Upward	/	Upward	/
DPR of Korea	1950-2006	Inverted U shape	1996	Inverted U shape	1991	Inverted U shape	1993
Russia	1992-2006	Downward	/	U shape	/	U shape	/
Philippines	1907-2006	Hump shape	1971/1997	Hump shape	1977/1997	Inverted U shape	1997

Continued

Country /Region	Periods	Carbon emissions intensity		Carbon emissions per capita		Total carbon emissions	
		Trend	Peaking year	Trend	Peaking year	Trend	Peak-ing year
Georgia	1992-2006	Undeter-minable	/	Undeter-minable	/	Undeter-minable	/
Kazakhstan	1992-2006	Downward	/	U shape	/	U shape	/
Rep. of Korea	1945-2006	Inverted U shape	1980	Upward	/	Upward	/
Kyrgyzstan	1992-2006	Undeter-minable	/	Undeter-minable	/	Undeter-minable	/
Cambodia	1955-2006	Hump shape	1969/1998	N shape	1969 (first peak point)	N shape	1969 (first peak point)
Qatar	1950-2006	Inverted U shape	1993	N shape	1963(first peak point)	Upward	1969
Laos	1955-2006	Hump shape	1970/2002	Hump shape	1970/2002	N shape	1970(first peak point)
Lebanon	1950-2006	Inverted U shape	1990	Inverted U shape	2003	Inverted U shape	2003
Malaysia	1970-2006	Hump shape	1995/2003	Upward	/	Upward	/
Mongolia	1950-2006	Multi-hump shape	1980/1991	Inverted U shape	1988	N shape	1991(first peak point)
Bangladesh	1972-2006	Stabilizing	/	Upward	/	Upward	/
Nepal	1950-2006	Inverted U shape	1999	Upward	/	Upward	Upward
Japan	1950-2006	Inverted U shape	1973	Stabilizing	/	Stabilizing	/
Saudi Arabia	1950-2006	Inverted U shape	1993	Hump shape	1980/1993	N shape	1993
Sri Lanka	1950-2006	N shape	1969(first peak point)	Upward	/	Upward	/
Tajikistan	1992-2006	Downward	/	U shape	/	U shape	/
Taiwan China	1896-2006	Hump shape	1927/1941	Upward	/	Upward	/
Thailand	1931-2006	Inverted U shape	2004	Upward	/	Upward	/
Turkey	1865-2006	Inverted U shape	1986	Upward	/	Upward	/
Turkmeni-stan	1992-2006	Inverted U shape	1995	N shape	1994(first peak point)	N shape	1994(first peak point)

Continued

Country /Region	Periods	Carbon emissions intensity		Carbon emissions per capita		Total carbon emissions	
		Trend	Peaking year	Trend	Peaking year	Trend	Peak-ing year
Uzbekistan	1992-2006	Inverted U shape	1993	Anti-N shape	2002(first peak point)	N shape	2002(first peak point)
Hong Kong China	1938-2000	Inverted U shape	1975	Inverted U shape	1993	Inverted U shape	1993
Singapore	1957-2006	Inverted U shape	1970	Inverted U shape	1994	Inverted U shape	1997
Syria	1931-2006	Inverted U shape	1991	Inverted U shape	1999	Upward	/
Armenia	1992-2006	Downward	/	Upward	/	U shape	/
Yemen	1991-2006	Undeterminable	/	Undeterminable	/	Upward	/
Iraq	1927-2006	N shape	1995	Multi-hump shape	1966/1976/1989	Upward	/
Israel	1930-2006	Multi-hump shape	1953/1966/1997	Inverted U shape	1997	Upward	/
India	1878-2006	Inverted U shape	1992	Upward	/	Upward	/
Indonesia	1889-2006	Stabilizing	/	Upward	/	Upward	/
Jordan	1950-2006	Inverted U shape	1990	N shape	1987(first peak point)	Upward	/
Vietnam	1893-2006	U shape	/	U shape	/	Upward	/
China	1902-2006	Hump shape	1960/1978	Upward	/	Upward	/
Bhutan	1970-2006	/	/	/	/	Upward	/
Brunei	1933-2006	/	/	/	/	Multi-hump shape	1949/1973/1978
Cyprus	1950-2006	/	/	/	/	Upward	/
Iran	1911-2006	/	/	/	/	Upward	/
Kuwait	1946-2006	/	/	/	/	Upward	/
Macao China	1954-2006	/	/	/	/	Upward	/
Maldives	1971-2006	/	/	/	/	Upward	/
Myanmar	1928-2006	/	/	/	/	Upward	/
Timor-Leste	2002-2006	/	/	/	/	Upward	/

Note:

"/ " indicates that no clear trend is displayed or data is unavailable

Source:

CDIAC, 2010; Madison, 2009

We can see from the above table that among Asian economies only the evolutionary trend of carbon emissions in Hong Kong China and Singapore conforms to the regular pattern of three inverted U-shaped curves. Although three inverted U-shaped curves also occur in the evolutionary trend of carbon emissions in Afghanistan and DPR of Korea, it is not a result from normal economic development. Most probably, this has to do with economic recession or instability incurred by war, political instability, changes in international political relations, domestic policy weakness, etc. More than 10 economies have transcended the peak of carbon emissions intensity, but a considerable number of economies have not finished this process and are still in a stage of fluctuations. This indicates that Asia's mode of economic development is relatively backward. At present, per capita carbon emissions and total carbon emissions are going up in most Asian economies.

4.2.6 Trend of SO_2 emissions in Asia

SO_2 emissions are a typical indicator of general environmental pollution. A good deal of research into the relations between SO_2 emissions and economic development has been done in the academia and many findings have produced evidence that the EKC relations exist. Under strict supervisions, total SO_2 emissions in many countries, notably developed economies, are beginning to go down. This partly confirms Stern's (2004) deduction: in economies where development is slow, progress made in emission reduction technologies can overcome the scale effect of pollutant discharge caused by per capita income growth; in middle-income economies where development is fast, the effect of income growth overwhelms the contribution made by emission reduction technologies.

Because time series data on SO_2 emissions in Asian economies are extremely limited, we can only describe the trend of SO_2 emissions at different periods (Figures 4.17-4.19). Since 1990, SO_2 emissions intensity has been on the decline, down 1.28% annually; per capita SO_2 emissions seem to exhibit a U shape trend; total SO_2 emissions exhibit an apparently rising trend, up 1.62% annually.

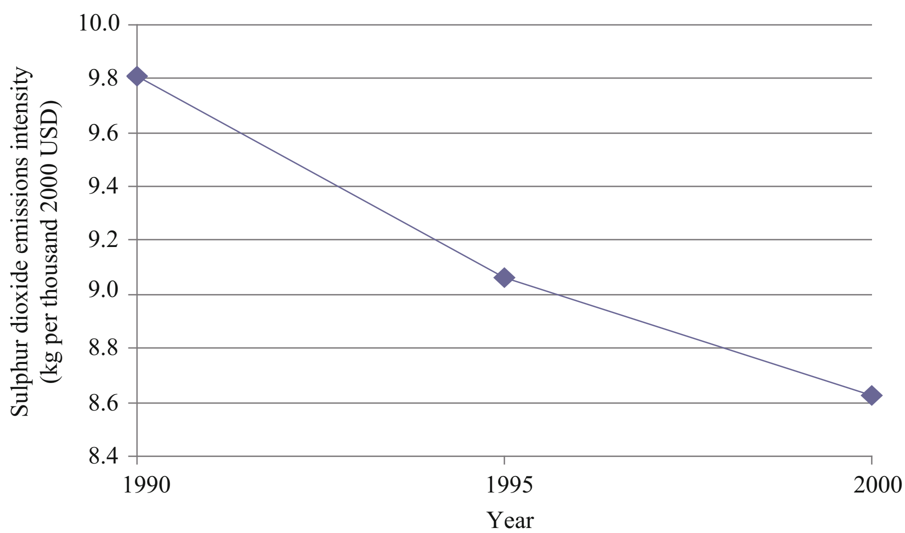

Figure 4.17 Trend of sulphur dioxide emissions intensity in Asia (1990-2000)
(Source: UNEP, 2010)

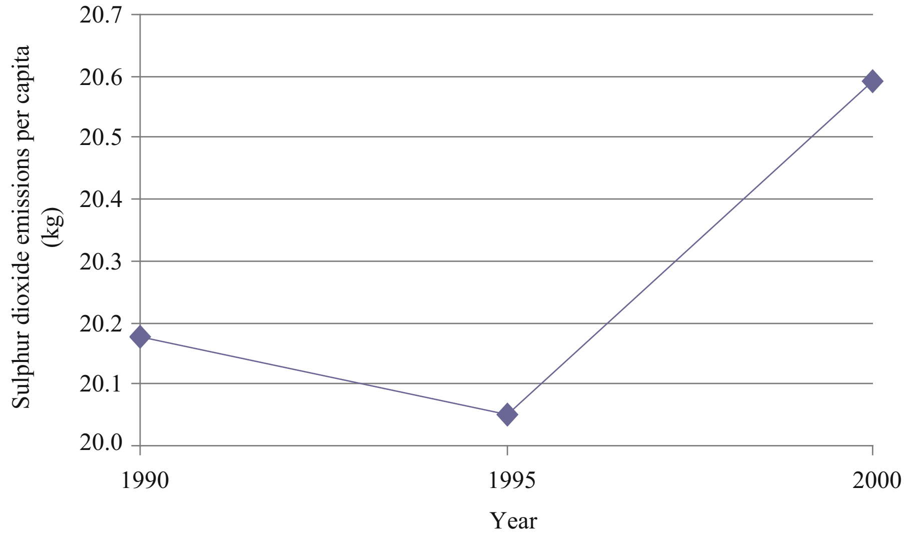

Figure 4.18 Trend of sulphur dioxide emissions per capita in Asia (1990-2000)
(Source: UNEP, 2010)

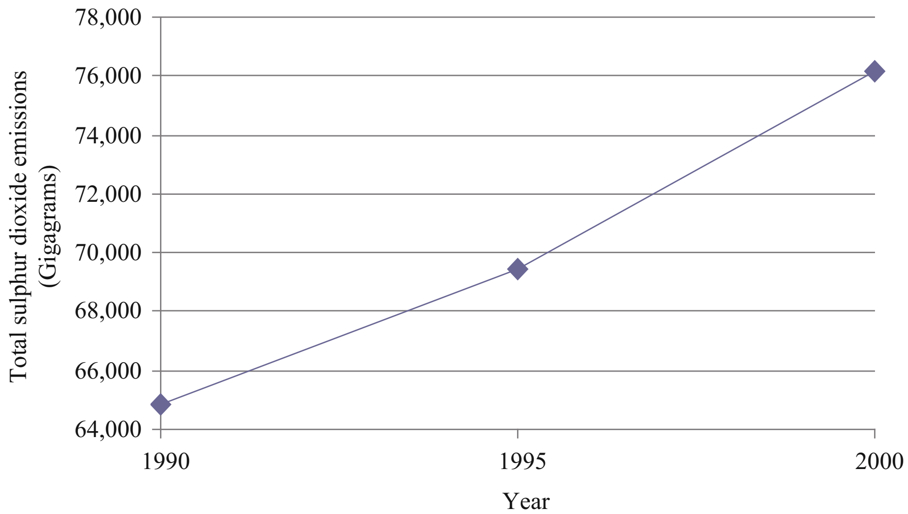

Figure 4.19 Trend of total sulphur dioxide emissions in Asia (1990-2000)
(Source: UNEP, 2010)

Table 4.6 shows the changes in SO_2 emissions in Asian economies. In comparison with 1990, per capita SO_2 emissions in 15 economies dropped slightly and total SO_2 emissions went down in 9 of the 15 economies. In other economies, per capita SO_2 emissions and total SO_2 emissions exhibit a rising trend.

Table 4.6 The change of SO_2 emissions intensity, SO_2 emissions per capita and total SO_2 emissions in Asian economies (1990-2000)

Country /Region	SO_2 emissions intensity (kg per thousand 2000 USD)			SO_2 emissions per capita (kg)			Total SO_2 emissions (Gigagrams)		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
Armenia	30.6	10.2	7.3	24.4	4.7	4.5	86	15	14
Azerbaijan	19.4	69.8	31.2	24.3	34.1	20.5	174	262	165
Bahrain	7.4	5.4	10.5	69.9	60.6	128.6	34	35	84
Bangladesh	6.3	5.3	4.7	1.6	1.5	1.6	186	194	222
Bhutan	14.2	12.2	9.0	6.7	7.5	6.9	4	4	4
Brunei	0.6	1.6	1.4	10.4	29.7	25.8	3	9	9
Cambodia		7.1	8.0	1.7	1.6	2.3	17	18	29
China	57.5	43.6	28.7	22.5	28.7	27.3	25,566	34,544	34,454
Cyprus	5.8	5.8	6.6	52.7	61.1	78.4	36	45	62
Georgia	5.2	2.5	3.5	7.8	1.1	2.2	43	6	11
India	18.6	18.7	17.2	5.9	7.0	7.8	5,020	6,484	7,920
Indonesia	6.5	5.0	8.2	4.0	4.2	6.6	712	798	1,348
Iran	16.4	14.9	13.8	21.2	20.9	21.9	1,155	1,234	1,401
Iraq			15.8	19.2	18.3	16.3	363	395	410
Israel	3.9	3.8	3.6	60.2	66.8	71.2	281	370	448
Japan	0.5	0.5	0.6	16.9	17.2	20.5	2,085	2,162	2,597
Jordan	14.8	14.7	14.3	23.9	25.2	25.3	76	106	121
Kazakhstan	98.8	130.5	111.6	159.3	133.5	137.1	2,604	2,112	2,041
Kuwait		6.9	8.0	61.3	131.7	137.1	130	237	300
Kyrgyzstan	34.9	21.6	24.0	16.2	4.9	6.7	72	23	33
Laos	12.4	10.0	30.3	2.8	2.7	9.7	12	13	53
Lebanon	6.2	5.6	6.2	18.9	25.6	28.2	56	89	106

Continued

Country /Region	SO_2 emissions intensity (kg per thousand 2000 USD)			SO_2 emissions per capita (kg)			Total SO_2 emissions (Gigagrams)		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
Malaysia	7.8	5.8	4.5	20.4	20.9	18.0	370	430	418
Maldives		2.3	1.7	2.6	3.9	3.8	1	1	1
Mongolia	13.6	13.2	11.2	6.7	5.6	5.1	15	13	12
Nepal	16.6	15.5	15.2	2.9	3.1	3.4	56	68	83
Oman	4.0	5.7	4.8	27.7	44.3	39.5	51	96	95
Pakistan	8.3	9.0	9.6	3.8	4.6	5.2	415	567	713
Philippines	11.0	10.1	9.1	9.9	9.1	8.9	619	634	688
Qatar			1.5	55.0	50.2	44.3	26	26	27
Rep. of Korea	8.2	7.6	8.0	56.7	73.0	91.2	2,430	3,291	4,285
Russia	45.5	40.8	37.7	118.4	66.0	66.9	17,551	9,773	9,793
Saudi Arabia	4.4	4.3	6.7	39.1	39.2	60.9	636	717	1,257
Singapore	7.5	6.1	11.8	109.9	118.7	271.6	335	418	1,094
Sri Lanka	3.9	3.4	6.6	2.2	2.4	5.8	38	44	108
Syria	22.0	20.4	19.1	20.4	24.1	22.3	259	352	369
Tajikistan	5.0	6.2	7.3	2.1	0.9	1.0	11	5	6
Thailand	9.6	10.3	10.6	13.4	20.5	20.9	761	1,233	1,306
Turkey	8.5	8.1	7.8	28.4	28.9	31.2	1,594	1,771	2,075
Turkmenistan	43.5	27.4	24.5	45.3	15.6	15.8	166	65	71
United Arab Emirates	3.3	2.9	13.3	82.6	65.6	290.5	154	160	941
Uzbekistan	33.9	36.8	28.0	23.2	18.4	15.6	476	419	385
Vietnam	11.0	8.7	8.2	2.5	2.7	3.3	166	194	256

Continued

Country /Region	SO_2 emissions intensity (kg per thousand 2000 USD)			SO_2 emissions per capita (kg)			Total SO_2 emissions (Gigagrams)		
	1990	1995	2000	1990	1995	2000	1990	1995	2000
Yemen	6.4	5.2	37.7	2.8	2.4	19.6	35	38	356
Asia	9.8	9.1	8.6	20.2	20.0	20.6	64,880	69,468	76,170
World	6.3	5.2	4.6	28.9	24.6	24.3	152,531	140,087	147,997

Source:
UNEP, 2010

4.2.7 Trend of organic water pollutant (OWP, i.e., BOD) discharge in Asia

There are also different studies on the relations between OWP discharge and economic development. Hettige and others (2000) employed international panel data in their studies and their findings show that EKC relations do not exist between industrial pollutants and economic growth. We do not have sufficient data on water pollutants; the time series are short; and it is very difficult to obtain data about Asia as a whole. For these reasons, our analysis and judgments are made on only a small number of economies for which statistical data are available (Figures 4.20-4.22 and Table 4.7).

As shown in Figure 4.20, since 1994 OWP discharge intensity in the 6 economies in the figure has exhibited a downward trend. In Oman, it has been fluctuating. This makes Oman the only exception. In terms of per capita OWP discharge and total OWP discharge, Oman maintains a rising trend while others are in a stable or declining stage.

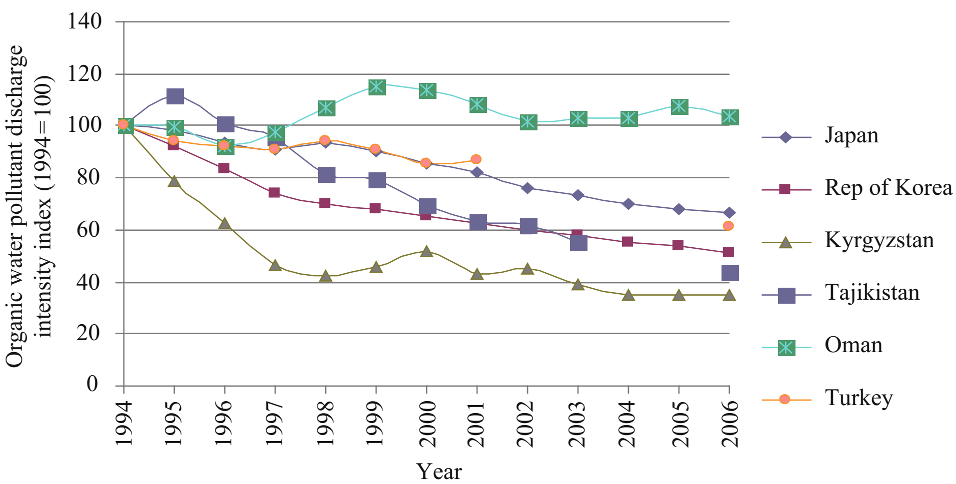

Figure 4. 20 Trend of OWP discharge intensity in six Asian economies (1994-2006)
(Source: UNEP, 2010)

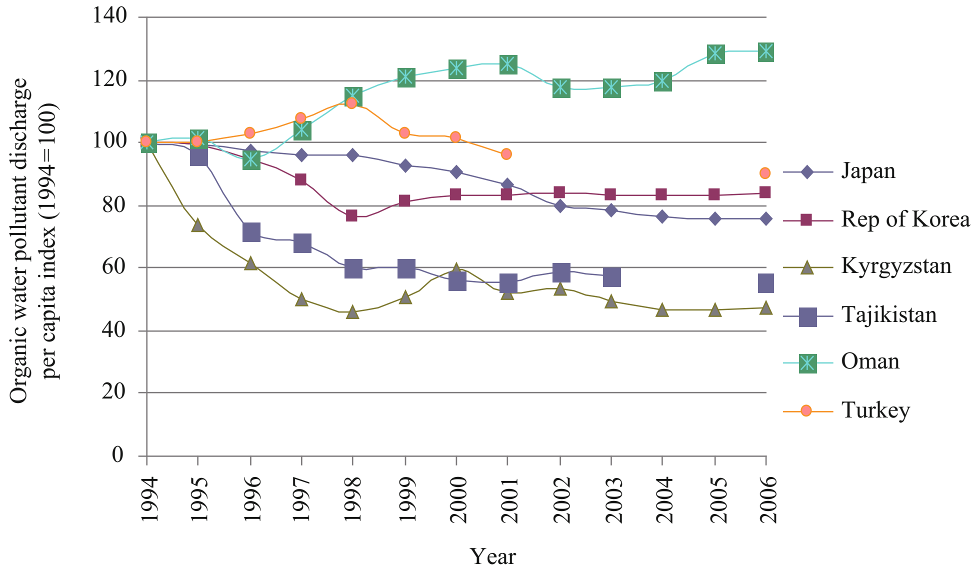

Figure 4.21 Trend of OWP discharge per capita in six Asian economies (1994-2006)
(Source: UNEP, 2010)

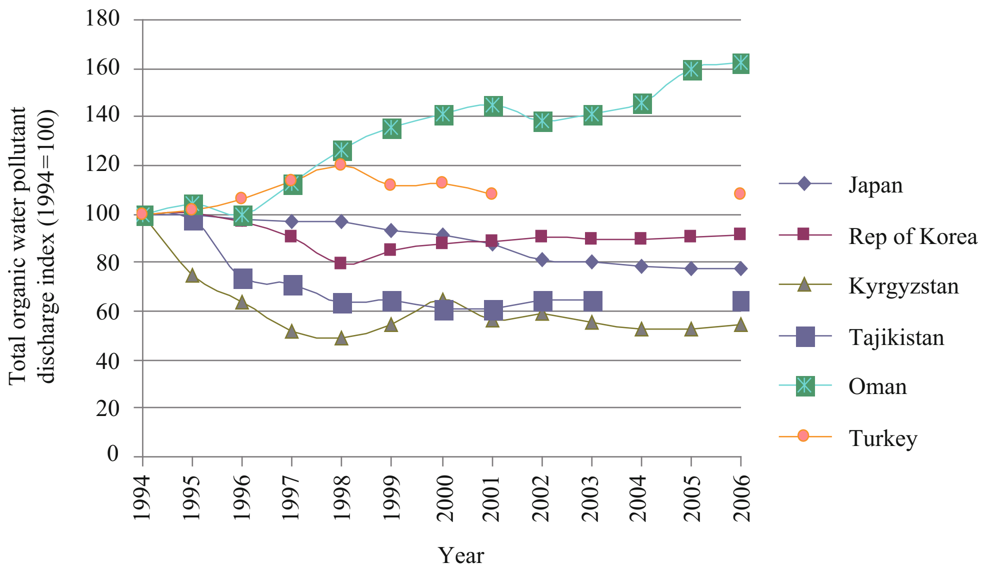

Figure 4.22 Trend of total OWP discharge in six Asian economies (1994-2006)
(Source: UNEP, 2010)

Table 4.7 shows the trend of OWP discharge in Asian economies since the 1990s. We can find that except for a small number of economies including Vietnam and Yemen, OWP discharge intensity in other countries exhibits a downward trend. In 2006, per capita OWP discharge in 10 economies rose and total OWP discharge in 7 economies fell.

Table 4.7 The change of OWP discharge intensity, OWP discharge per capita and total OWP discharge in Asian economies (1995-2006)

Country	OWP discharge intensity (gram per thousand 2000 USD)			OWP discharge per capita (kg)			Total OWP discharge (million kg)		
	1995	2000	2006	1995	2000	2006	1995	2000	2006
Indonesia		1,653.49	1,271.43		1.33	1.26		272.86	278.86
Japan	119.04	104.12	80.65	4.22	3.83	3.21	529.18	485.98	409.79
Malaysia		717.49	608.28		2.89	2.91		67.29	76.07
Philippines			358.88			0.41			35.73
Singapore		126.76	103.69		2.92	2.93		11.75	12.89
Rep. of Korea	299.32	211.55	166.94	2.86	2.40	2.42	128.87	112.84	116.66
Thailand		992.65	736.25		1.95	1.83		121.82	121.84
Vietnam		3,049.38	3,770.16		1.22	2.17		95.06	182.68
Bangladesh	2,505.19		1,690.43	0.71		0.71	91.53		110.60
Kazakhstan		25.16	18.71		0.03	0.04		0.46	0.62
Kyrgyzstan	5,730.56	3,759.93	2,541.52	1.30	1.05	0.83	5.97	5.15	4.32
Tajikistan	10,385.52	6,439.78	4,081.80	1.54	0.90	0.89	8.92	5.54	5.88
Azerbaijan	4,025.81	1,387.10	514.92	1.96	0.91	0.81	15.09	7.31	6.87
Cyprus		279.27	252.04		3.31	3.39		2.60	2.87
Iran	551.98	506.64	416.89	0.78	0.80	0.84	45.85	51.32	58.69
Iraq						0.10			2.81
Israel	164.07	127.33	106.94	2.89	2.53	2.21	16.01	15.88	15.62
Jordan	757.79	797.76	797.60	1.31	1.41	1.79	5.48	6.75	9.93
Lebanon			256.61			1.30			5.37
Oman	92.23	105.53	95.83	0.71	0.87	0.91	1.55	2.10	2.42
Qatar		48.79	46.46		1.40	1.36		0.87	1.36
Syria		115.09	65.78		0.13	0.08		2.22	1.64
Turkey	279.54	252.23	181.76	1.00	1.01	0.90	61.25	67.40	64.86
Yemen		25.93	48.91		0.01	0.03		0.24	0.59
Russia		2,219.25	1,344.63		3.94	3.56		576.36	506.65

4.3 Resource consumption and environmental change in Asia

On the basis of assessing the changes of resource consumption and pollutant discharge, we make further analysis on the resource consumption and environmental change of various economies in Asia.

4.3.1 Change of resources and environmental performance (REP) in Asia

(1) Resource and Environmental Performance Index(REPI)

CAS Sustainable Development Strategy Study Group (2006) proposed the Resource and Environmental Performance Index (REPI) to evaluate the resource and environmental performance of various countries and areas in Asia. It is expressed as:

$$REPI_j = \frac{1}{n}\sum_{i}^{n} w_{ij} \frac{x_{ij}/g_j}{X_{i0}/G_0} \qquad (4\text{-}1)$$

where $REPI_j$ is the REPI of country or region j; w_{ij} is the weighting for consumption of resource i or pollutant discharge in country or region j, x_{ij} is the total amount of consumption of resource i or pollutant discharge in country or region j, g_j is the GDP of country or region j, X_{i0} is the total amount of consumption of resource i or pollutant discharge globally, G_0 is the global GDP. x_{ij}/g_j represents the intensity of consumption of resource i or pollutant discharge in country or region j, while X_{i0}/G_0 represents the global intensity. To make the REPI of different countries or regions comparable, we can set X_{i0}/G_0 as the fixed base period.

Essentially, formula (4-1) represents the weighted average of intensity of n kinds of resources consumption or pollutant discharge in a country or region versus the global intensity. The lower the value of REPI is, the higher the level of REP is, and vice versa. As a result, the value of REPI can not only show the gap between the REP of a country or region and the global average, but indicate the gap between a country or region with other countries or regions. The value of REPI equaling 1 means the REP of a country or region is exactly the same as the global average. The value of more than 1 suggests the REP of a country or region is lower than the global average, while the value of less than 1 shows the REP of a country or region is higher than the global average.

As a composite index to measure eco-efficiency, REPI can be widely applied at different levels including international, national, regional, industrial, and company levels. It is relatively flexible to select different kinds of resources and pollutants for calculation of REPI according to actual conditions and data availability at different levels. However, it would be difficult to weigh environmental indicators according to their contribution to environmental impact. For simplicity, the equal weights are given to environmental indicators when we calculate REPI at different levels. It should be noted that REPI can only be used to demonstrate the general condition of the REP of a country or region. Its result and ranking may be subject to the impact of selecting different indexes and monetary exchange methods (Chen et al., 2008).

(2) REP of various countries in the world (1994-2007)

According to the accessibility and reliability of data, we have selected five categories of indicators on resource consumption and pollutant discharge, and employed formula (4-1) to conduct integrated assessment on the REP for 63 countries (including 19 countries in Asia) worldwide between 1994 and 2007 so as to measure their contributions to the global resources and environment. The GDP data is calculated with constant USD in 2000.

In 2007, the accumulated GDP of these 63 countries accounted for 91.5% of the global one. The five categories of indicators, i.e., primary energy use, consumption of finished steel, consumption of non-ferrous common metals, consumption of ozone-depleting substances, and carbon dioxide emissions from the consumption of energy, are selected. Among them, the first three indicators are mainly used to represent the performance of material energy use, while the last two ones focus on the environmental performance. The result and rankings are shown in Figure 4.23.

Of the 63 countries worldwide in 2007, the top 10 in terms of REP were Switzerland, England, Denmark, Ireland, Japan, Norway, France, Netherland, USA, and Sweden successively, with their REPI 1/3-1/2 of the global average; while the last 10 countries were Malaysia, Romania, Bulgaria, Iran, Vietnam, Russia, Kazakhstan, Bahrain, and Ukraine, with their REPI as 2.3-5.6 times as the world average.

(3) Correlation between REP and economic growth of different countries worldwide(1994-2007)

Figure 4.24 shows the correlation between REP and economic growth (expressed with GDP percapita) for the 63 countries between 1994 and 2007.

It can be learned that the REPI tends to decline significantly with the rising of economic growth. The REP in developed countries are generally higher than those of the developing countries. In addition, the countries with higher REPI are also those with relatively poor REP, and their GDP percapita are often registered to be below 5,000 USD.

(4) REP of Asian countries (1994-2007)

The results and rankings of REP for the 19 countries in Asia are shown in Tables 4.8 and 4.9. Table 4.9 suggests that the REP for most of the Asian countries lag behind in the rankings. In 2007, except Japan (the 5^{th}) and Singapore (the 17^{th}), other Asian countries ranked after the 30^{th} . Such countries as Thailand, Malaysia, Iran, Vietnam, Russia, Kazakhstan, China and Bahrain all ranked behind the 50^{th}, which, to some extent, indicated that most Asian countries adopted an extensive pattern in economic development.

Between 1994 and 2007, the REPI of the 19 countries in Asia were generally 1.5-1.8 times that of the global average, with the REP below the global figure. As shown in Figure 4.25, the REPI in Asia exhibits a U-shaped trend of slowly falling before recovering gradually, but it tends to rise in general, with an annual average growth of 0.35%. This indicates that the REP in Asia has been exacerbating. During the same period, however, the global REPI was on the decline, down by 1.32% annually.

(5) Correlation between REPI and per capita GDP in Asia(1994-2007)

The correlation between REPI and per capita GDP for the 19 countries in Asia between 1994 and 2007 is shown in Figure 4.26. It suggests that generally the REPI is negatively correlated with per capita GDP in Asia: the higher the per capita GDP of a country, the lower its REPI.

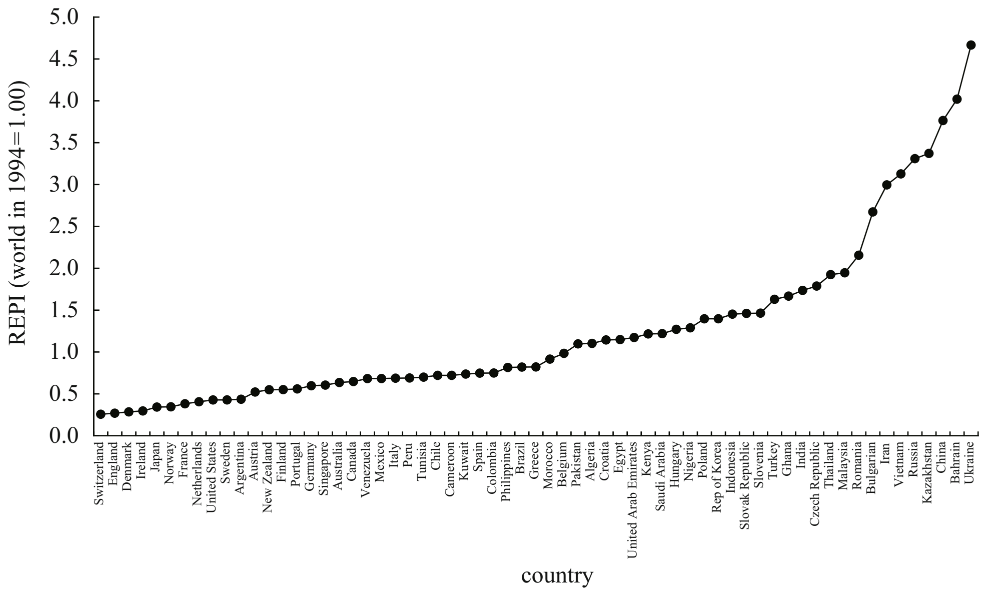

Figure 4.23　REPI ranking of 63 countries in 2007

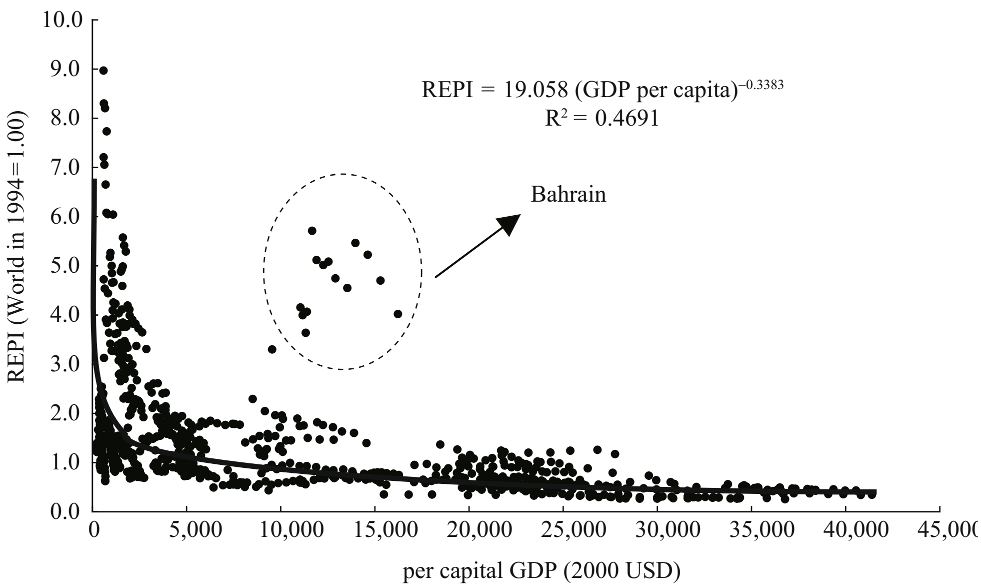

Figure 4.24　The correlation between REPI and GDP per capita in 63 countries (1994-2007)

Table 4.8 REPI of 19 countries in Asia based on five categories of resource consumption and pollutant discharges (1994-2007) (World in 1994=1.00)

Country /Region	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Bahrain	4.155	3.996	3.638	4.067	5.712	5.117	5.016	5.086	4.746	4.550	5.465	5.225	4.700	4.020
China	4.724	4.537	3.907	3.839	4.442	3.641	3.416	3.273	3.267	3.612	3.632	3.825	3.755	3.764
India	2.290	2.220	2.220	2.164	2.065	2.238	2.151	1.992	2.019	1.946	1.846	1.726	1.744	1.735
Indonesia	1.772	1.855	1.821	1.696	1.475	1.542	1.559	1.589	1.569	1.486	1.521	1.346	1.181	1.452
Iran	3.077	2.792	2.654	3.368	3.304	3.074	3.138	3.205	3.470	3.395	3.336	3.123	2.905	2.996
Japan	0.459	0.495	0.420	0.421	0.386	0.389	0.399	0.378	0.367	0.376	0.375	0.360	0.357	0.342
Kazakhstan	6.042	5.000	4.657	3.932	4.098	4.256	4.228	4.034	3.829	3.782	3.817	3.993	3.821	3.372
Rep. of Korea	2.294	2.047	1.963	1.959	1.582	1.888	1.895	1.755	1.819	1.764	1.719	1.632	1.602	1.397
Kuwait	——	——	——	——	——	——	——	——	0.951	0.884	0.886	0.864	0.806	0.736
Malaysia	2.606	2.614	2.403	2.419	1.908	2.096	2.071	2.121	2.144	1.847	1.898	1.950	1.888	1.946
Pakistan	1.369	1.388	1.278	1.238	1.122	1.266	1.320	1.244	1.234	1.158	1.126	1.025	1.027	1.097
Philippines	1.735	1.828	1.833	1.651	1.381	1.431	1.423	1.273	1.241	1.130	1.025	0.947	0.848	0.815
Russia	5.414	5.575	4.930	4.591	4.883	4.987	5.291	4.194	4.113	3.904	3.822	3.727	3.647	3.309
Saudi Arabia	1.250	1.212	1.211	1.181	1.215	1.163	1.131	1.220	1.289	1.275	1.300	1.276	1.332	1.219
Singapore	1.367	1.266	1.155	——	1.093	0.917	0.867	0.940	0.910	0.906	0.911	0.884	0.793	0.605
Thailand	2.311	2.516	2.241	2.083	1.707	1.958	1.982	2.076	2.137	2.190	2.264	2.233	2.052	1.924
Turkey	1.230	1.483	1.478	1.483	1.531	1.391	1.446	1.332	1.399	1.509	1.486	1.529	1.548	1.629
United Arab Emirates	——	——	——	——	——	1.215	1.145	1.117	1.243	1.202	1.206	1.242	1.259	1.173
Vietnam	——	——	——	——	——	1.676	1.777	2.045	2.500	2.377	2.543	2.356	2.405	3.127
Asia	1.472	1.500	1.371	1.368	1.417	1.377	1.379	1.328	1.371	1.444	1.509	1.495	1.503	1.540

Table 4.9 Rankings of resource and environment performance of 19 Asian countries in 63 countries (1994-2007))

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Bahrain	51	51	53	53	55	59	59	61	62	62	63	61	61	62
China	52	53	54	51	53	56	57	58	58	59	59	59	59	61
India	43	46	46	45	47	53	53	50	52	53	51	50	50	51
Indonesia	39	43	42	39	37	45	46	45	47	45	47	44	39	46
Iran	48	50	50	49	51	55	56	57	59	58	58	57	57	57
Japan	5	5	4	4	4	5	5	5	5	5	5	4	5	5
Kazakhstan	54	54	55	52	52	57	58	59	60	60	60	60	60	60
Rep. of Korea	44	45	44	43	41	49	49	48	48	50	48	48	48	45
Kuwait	——	——	——	——	——	——	——	——	30	27	28	27	26	27
Malaysia	47	49	49	47	45	51	52	54	54	52	53	52	52	54
Pakistan	35	35	33	31	29	36	37	36	37	37	35	34	37	35
Philippines	38	42	43	38	34	42	41	37	38	35	34	31	30	30
Russia	53	55	56	54	54	58	60	60	61	61	61	58	58	59
Saudi Arabia	33	28	32	30	31	33	32	35	40	40	42	40	44	41
Singapore	34	30	30	——	28	25	24	28	27	28	30	28	24	17
Thailand	45	48	47	44	43	50	50	53	53	54	55	53	53	53
Turkey	32	37	38	35	38	41	42	39	43	46	46	47	47	49
United Arab Emirates	——	——	——	——	——	34	33	31	39	38	37	39	42	39
Vietnam	——	——	——	——	——	47	47	52	56	56	56	55	55	58

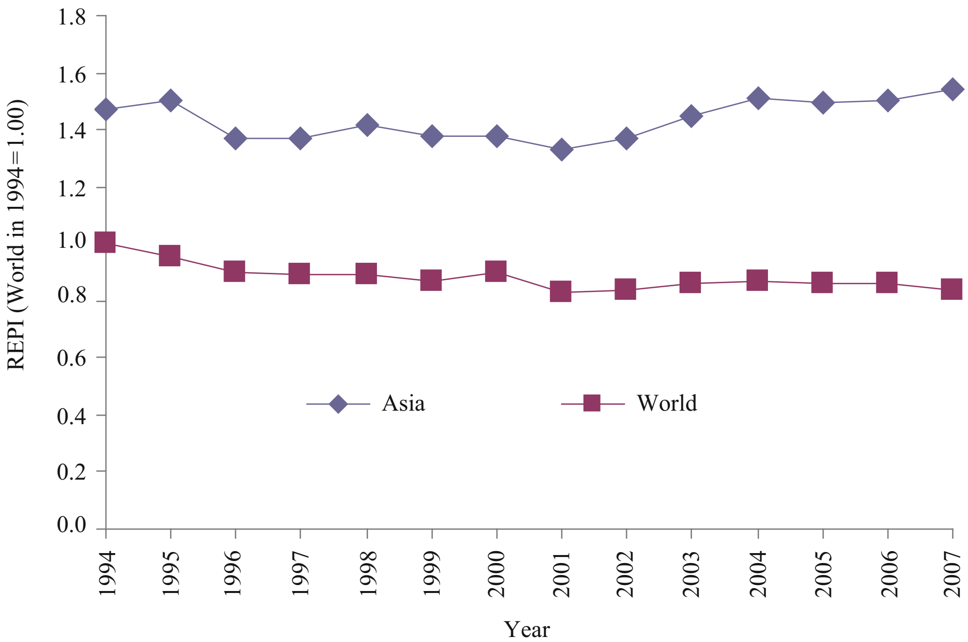

Figure 4.25 REPI in Asia and the world (1994-2007)

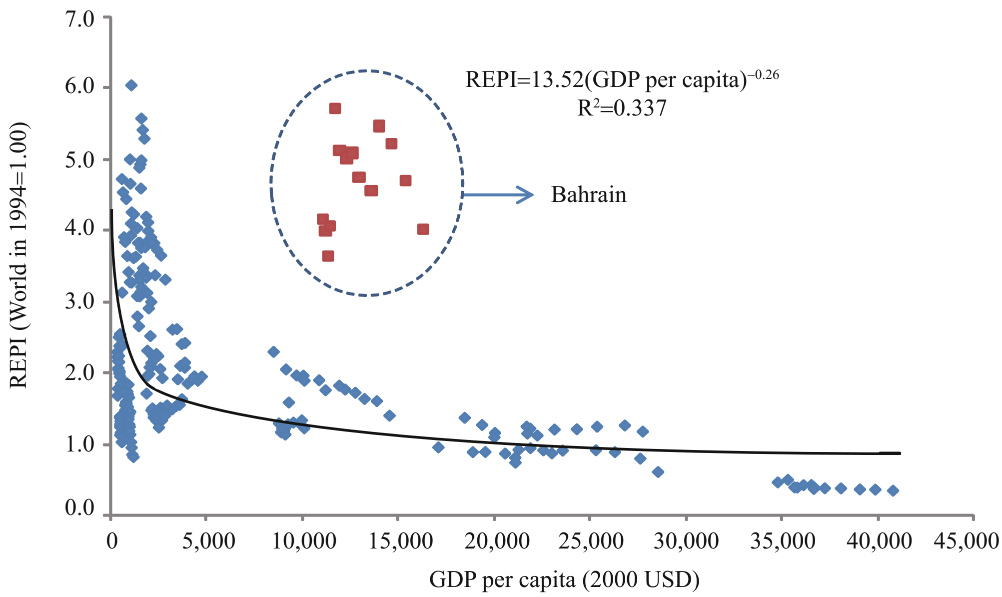

Figure 4.26 The correlation between REPI and per capita GDP in 19 Asian countries (1994-2007)

4.3.2 The change of per capita resource consumption and pollutant discharge in Asia

(1) Per capita resource consumption and pollutant discharge index (PCI)

We have proposed the per capita resource consumption and pollutant discharge index (PCI) to show the per capita change of five categories of resource consumption and pollutant discharge. It is expressed as

$$PCI_j = \frac{1}{n}\sum_{i}^{n} w_{ij} \frac{x_{ij} / p_j}{X_{i0} / P_0} \quad (4\text{-}2)$$

where PCI_j is the PCI of country or region j; w_{ij} is the weighting for consumption of resource i or pollutant discharge in country or region j, x_{ij} is the total amount of consumption of resource i or pollutant discharge in country or region j, p_j is the population number of country or region j, X_{i0} is the total amount of consumption of resource i or pollutant discharge globally, P_0 is the global population. x_{ij}/P_j represents the per capita amount of consumption of resource i or pollutant discharge in country or region j, while X_{i0}/P_0 represents the global per capita amount. To make the PCI of different countries or regions comparable, we can set X_{i0}/P_0 as the fixed base period, while giving the same weighting for various resources and environmental indicators.

Essentially, formula (4-2) represents the weighted average of per capita of n kinds of resource consumptions or pollutant discharges in a country or region versus the global per capita level. The lower the value of PCI is, the higher its pressure onto the global resources and environment is, and vice versa. As a result, the value of PCI can not only show the gap between the per capita resource consumption or pollutant discharge of a country or region and the global average, but indicate the gap between a country or region with other countries or regions. The value of PCI equaling 1 means the per capita resource consumption or pollutant discharge of a country or region is exactly the same as the global average. The value of more than 1 suggests the per capita resource consumption or pollutant discharge of a country or region is higher than the global average, while the value of less than 1 shows that the figure of a country or region is lower than the global average.

(2) Change of PCI in different countries worldwide (1994-2007)

Formula (4-2) is applied to calculate the PCI of 63 countries in the world, whose results are shown in Figure 4.27. In 2007, the top 10 in terms of PCI were Bahrain, UAE, Belgium, Rep. of Korea, Slovenia, Singapore, Canada, USA, Kuwait and Finland successively, with their PCI 3-12 times that of the global average; while the last 10 countries were Columbia, Indonesia, Morocco, India, Philippines, Pakistan, Nigeria, Kenya, Ghana and Cameroon, with their PCI 1/10-1/3 of the global average.

(3) Correlation between PCI and per capita GDP of different countries (1994 -2007)

The correlation between PCI and per capita GDP of the 63 countries worldwide between 1994 and 2007 is shown in Figure 4.28. The figure suggests that there exists an inverted U-shaped relation between PCI and per capita GDP for these countries except Bahrain. The per capita GDP at the inflexion stood at approximately 25,000 in constant USD in 2000.

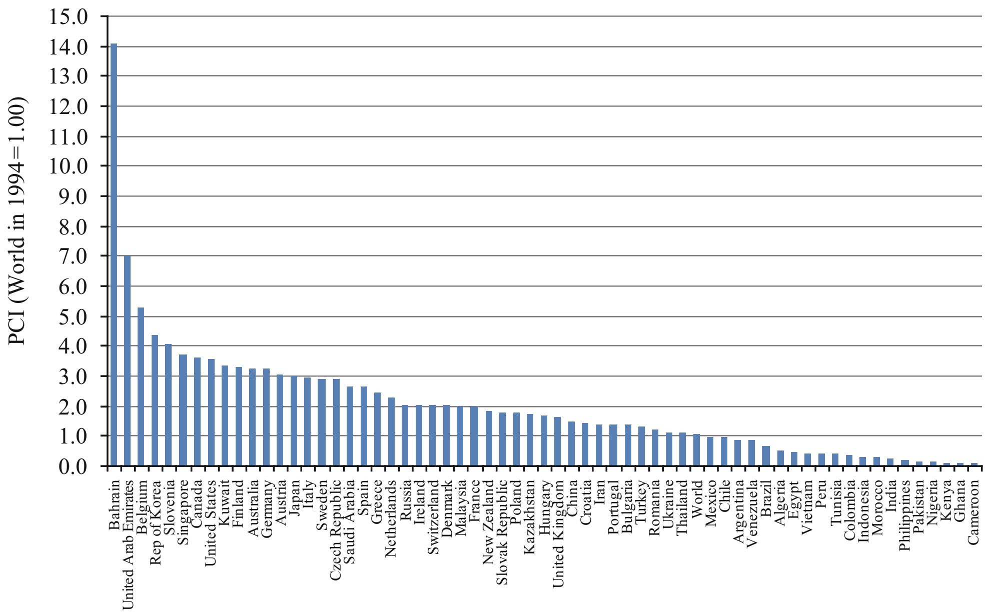

Figure 4.27 PCI ranking of 63 countries in 2007

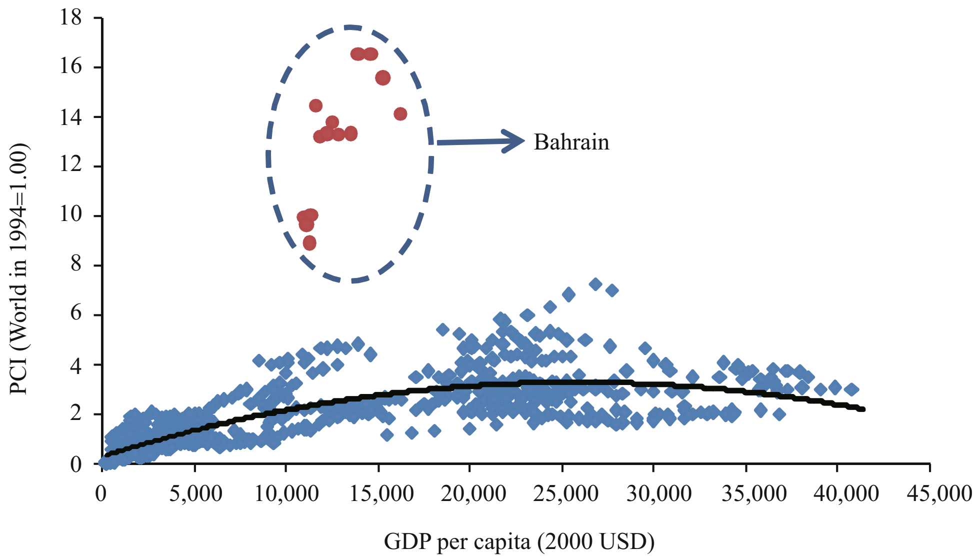

Figure 4.28 The relationship between PCI and GDP per capita in 63 countries (1994-2007)

(4) Change of PCI of Asian countries (1994-2007)

The results and rankings of PCI for the 19 countries in Asia are shown in Tables 4.10 and 4.11. As Table 4.11 suggests, in 2007, the PCI of Bahrain and UAE ranked the first and second respectively among those of the 63 countries worldwide. They were followed by Rep. of Korea (the 4^{th}), Singapore (the 6^{th}) , Kuwait (the 9^{th}), Japan (the 14^{th}) , and Saudi Arabia (the 18^{th}), while other countries ranked behind the 20^{th}.

Between 1994 and 2007, though the PCI in Asia was generally lower than the world average, it grew 1.47% annually, higher than the world average growth of 0.64%. This has narrowed the gap of PCI between Asia and the world average, as shown in Figure 4.29.

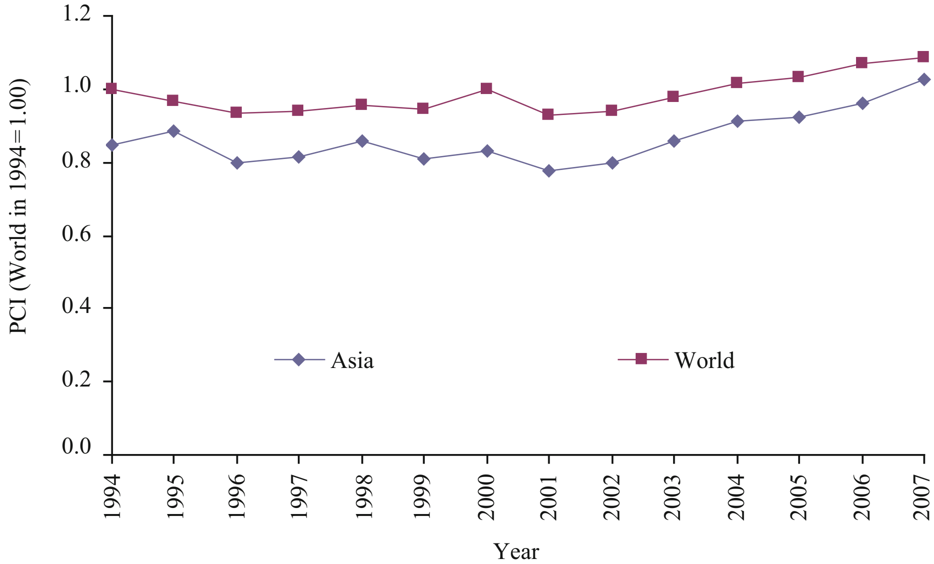

Figure 4.29 The change of PCI in Asia and the world (1994-2007)

(5) Correlation between PCI and per capita GDP of various countries in Asia (1994-2007)

Figure 4.30 shows the correlation between PCI and per capita GDP of various countries in Asia. It can be found the PCI and per capita GDP of various countries in Asia, except Bahrain, display the same relation as the global one, i.e., inverted U-shaped relation.

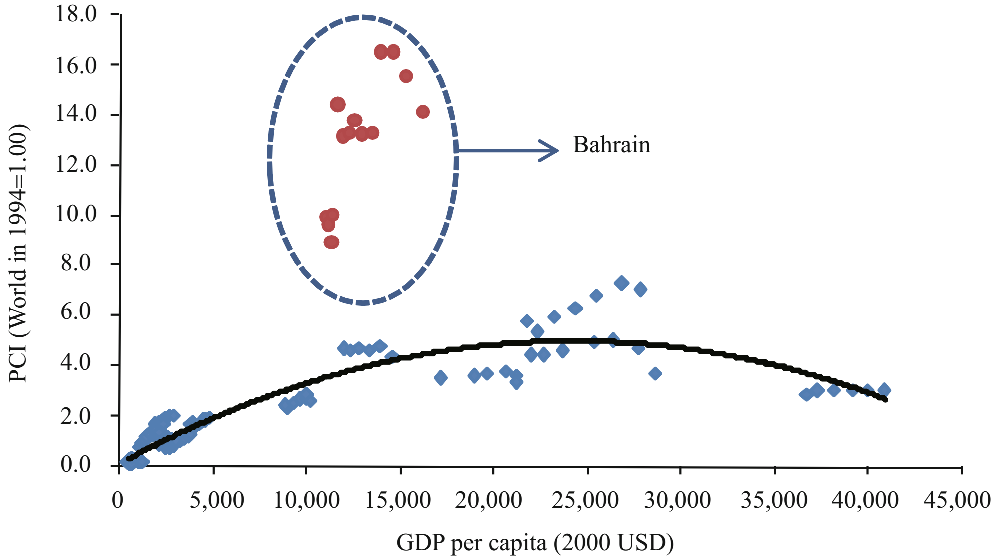

Figure 4.30 The relationship between PCI and GDP per capita in 19 Asian countries (1994-2007)

Table 4.10 The PCI of 19 Asian countries based on five categories of resource consumption and pollutant discharges per capita (1994-2007) (World in 1994=1.00)

Region	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Bahrain	9.920	9.642	8.909	10.013	14.406	13.165	13.295	13.782	13.238	13.312	16.497	16.513	15.541	14.097
China	0.612	0.645	0.605	0.643	0.794	0.694	0.701	0.722	0.781	0.944	1.039	1.199	1.306	1.471
India	0.174	0.179	0.188	0.189	0.188	0.214	0.210	0.202	0.209	0.215	0.218	0.219	0.240	0.258
Indonesia	0.296	0.332	0.345	0.332	0.248	0.258	0.270	0.281	0.286	0.280	0.297	0.274	0.251	0.324
Iran	0.928	0.850	0.852	1.101	1.091	1.018	1.075	1.119	1.283	1.323	1.346	1.296	1.257	1.380
Japan	3.454	3.776	3.280	3.326	2.986	2.997	3.158	2.997	2.906	3.025	3.089	3.044	3.075	3.020
Kazakhstan	1.430	1.106	1.305	1.145	1.250	1.153	1.214	1.271	1.292	1.376	1.507	1.713	1.801	1.718
Rep. of Korea	4.219	4.052	4.118	4.260	3.182	4.128	4.457	4.255	4.692	4.667	4.747	4.675	4.811	4.395
Kuwait	——	——	——	——	——	——	——	——	3.517	3.612	3.744	3.842	3.675	3.360
Malaysia	1.825	1.960	1.933	2.036	1.451	1.653	1.737	1.747	1.803	1.610	1.742	1.848	1.861	2.003
Pakistan	0.148	0.153	0.144	0.138	0.125	0.143	0.151	0.142	0.142	0.137	0.138	0.132	0.137	0.152
Philippines	0.332	0.358	0.372	0.345	0.281	0.295	0.304	0.271	0.271	0.253	0.239	0.227	0.210	0.212
Russia	1.973	1.950	1.667	1.579	1.594	1.739	2.030	1.695	1.749	1.791	1.888	1.969	2.085	2.050
Saudi Arabia	2.483	2.349	2.368	2.311	2.389	2.237	2.229	2.365	2.449	2.553	2.680	2.733	2.874	2.663
Singapore	5.457	5.303	5.004	——	4.732	4.217	4.315	4.451	4.440	4.618	4.987	5.025	4.733	3.732
Thailand	0.965	1.134	1.058	0.959	0.696	0.825	0.866	0.920	0.989	1.077	1.174	1.201	1.153	1.128
Turkey	0.672	0.853	0.893	0.946	0.989	0.842	0.924	0.774	0.864	0.971	1.035	1.129	1.207	1.313
United Arab Emirates	——	——	——	——	——	5.748	5.377	5.376	5.832	6.014	6.337	6.813	7.298	7.036
Vietnam	——	——	——	——	——	0.136	0.154	0.187	0.242	0.243	0.276	0.274	0.299	0.417
Asia	0.847	0.886	0.797	0.814	0.860	0.807	0.832	0.774	0.797	0.859	0.911	0.921	0.963	1.024

Table 4.11 PCI ranking of 19 Asian countries in 63 countries (1994-2007)

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Bahrain	1	1	1	1	1	1	1	1	1	1	1	1	1	1
China	46	45	46	42	43	45	46	46	45	44	42	37	36	34
India	53	52	53	50	52	54	55	56	57	57	57	56	55	56
Indonesia	51	49	50	47	51	53	54	54	54	54	53	53	54	54
Iran	41	41	43	33	36	35	35	36	35	35	35	35	37	36
Japan	9	7	9	6	11	13	12	13	13	13	12	12	14	14
Kazakhstan	29	38	31	32	33	34	33	34	34	34	34	29	31	31
Rep. of Korea	5	6	4	3	7	6	4	5	4	4	5	5	4	4
Kuwait	——	——	——	——	——	——	——	——	8	8	9	7	9	9
Malaysia	24	24	22	19	28	28	27	28	27	31	28	26	26	26
Pakistan	54	53	55	52	55	56	58	60	59	59	58	57	57	58
Philippines	49	48	49	46	50	51	52	55	55	55	56	55	56	57
Russia	22	25	27	25	26	26	23	29	29	27	27	24	24	22
Saudi Arabia	15	17	15	15	16	20	21	19	19	18	17	17	17	18
Singapore	2	2	2	——	3	5	6	4	5	5	4	4	5	6
Thailand	40	37	37	37	45	43	43	41	39	38	39	36	40	42
Turkey	44	40	40	38	38	41	40	45	43	43	43	39	38	39
United Arab Emirates	——	——	——	——	——	2	2	2	2	2	2	2	2	2
Vietnam	——	——	——	——	——	58	57	57	56	56	55	54	52	50

4.3.3 Change of the total amount of resource consumption and pollutant discharge in Asia

(1) Index of Total Amount of Resource Consumption and Pollution Discharge (TI)

We have proposed the Index of Total Amount of Resource Consumption and Pollution Discharge (TI) to show the change of the total amount of five categories of resource consumption and pollutant discharge. It is expressed as

$$TI_j = \frac{1}{n}\sum_{i}^{n} w_{ij}\frac{x_{ij}}{X_{i0}} \tag{4-3}$$

where TI_j is the TI of country or region j; w_{ij} is the weighting for consumption of resource i or pollutant discharge in country or region j, x_{ij} is the total amount of consumption of resource i or pollutant discharge in country or region j, X_{i0} is the total amount of consumption of resource i or pollutant discharge globally. To make the TI of different countries or regions comparable, we can set X_{i0} as the fixed base period, while giving the same weighting for various resources and environmental indicators.

Essentially, formula (4-3) represents the weighted average of total amount of n kinds of resources consumptions or pollutant discharges in a country or region versus that of the global total amount. The higher the value of TI is, the higher its pressure onto the global resources and environment is, and vice versa. As a result, the value of TI can show the gap between a country or region and other countries or regions in terms of the total amount of resource consumption or pollutant discharge.

(2) Change of TI of various countries worldwide (1994-2007)

Formula (4-3) is employed to calculate the TI of 63 countries in the world, whose results are shown in Figure 4.31. In 2007, the top 10 in terms of TI were China, USA, Japan, Russia, India, Germany, Rep. of Korea, Italy, Brazil, and France successively; while the last 10 countries were Morocco, Kuwait, Ireland, Slovenia, New Zealand, Croatia, Kenya, Tunisia, Ghana and Cameroon. Between 1994 and 2007, the TI of most countries worldwide exhibited a trend of growth, except the 12 countries, i.e., Argentina, Canada, Japan, Philippines, Romania, Russia, Singapore, Switzerland, Ukraine, England, USA, and Venezuela.

(3) Relation between TI and per capita GDP of various countries in the world (1994-2007)

As the TI of different countries vary greatly, there does not exist a significant relationship between TI and per capita GDP for the 63 countries worldwide (Figure 4.32).

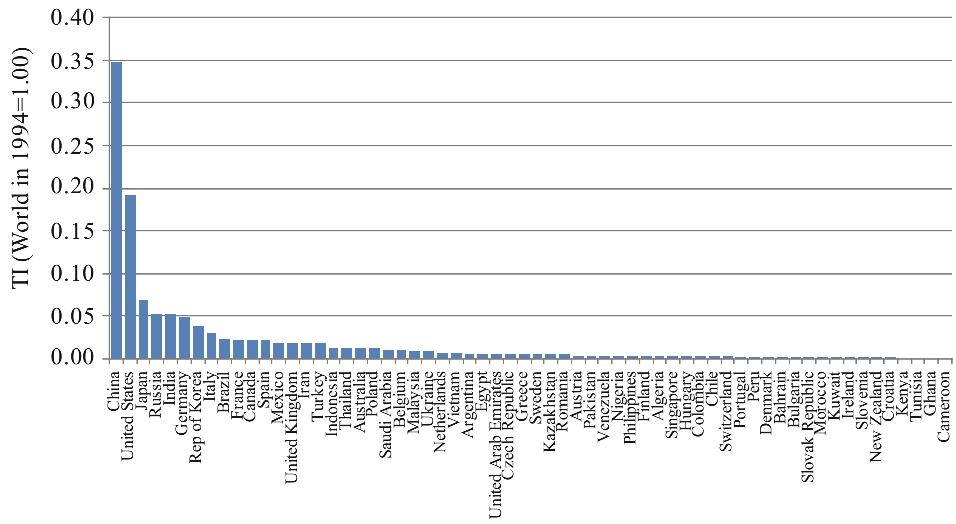

Figure 4.31 TI ranking of 63 countries in 2007

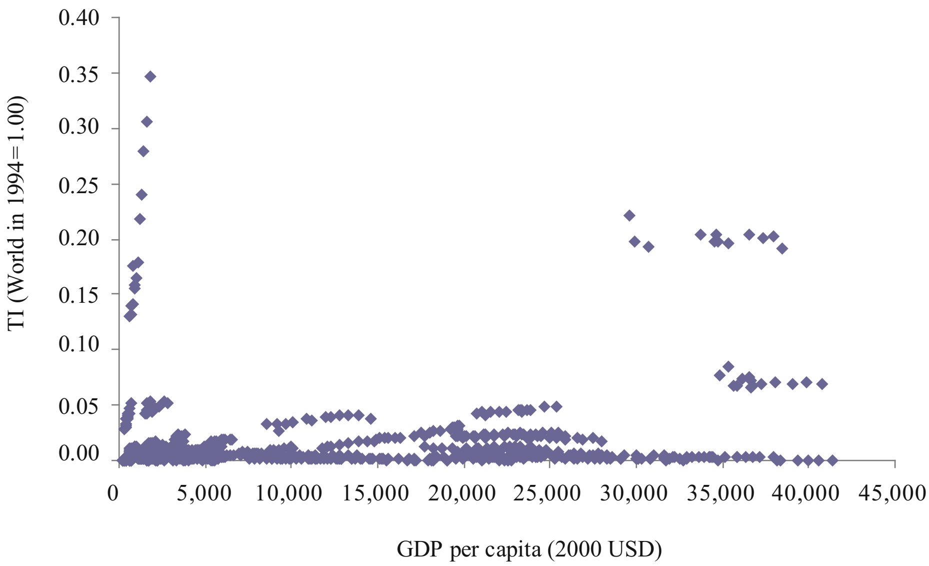

Figure 4.32 The relationship between TI and per capita GDP in 63 countries (1994-2007)

(4) Change of TI in Asia (1994-2007)

The results of TI for the 19 countries in Asia are shown in Table 4.12. As Table 4.12 suggests, in 2007, listed in top 10 in terms of TI were five countries in Asia: China (the 1st), Japan (the 3rd), Russia (the 4th), India (the 5th), and Rep. of Korea (the 7th). By excluding the difference of per capita and accumulated impacts, the TI indicate that Asia region as a whole contributed significantly to the pressure onto global resources and environment.

Between 1994 and 2007, the TI in Asia rose by 4.1% annually, higher than the world average growth of 1.9%. This has increased the share of Asia in the world in terms of the five categories of resource consumption and pollutant discharge, as shown in Figure 4.33.

Table 4.12 shows the change of TI for the 19 countries in Asia. It can be found that TI for most countries in Asia, except Japan, Singapore, Philippines and Russia, exhibited a significant trend of growth.

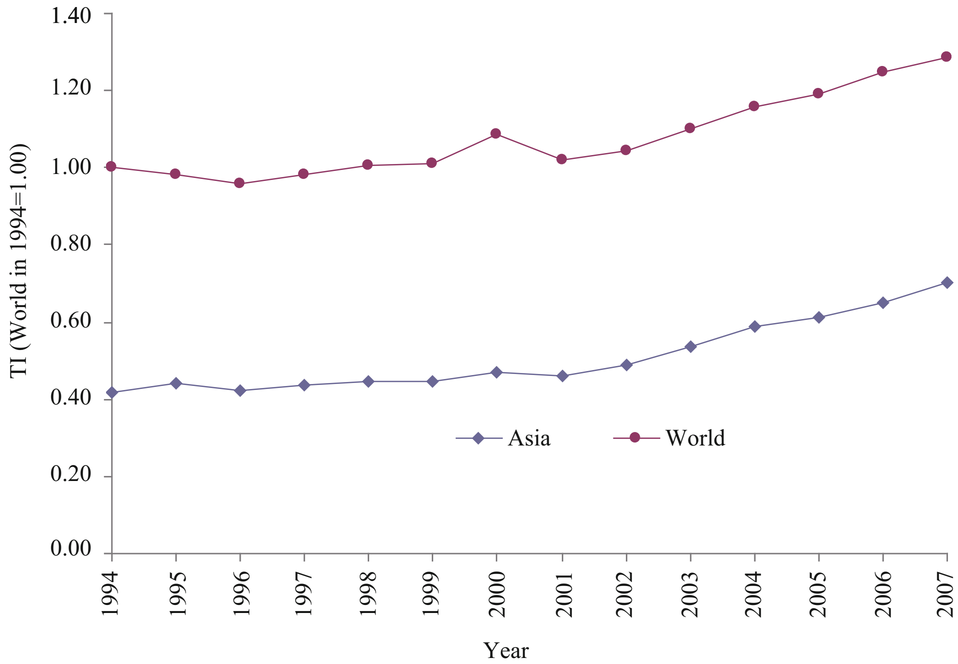

Figure 4.33 The change of TI in Asia and the world (1994-2007)

(5) Relation between TI and per capita GDP in Asia (1994-2007)

Figure 4.34 shows the relation between TI and per capita GDP in Asia. Similar to that of the 63 countries worldwide, there also does not exist a significant relationship between these two figures for the 19 countries in Asia between 1994 and 2007.

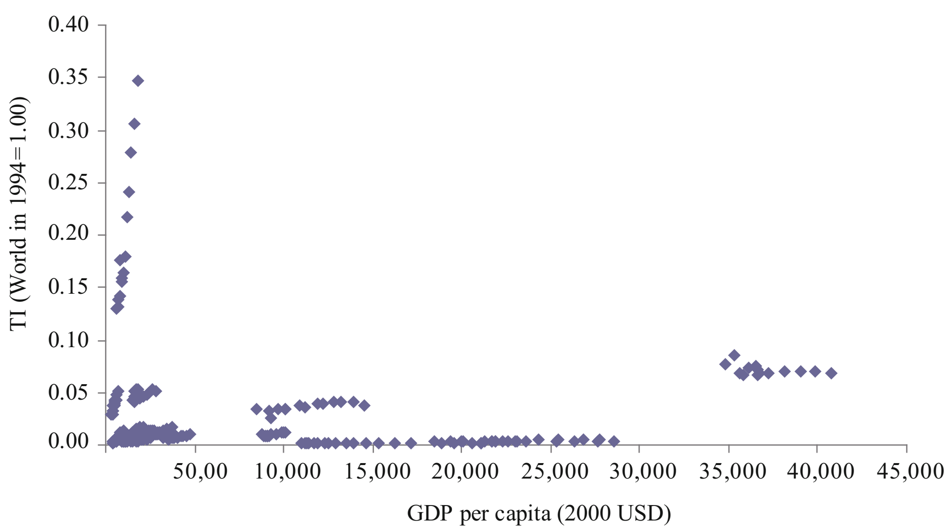

Figure 4.34 The relationship between TI and GDP per capita in 19 Asian countries (1994-2007)

Table 4.12 TI of 19 Asian countries based on five kinds of total resource consumption and pollutant discharges (1994-2007) (World in 1994=1.00)

Region	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Bahrain	0.0010	0.0010	0.0009	0.0011	0.0016	0.0015	0.0015	0.0016	0.0016	0.0017	0.0021	0.0021	0.0021	0.0019
China	0.1305	0.1390	0.1317	0.1414	0.1764	0.1556	0.1583	0.1642	0.1788	0.2175	0.2408	0.2795	0.3061	0.3469
India	0.0286	0.0298	0.0320	0.0326	0.0330	0.0383	0.0383	0.0373	0.0392	0.0410	0.0421	0.0430	0.0477	0.0519
Indonesia	0.0101	0.0114	0.0121	0.0118	0.0089	0.0094	0.0099	0.0105	0.0108	0.0108	0.0116	0.0108	0.0100	0.0131
Iran	0.0096	0.0090	0.0091	0.0120	0.0121	0.0114	0.0123	0.0130	0.0151	0.0159	0.0164	0.0160	0.0158	0.0175
Japan	0.0772	0.0847	0.0738	0.0750	0.0675	0.0679	0.0717	0.0682	0.0663	0.0691	0.0706	0.0696	0.0703	0.0690
Kazakhstan	0.0041	0.0031	0.0036	0.0031	0.0034	0.0031	0.0032	0.0034	0.0034	0.0037	0.0040	0.0046	0.0049	0.0048
Rep. of Korea	0.0335	0.0327	0.0335	0.0350	0.0263	0.0344	0.0375	0.0360	0.0400	0.0399	0.0408	0.0403	0.0416	0.0381
Kuwait	——	——	——	——	——	——	——	——	0.0015	0.0016	0.0016	0.0017	0.0017	0.0016
Malaysia	0.0066	0.0072	0.0073	0.0079	0.0058	0.0067	0.0072	0.0074	0.0078	0.0071	0.0078	0.0085	0.0087	0.0095
Pakistan	0.0032	0.0034	0.0032	0.0032	0.0029	0.0034	0.0037	0.0036	0.0037	0.0036	0.0037	0.0037	0.0039	0.0044
Philippines	0.0040	0.0044	0.0047	0.0044	0.0037	0.0039	0.0041	0.0038	0.0038	0.0037	0.0035	0.0034	0.0032	0.0033
Russia	0.0523	0.0517	0.0440	0.0416	0.0419	0.0455	0.0531	0.0442	0.0455	0.0463	0.0486	0.0504	0.0531	0.0521
Saudi Arabia	0.0080	0.0078	0.0080	0.0080	0.0085	0.0081	0.0082	0.0089	0.0095	0.0101	0.0108	0.0113	0.0122	0.0115
Singapore	0.0033	0.0033	0.0033	——	0.0033	0.0030	0.0031	0.0033	0.0033	0.0034	0.0037	0.0038	0.0037	0.0031
Thailand	0.0098	0.0117	0.0110	0.0101	0.0074	0.0089	0.0094	0.0101	0.0109	0.0120	0.0131	0.0135	0.0131	0.0129
Turkey	0.0073	0.0094	0.0100	0.0108	0.0115	0.0100	0.0111	0.0095	0.0108	0.0123	0.0132	0.0146	0.0158	0.0174
United Arab Emirates	——	——	——	——	——	0.0032	0.0031	0.0033	0.0038	0.0041	0.0045	0.0050	0.0055	0.0055
Vietnam	——	——	——	——	——	0.0019	0.0021	0.0026	0.0034	0.0035	0.0041	0.0041	0.0045	0.0063
Asia	0.4181	0.4425	0.4221	0.4353	0.4475	0.4448	0.4677	0.4592	0.4881	0.5354	0.5897	0.6128	0.6497	0.7031

4.4 Conclusions on the evolution stages of the relation between environment and development in Asia

Through the above-mentioned theories and empirical study, we can generally reach the following conclusions:

(1) The relation between environment and development follows an evolution pattern in order of three inverted U-shaped curves.

On a long term basis, with economic growth, technology change and policy incentives, the environmental impact generally follows a pattern of evolution from a strong inverted U-shaped curve of environmental impact intensity, to an inverted U-shaped curve of per capita environmental impact and to an inverted U-shaped curve of the total environmental impact, which is also the internal requirement of environmental sustainability. Due to the limited data availability and quality, this conclusion has just been partially proved by the empirical research on the relevant environmental indicators of China, other major economies in Asia and even in the world (Chen et al., 2010; Liu et al., 2008; CAS Sustainable Development Strategy Study Group, 2009).

(2) The evolution process of environmental impact can be divided into four stages and these stages are subject to different drivers.

Based on the peak values of three inverted U-shaped curves, we can divide the evolution process into four stages: pre-peak or materialization stage of environmental impact intensity, stage between peak of environmental impact intensity and that of per capita environmental impact, stage between peak of per capita environmental impact and that of total environmental impact, and stage of steady declining of total environmental impact. When the peak of per capita environmental impact coincides with that of the total environmental impact, the above four stages will then be changed into three stages, which can also be seen as an exceptional case of the four stages. In general, the peak of environmental impact intensity is easier to be transcended compared to that of the total environmental impact.

At the pre-peak or materialization stage of environmental impact intensity, the growth of resource consumption or pollutant discharge is mostly driven by the wide application of technologies that may lead to the increase of resource consumption or pollutant discharge; at the stage between the peak of environmental impact intensity and that of per capita environmental impact, the economic growth is defined to be the major driver for the increase of resource consumption and pollutants discharge; while at the stage between the peak per capita environmental impact and that of total environmental impact and the stage of steady declining total environmental impact, the amount of resource consumption or pollutant discharge will mainly depend on the technology change on resource saving or pollutant reduction.

(3) Asia has not generally broken away from the stage of materialization,

and the transformation of its growth model is stuck in a dilemma.

Empirical analysis on the relation between individual environmental indicators and economic growth in Asia suggests that the primary energy use and SO_2 emissions intensity in Asia tend to decline, while its per-capta and total amount is still on the rise. This shows that the energy use and SO_2 emissions in Asia is relatively decoupling with its economic growth, or it is still in a stage of relative dematerization. At present, more and more economies in Asia have successfully reduced the total discharge of organic water pollutants (i.e., BOD), indicating that the economic growth in Asia has begun to absolutely decouple with its BOD discharge. Under the framework of international conventions, the total consumption of ODS in Asia is on the decline. This suggests the absolute decoupling of its economic growth with ODS consumption in Asia.

However, the carbon emissions intensity and the finished steel and non-ferrous common metals use intensity are still growing in Asia, which has largely resulted in the fast growth of per capita and total amount of carbon emissions, that of the finished steel and non-ferrous common metals use. This also shows that the use and pollutant discharge of the above three resources is still in a process of materialization.

We have used REPI and other indicators to conduct empirical analysis on the relationship between the resources & environment and the economic growth in Asia. REPI mainly focuses on showing the impact of economic growth on resources and environment from a perspective of production, and reflects the use efficiency of unrenewable resources. Although the selection of the GDP price and the types of environmental indicators, as well as the same weighting of various indicators may influence the results of REPI, this indicator can define the overall ecological efficiency in a country or region in a simple and flexible manner. Since the 1990s, the REPI of use and pollutant discharge for five types of resources, i.e., primary energy, finished steel, non-ferrous common metals, ODS and carbon dioxide, exhibits a trend of slight increase, while the PCI and TI tend to grow significantly. The total growth rate of PCI and TI surpasses that of REPI, suggesting that Asia has not completely broken away from the stage of materialization.

(4) The major drivers of the environmental change in Asia are changing.

As Asia has not completely shaken off the stage of materialization, the proliferation and application of the technologies that can lead to the increase of resources use and pollutants discharge is still contributing to the environmental change in the region, despite its relatively small impact. Meanwhile, some environmental indicators in Asia have been relatively dematerialized or decoupled with economic growth, and a few indicators have even been absolutely dematerialized or decoupled with economic growth. This shows that the progress of the resources-saving and environment-friendly technologies has already played a positive role in addressing some environmental issues. However, the resources-saving and environment-friendly technologies are not strong enough to replace the leading role of the technologies that can lead to the increase of resources use and pollutant discharge in the whole economic and technological system in the short term. As a consequence, the resource and environmental performance in Asia will still be well below the world average in the foreseeable future.

The low growth rate of REPI in recent years indicates that the major drivers of environmental change in Asia have transformed from the energy-intensive, resource-intensive and pollutant-intensive technology change to economic growth. Nevertheless, the technical system that focuses on technologies increasing energy use and pollutants discharge cannot be fundamentally changed in the short term. The extensive economic growth model will persist in the long run. In addition, pursuing economic growth will be the top priority of poverty reduction strategy for various countries in Asia. All these factors will produce more pressures or impacts on the resources and environment in Asia.

(5) Addressing the environmental challenges in Asia must take into account its development stage and actual conditions.

The evolutionary pattern of three inverted U-shaped curves between the relations of environment and development shows that efforts must be made step by step to address the environmental challenges of a country or region by taking into consideration its development stage and actual condition. Different objectives and priorities should be defined at different development stages. At a lower development stage, focus should be made on enhancing resource and environmental performance; while it should concentrate on controlling the per capita and total amount of resource consumption or pollutant discharge at a higher development stage.

As the current economic development level in Asia generally lags behind that of some other regions, the key to addressing environmental challenges in Asia should be defined to improve its resource and environmental performance, and try to transcend and steadily reduce the major resources consumption and pollutants discharge in a certain period of time. Moreover, as the economies that belong to different development stages co-exist within Asia, no ‘one-size-fit-all’ solution is available for various economies to achieve sustainability. As for some developed or relatively developed economies like Japan, Singapore, Rep. of Korea, Hong Kong China and Taiwan China, the basic target can be defined to transcend the peak of per capita and total amount for resource consumption or pollutant discharge. While for other developing countries or areas in Asia, focus should be made on enhancing resource and environmental performance, transcend and steadily reduce the peak of various resource consumption and pollutant discharge intensity, and slow down the growth of resource consumption and pollutant discharge.

(6)Addressing environmental challenges in Asia calls for holistic approach and comprehensive supporting measures.

The environmental problems in Asia are caused by a combination of various factors, including population, economic, technological, institutional and cultural factors. They include direct and indirect factors, as well as major and minor ones. These factors interact with each other, forming a complex, diversified, multi-level and multi-loop system. There often exists a tradeoff between/among different factors at different stages of environmental change. As a result, a holistic approach, instead of a simple measure, must be taken to tackle the environmental challenges in Asia. It should focus on transcending the peak of resource consumption and pollutant discharge as early as possible at an environmental cost well below that of the developed countries while boosting the economic development and enhancing the living standards in Asia through implementing such measures as proactive institutional arrangement, restructuring, and innovation.

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5 Green Transition and Innovation in Asia

5.1 Green transition is the realistic choice of Asia

Since the early 21st century, the transition from the convetional, economic growth-based model to the green growth-based model that balances the economic development and environmental protection has aroused increasing interest from the global community in the process of tackling a series of global issues and challenges such as climate change, shortage of strategic resources and financial crisis (CAS Sustainable Development Strategy Study Group, 2010). In particular, a new trend of transition towards green and low-carbon growth is taking shape in the world under the context of addressing the double challenges of global financial crisis and global climate change. Different international organizations and economies have released many green development strategies, plans or actions, e.g., the Green New Deal advocated by UNEP (2008), the Green Growth Strategy of OECD (2009), Decision of Transforming Towards Eco-Efficient Economy by the Council of the European Union (2009), Europe 2020 Policy Document of EC (Communication from the European Commission, 2010). They are aimed to achieve multiple objectives, such as realizing short-term economic recovery and long-term economic growth, ensuring energy security, addressing climate change, developing new industries, creating new jobs, building up new strength, and enhancing future competitiveness.

5.1.1 Concept of green development

The concept of green development can be dated back to the 1960s, when the US scholar Boulding proposed Economics of the Spaceship Earth (Boulding, 1966). His concept was followed by the ideas of Steady-State Economics, Green Economy and Ecological Economy proposed by Daly and Pearce, among others (Daly, 1973; Pearce et al., 1989; Daly et al., 2004). New contents are added to the concept of green development with the changing environmental problems and the deeper understanding on these problems.

To date, however, no uniform definition on green development is available. According to UNESCAP (2006), green growth is the growth in GDP that maintains or restores environmental quality and ecological integrity. Green growth is about meeting the needs of all people with the lowest possible environmental impact. As OECD (2010) pointed out, green growth can be seen as a way to pursue economic growth and development, while preventing environmental degradation, biodiversity loss and unsustainable natural resource use. It aims at maximizing the chances of exploiting cleaner sources of growth, thereby leading to a more environmentally sustainable growth model.

Although the connotation of green development varies under different contexts and conditions, and is subject to dynamic changes, green development is a new economic development model that contributes to energy conservation and environmental protection compared with the conventional development model. It, in essence, "highlights the coordination between economic growth and environmental protection" (UNDP, 2002), and aims to break through the constraint of limited resources and environment capacity onto economic growth, decouple the economic growth from resource consumption and pollutants discharge, and achieve the win-win situation between environment and development.

Green development is associated with both developed and developing countries (OECD, 2010). However, due to the difference between development stages, technological levels, natural conditions, resource and environmental issues, these two types of countries have different focuses on promoting green development (Table 5.1).

Table 5.1 Different focuses of developed and developing countries on green development

Features	Developed countries	Developing countries
Development tasks	Short-term economic recovery, long-term economic growth, building new strength, creating new industries and jobs, among others	Seeking sustainable, rapid economic growth, eradicating poverty, increasing opportunities of employment, providing basic education, ensuring food security, providing necessary public services such as water supply and healthcare service, improving living standard, expediting economic growth and enhancing international competitiveness
Environmental problems	Climate change, energy security, biodiversity loss, and hazardous chemical products, etc.	conventional water and air pollution, solid waste pollution, climate change, hazardous waste pollution, water problems, mineral resources problems, energy deprivation and security, deforestation and biodiversity loss, etc.
Target identification	Aiming to control the per capita and total amount of resource use and pollutants discharge	Mainly aiming to improve the resource and environmental performance

Continued

Features	Developed countries	Developing countries
Environmental protection approach	Focusing on prevention, controlling the whole process of production and consumption, and making decisions to balance environment and development	Shifting the focus from production process control to the production and consumption process control and source control, enhancing decision-making to balance environment and development
Innovation pathway	Incremental innovation and system innovation	Focusing on incremental innovation, seeking system innovation to achieve significant advancement of green technology
Management approach	Highlighting market-based approaches, supplementing with regulation and voluntary measures, stressing combination of different policies	Enhancing the integrated use of market-based approaches and other tools, based on the use of regulation approach
Governance pathway	Stressing the bottom-up approach, promoting the involvement of various stakeholders and establishing partnership	Shifting from focusing on top-down approach to the combination of top-down and bottom-up approaches; enhancing public participation, and actively promoting the partnership

5.1.2 Green development is also the realistic choice of Asia

Asia is now at a crucial "crossroad" for its development. On one hand, thanks to its rapid economic growth over the last decades, Asia has made outstanding achievements in reducing poverty and creating jobs, and contributed significantly to the global socio-economic development. On the other hand, these drivers of economic miracles in Asia have also become the major factors for environmental damage, and the rapid economic development in the region has largely been achieved at the cost of its resources and environment. As mentioned above, Asia is now confronted with severe challenges in terms of increasingly complex environmental and resource problems. If the existing development model and the drivers of environmental damages cannot be altered as soon as possible, the environmental pressures onto the resources and environment in Asia will continue to rise, thus posing a major threat to its sustainable development and economic growth in the future.

As a result, transition towards green development and achieving green growth will be the realistic choice of Asia. This will not only break through the constraints of limited environmental carrying capacity in Asia, address the severe challenges of resources and environment in the region, but also accommodate to the international trend and promote the global sustainable development process. It is of great importance for the rising countries and the developed economies in Asia to mainstream the "green development" into the national strategies, integrate the green concept into each stage of socio-economic development, transform the extensive development pattern into an intensive one with comprehensive innovation, and create sustainable growth and competitiveness. The significance is mainly reflected in the following aspects:

5.1.2.1 Tackling the conventional scarcity of strategic resources and the environmental problems

With the ongoing economic development, the competition of various countries in the world for conventional strategic resources (e.g., fossil resources, iron mines, water and grain) has become increasingly fierce, which, in turn, exacerbated the tight supply of limited resources. This will not only pose a long-term challenge to the socio-economic development of some Asian countries, but increase or trigger the conflicts in the region. In particular, as the economic development in some Asian countries largely depend on natural resources, and is vulnerable to climate changes, their economic growth will rest with their prompt adaptability and good governance of natural resources (OECD, 2010).

While the conventional environmental issues in many developing countries in Asia have not yet been addressed promptly, new environmental problems have emerged to combine with the old ones. These problems have multiplied and exhibited a trend of growing from local to regional scales, thus making it more complicated to solve the conventional environmental problems in Asia. Expediting the process of transforming towards green development can not only mitigate the shortage of conventional strategic resources, but also help the developing countries in Asia transcend the peak of Environmental Kuznets Curves (EKC) at a much lower environmental costs compared with that of the developed countries at the same stage when these developing countries are suffering from a lower income level so as to ultimately tackle the conventional environmental problems and halt the ongoing deterioration of environmental quality in Asia.

5.1.2.2 Addressing the long-term severe challenge of global climate change

As one of the new environmental problems, global climate change featured with climate warming has become a key environmental challenge for the Asian countries, and addressing the climate change and low-carbon growth will be considered a core task for Asia to achieve its sustainable development in the long run. However, addressing climate change largely rests with the controlled use of fossil resources and reduced carbon emissions in economic development. As the conventional economic developed model heavily depends on the use of fossil energies, reducing carbon emissions requires these Asian countries to transfer from the conventional, high-carbon development model to a low-carbon one.

With its fast growth rate of carbon emissions, Asia is about to become the region with the largest greenhouse gas (GHG) emissions worldwide and is, therefore, faced with increasing pressure from the global community in emission reduction. It is also known as one of the regions in the world that are mostly vulnerable to climate change. If no efforts were done to promote its transformation towards low-carbon growth and work with the global community to jointly combat climate change, the Asian region would suffer more adverse impacts from future climate change at heavier costs. It has no other choice but to implement the strategy of green, low-carbon growth, establish stable, clearly-defined and long-term stimulus policies, enhance the energy use efficiency and facilitate the large-scale application of low-carbon energy. This can not only help Asian countries decouple their economic development from the GHG emissions, but also contribute to the target of controlling global climate warming.

5.1.2.3 Creating new economic growth areas and enhancing international competitiveness

To weather through the global financial crisis that broke out in late 2008, many countries in the world have released economic stimulus packages or other measures. A common component of these policies is "green growth" (OECD, 2009). These stimulus packages are structurally aimed not only to promote the short-term economic recovery, but also to create new economic growth areas and enhance their long-term competitiveness, including the creation of new industries and new jobs. These plans indicate that the global economic development will be ushered into a new era of unprecedented innovation, and that the emerging industries such as new energy are likely to become the major forces of promoting the development of global economy.

Facilitating the green transition in Asia and seeking cleaner growth sources (including the development of new green industries, creation of new jobs and new technologies, and the promotion of new green growth collaboration) will help the Asian developing countries break through the "green trade barriers" of the developed countries and enhance the international competitiveness of their products. In addition, it will enable these countries to leverage their own advantages as late-comers to make significant technological advancement, create emerging strategic industries such as energy saving and environmental protection, new energy and electric vehicles, promote the sustainable economic growth, create many green jobs, and enhance their capacity of involving in the new round of international competition.

To date, green development has been welcomed and highlighted by more and more Asian countries. Under the call of a number of international organizations including UNESCAP, UNEP and OECD (UNESCAP, 2005; UNEP, 2008, 2009; OECD, 2009), many Asian countries have put the concept of green development into practice, and the green development has been mainstreamed into the national development strategy. In September 2008, for instance, the government of Rep. of Korea released the low carbon, green growth vision, which aims to achieve three objectives (i.e., Energy Conservation and Pollution Reduction, creating new jobs and fostering new drivers for economic growth) by developing green technologies and renewable energies. In April 2009, the Japanese government published the draft policy of the Innovation for Green

Economy and Society, with an objective of enhancing the "green economy" in Japan by implementing such measures as reducing GHG emissions. Moreover, before and after the Copenhagen Summit 2009, apart from Japan which promises to reduce GHG emissions as a party of UNFCCC Annex I, other countries in Asia which are not the parties of UNFCCC Annex I, including China, India, Indonesia, Maldives, Rep. of Korea, Singapore, Bhutan and Israel, have also committed to mitigate the CO_2 emissions on voluntary basis (Table 5.2). Although Jordan, Georgia, Armenia, Afghanistan and Mongolia, among others, have not clearly defined their emission reduction targets, they have promised to take active measures in mitigating and adapting to climate change. All these commitments have highlighted the political wills of Asian countries to promote green development and low-carbon development.

Table 5.2 The Asian countries that have released their targets for greenhouse gas emissions reduction

Country	Target for GHG emissions reduction	Base year	Notes
Japan	Quantified economy-wide emissions targets for 2020: 25% reduction	1990	Premised on the establishment of a fair and effective international framework in which all major economies participate and on agreement by those economies on ambitious targets.
Kazakhstan	Quantified economy-wide emissions targets for 2020: 15% reduction	1992	/
Russia	Quantified economy-wide emissions targets for 2020: 15%-25% reduction	1990	The ranges of the GHG emissions reduction will depend on the following conditions: 1. Appropriate accounting of the potential of Russia's forest in frame of contribution in meeting the obligation of the anthropogenic emission reduction; 2. Undertaking by all major emitters the legally binding obligation to reduce anthropogenic GHG emissions.
China	China will endeavor to lower its CO_2 emissions per unit of GDP by 40%-45% by 2020	2005	The above-mentioned autonomous domestic mitigation actions are voluntary in nature
India	India will endeavor to reduce the emissions intensity of its GDP by 20%-25% by 2020	2005	1. The emissions from agriculture sector will not form part of the assessment of emissions intensity; 2. The proposed domestic actions are voluntary in nature and will not have a legally binding character.
Indonesia	The emissions will be reduced by 26% by 2020	/	/
Israel	Strive for target of 20% reduction of GHG emissions by 2020 below BAU	/	Main actions for achieving reduction target include: 10% renewable energy for electricity generation by 2020; 20% reduction of electricity consumption by 2020

Continued

Country	Target for GHG emissions reduction	Base year	Notes
Maldives	Achieve carbon neutrality as a country by 2020	/	1. The government will register a request for technological, financial and capacity building support for implementation; 2. The present mitigation action is voluntary and unconditional.
Singapore	Mitigation measures leading to a reduction of greenhouse gas emissions by 16% below BAU level in 2020	/	1. Although a legally binding agreement has yet to be achieved, Singapore will nonetheless begin to implement the mitigation and energy efficiency measure announced under the Sustainable Singapore Blueprint in April 2009. These measures are an integral part of the measures to achieve a 16% reduction below BAU. 2. When a legally binding global agreement on climate change is reached, Singapore will implement additional measures to achieve the full 16% reduction below BAU in 2020.
Bhutan	Ensure that the emissions do not exceed the sequestration capacity	/	/
Rep. of Korea	To reduce national greenhouse gas emissions by 30% from the BAU emissions by 2020	/	/

Source:

UNFCCC, Appendix I——Quantified economy-wide emissions targets for 2020, http://unfccc.int/home/items/5264.php; UNFCCC. Appendix II —— Nationally appropriate mitigation actions of developing country Parties, http://unfccc.int/home/items/5265.php

5.2 Green innovation is crucial to achieve green development in Asia

5.2.1 Enhancing resources and environmental performance is the precondition and basis for green development in Asia

Balancing the economic growth and environmental sustainability calls for reducing the environmental impacts of the current human activities to a level that can ensure sustainability, and maintaining at these levels while ensuring the ongoing growth of incomes (Ekins, 2000). In other words, green growth can only be achieved without adding more environmental impacts while pursuing economic growth. More importantly, its environmental impact should be reduced to a certain limit, or the economic growth must be absolutely decoupled from its environmental impact.

In Chapter 4, we have proposed that in order to reduce the impact or pressure of human activities onto the environment, the first and foremost thing for us to do is to transform the environmental impact intensity (including resource consumption or pollutant discharge intensity) in Asia from a pattern of ongoing increase to a pattern of stable decline. This serves as the precondition to control the total amount of resource consumption or pollutant discharge. Secondly, it requires the Asian countries to transfer their economic growth from an extensive model to an intensive one. For this reason, enhancing eco-efficiency or the resource and environmental performance provides the precondition and basis for green development in the region. As Asia has not yet completely broken away from the stage of materialization, the top priority for Asia in terms of green transition is to continuously reduce its environmental impact intensity, and to improve its resource and environmental performance.

5.2.2 Green innovation is key to the green development in Asia

5.2.2.1 The connotation and essence of green innovation

Green development model as a new model is the transformation and innovation of the conventional one. This innovation is often comprehensive, involving various dimensions such as technology, institution, organization and culture, covering both macro and micro levels, and even being revolutionary or radical. Though the concept of innovation and practice of green innovation emerged at an earlier stage, it was not until the 1990s that the concepts on innovation related to sustainable development have begun to attract greater attention with the increasing public awareness on the concept of sustainable development. These concepts on innovation include green or environmental innovation, ecological innovation, innovation for sustainability and system innovation. All these concepts or ideas can be called green or innovation for sustainability.

However, no uniform definition is available on green innovation or innovation for sustainability, a key link between innovation and sustainable development. According to Kemp et al. (2001), environmental innovation consists of new or modified processes, techniques, systems and products to avoid or reduce environmental damage. Sustainable innovation can only be successful if they allow for the same use value at lower environmental cost. Klemmer et al. (1999) broadly define the term “environmental innovation” as all measures of relevant actors that lead to the development and application of new ideas, behaviors, products and processes and, thereby, contribute to a reduction of environmental burdens or to ecologically specified sustainability targets. This may include process and product innovations, organizational changes in the management of firms, and on the social and political level, changes in environmentally counter-productive regulation and legislation, consumer behavior, or lifestyle in general.

It can be seen that green innovation includes both environmental and economic and social dimensions. Green innovation mainly consists of technological, structural, organizational, institutional and social innovations. While technical innovation is mainly associated with the products and process innovation and even scientific innovation, green technical innovation is not only a simple technical concept. More importantly, it highlights promoting the commercialization of green technological results based on green markets (Li et al., 2009). Architectural innovation focuses on enhancing sustainability through the change of industrial and economic structures. Organizational innovation, including the new management forms, is often linked with products and process innovation.

While social innovation generally refers to the shift of living styles and consumption behaviors, institutional innovation means an institutional arrangement that transforms from one that does no good to the environment to one that contributes to the wise use of resources and environmental protection. All these innovations are related to the cultural innovation including the change of values. As a result, green innovation constitutes a group of innovations that are closely correlated with each other. In the past, people stressed too much on the role of technologies, while ignoring or paying little attention to the innovation of other factors that are related to technologies, which, in turn, obstructed the social functions of technologies. Therefore, more attention on the factors other than technologies should be paid in the process of achieving green innovation.

5.2.2.2 Green innovation oriented to transform development model is key to Asia's green development.

At present, the primary objective in Asia's green development is to improve resource and environment performance, which, in turn, depends on green innovation. Like labor productivity which was the theme of growth-oriented development, the improvement of resource productivity will be the theme that motivates and co-ordinates innovations in the 21st century (Weaver, 2005). Because resource and environment performance is, to a great extent, determined by technological, structural and institutional factors, green innovation aimed at improving resource and environment performance necessarily entails technological, architectural and institutional innovations.

Generally, three approaches can be adopted to improve resource and environment performance: ①Short-term adjustments of the present methods to meet the demands by means of research and innovation; ②Medium-term comprehensive technological upgrading or restructuring of a variety of products and processes by means of research and innovation; ③New system solutions involving a set of technologies, institutional arrangements and structural transformation distinct from the present development pattern. Approach ① and approach ② will not change the present leading development pattern and the potential for improving resource and environment performance is limited; whereas approach ③, which corresponds to innovation for sustainability or system innovation (Weaver, 2005), is path-breaking, signifying a shift in the course of development and creating a new pattern.

The former two innovation approaches fall into the category of "incremental innovation". Generally, it is possible to achieve improvement of resource and environment performance by a factor of 2 to 4 through incremental innovation, but radical innovation, system innovation or innovation for sustainability are necessary if resource and environment performance is to improve by a substantial factor of 10 (Geels et al., 2004).

System innovation aimed at a transition to sustainability or green development entails a transition or transformation from one system, e.g., transport system or energy system, to another. This type of innovation involves not only new technologies, but also new markets, consumers, regulations, infrastructure and cultural implications. System innovation has four important features: ①System innovation develops in a co-evolutionary manner and involves changes on the supply side (technology, knowledge and industrial structure) and the demand side (consumer preferences, cultural implications and infrastructure); ②System innovation is architectural, i.e., it upsets the connections between present technologies and their consumers and causes changes in the key elements and structure of the socio-technical system; ③ System innovation is a multi-agent interaction involving a wide range of social groups like industries, consumer groups, scientific communities, and political organizations; ④System innovation occurs over a long time scale and may last as long as several decades (Geels et al., 2004).

Asia's green transition and green development does not merely depend on incremental innovation, it also rests with system innovation or radical innovation aimed at hierarchical changes in systems. System innovation can substantially improve resource and environment performance through innovations and a new development pattern; it can basically escape the environmental pressure from within and outside Asia or lift the "bottleneck" restrictions that Asia faces, buying opportunities and time for Asia to catch up with the developed countries or to achieve leapfrog development.

5.2.2.3 Decisive factors in green innovation

As a new innovation paradigm, green innovation calls for redeployment and balance of all the motivating forces on the innovation chain (E3G, 2008). One of the prominent features of green innovation is the positive spillover effect during the innovation and divergent stages. In comparison with other products, green technologies or green products have a smaller influence on the environment. The society can benefit from this property of green technologies. However, the costs of green technologies are entirely carried by their developers (Beisea et al., 2005), which to some degree discourages developers from investment. Environmental policies, therefore, should be in tune with innovation policies.

The dual externality of green technology innovation highlights the role of environmental regulation in the green innovation system. If no pertinent environmental regulation policies are introduced, the competition between green technologies and conventional technologies will become twisted. Consequently, the enthusiasm in green technology innovation will be impaired and a negative effect will emerge in the research, development and proliferation of green technologies. The development of green technologies, a market oriented towards sustainable consumer demand and regulations thus constitute the governing factors in green innovation. Environmental regulations and environmental policies will have a profound effect on green innovation. Policies targeting environmental regulation, such as environmental subsidies, trading pollution permits, market admittance, performance standard, product standard, product ban, producer liability, information revelation, and voluntary agreement, can, to a certain degree, facilitate green technology innovation (Lu et al., 2003). With regard to market impetus, advocating shift of living pattern and consumption pattern is the main force that will stimulate green innovation.

5.2.2.4 Development trend of green innovation

1) Development trend of green technology innovation

The innovation of environmental technologies has roughly undergone four phases: ① end-of-pipe technologies featuring pollution elimination and resource reuse in the 1960s; ② waste-free technologies featuring rational use of resources at the end of the 1970s; ③ waste minimization in the middle of the 1980s; ④ clean technologies featuring energy conservation, consumption reduction, pollutant and toxic-substance reduction and pollution prevention technologies featuring waste reduction at the source in the 1990s (Liu, 2006). In the 21^{st} century, circular economy and low-carbon technologies have become the trend. During this whole process the public awareness on environmental protection has also increased.

However, the above innovations are largely innovations in individual technologies. The solution to many regional and global environmental problems calls for fundamental changes in the technological system. The development of a single technology is not sufficient to solve all the ecological and environmental problems in today's world. The whole technological system must undergo historical changes, which poses a severe challenge.

Green technology development in the 21^{st} century shows an "integration" trend. At present, sustainable technological innovations are beginning to demonstrate vigor and vitality. Substantial promotion of resource productivity is highly likely to trigger or lead to a new round of competitive advantages of nations (Hargroves et al., 2005) and become a commanding point in future economic and technological competition. The challenges posed by sustainable development also provide a basis for the restructuring and reorientation of national innovation systems. The present focus and basic goal is to transform the structural features of the technical regime so that various environmental problems can be better dealt with and the trajectory of technological innovations as a whole can be reshaped (Berkhout et al., 2004).

2) Development trends of green institutional innovation

Institutional innovations here cover organizational innovations, administrative innovations, policy instrument innovations, etc. At present, institutional innovations in international green development exhibit the following major trends:

①Transition from government to governance. Government functions are shifting from the conventional centralized, top-down administrative pattern to a more flexible, decentralized, multi-level and participative administrative pattern.

②Co-ordination between environment and development in policy-making. Green development calls for a shift from a segmented, closed administrative pattern to a comprehensive, coordinated one, i.e., "comprehensive" or "integrated" policy-making and administration.

③Shift of environmental protection from end-of-pipe treatment to prevention and whole process control of production and consumption.

④Emphasis on measures against climate change and low carbon technology; formation of new competitiveness through policy combination and technological innovation.

⑤Emphasis on industry policy and industry standard, such as industry directive and resource and environment performance standard.

⑥Multi-stakeholder cooperation and partnership between the government, enterprises and society.

⑦Shift from unilateral assumption of responsibilities by the state to various forms of bilateral and multi-lateral international cooperation in which common responsibilities are assumed in different degrees.

⑧Prioritization of institutional arrangements as the common approach to green development and emphasis on the collective effect of various policy instruments.

In brief, green innovation worldwide is heading towards an "integrated" system innovation featuring structural transformation and pattern shift. Structural improvement, long-term incentive systems and mechanisms, and all-round transformations have become important methods.

For Asia's developing countries where economic development is relatively slow, experiences and lessons of the developed countries can be learned. They can fully leverage their own advantages as late-comers and leapfrog to the latest sustainability technology in areas where they are further advanced, thus finding a strategic tunnel through the EKC (CAS Sustainable Development Strategy Study Group, 2010) in a manner that suits their own conditions.

5.3 Asia's favorable conditions for green development

Asia has already possessed some favorable conditions for a transition to green development: its development foundation, its opportunities and its basic experiences. Taking full advantage of these favorable conditions and opportunities and rising to various existing and potential challenges is of great significance for Asia's green development.

5.3.1 Strong government commitment and political will

Efficient and strong government is one of the major reasons for Asia's economic success; it also provides strong basis for Asia's green development. Asia is now in its materialization stage. It must achieve the goal of a steady decline of resource consumption and pollutant discharge intensity as soon as possible so that the ultimate goal of zero growth can be attained. Strong government commitment, robust political will and strict policies are, therefore, very crucial. It is pleased to see that more and more Asian countries have willingly accepted the concept of green development and are beginning to put it into practice, developing green growth strategies, taking corresponding measures to reduce energy consumption and greenhouse gas emissions, developing new energy sources, promoting energy efficient technologies and low-carbon technologies, etc. In order to enhance their governance abilities in resource and environment protection, some countries decentralized responsibilities for natural resources management and environmental protection to provincial and community levels (Zbicz et al., 2009). Many countries are developing a number of environmental laws, regulations and standards and are participating in international environmental protection through bilateral or multi-lateral environmental agreements (UNEP, 2007). This has provided institutional basis for Asia's transition to green development.

5.3.2 The cultural tradition of diligence and frugality

Asia's traditional culture advocates diligence and frugality. This aspect of Asia's traditional culture and its emphasis on man and nature in harmonious coexistence played a significant role in East Asia's rapid economic development. Most notably, high saving rates and high investment rates made possible by frugality have given a strong impetus to Asia's economic growth. Apart from this, the same cultural tradition can provide Asia's green transition with important ideological support, accumulating and providing considerable financial support for green development and green innovation and contributing to the formation of a non-westernized moderate consumption pattern adapted to Asia's resource and environment conditions and energy-saving and emission-reduction criteria. Asia's per capita consumption is low, but demands for higher living quality are rising, consumption upgrading, domestic demand being expanded, and western consumerism is gaining popularity. This will inevitably lead to conflicts between different consumer concepts in Asia. Therefore, establishing a green, sustainable consumption pattern in advance is of crucial significance for Asia's green transition.

5.3.3 The largest potential green consumer market in the world

One of Asia's advantages for green development is that it boasts the largest potential green consumer market in the world. The efforts to solve resource and environmental problems, the efforts to counter climate change, as well as the efforts to deal with the financial crisis, can create enormous demands and a big market for Asia's green economy and lowcarbon development. In the meantime, green innovation will create more business opportunities.

Currently, many Asian countries are entering the phase of large-scale infrastructure development. Infrastructure construction for the industry, transportation, building and energy sectors is growing at a rapid speed and investment demands in the future will be greater. Because infrastructure projects have long life cycles, investment into and construction of these infrastructure and production capacities (especially energy and environmental infrastructure), to a large extent, determines the future performance and development trend of energy-saving and emission-reduction. If actions are delayed, Asia will be locked in its infrastructure with high energy consumption and high pollutant discharge (World Bank, 2010). Future generations will have to pay a much higher price for emission reduction. If necessary actions are applied, a new type of infrastructure construction which saves energy and reduces emissions will have enormous demands and opportunities.

With the rise of consumption standards among Asian residents and the upgrading of consumption structure, consumer demands for durable consumer goods including household appliances, housing, and cars increase substantially. This has stimulated the development of the heavy industry and the chemical industry and has aggravated the resource and environmental pressure on Asia. If properly guided, this pressure can become a force that pushes forward green development. Through the development of new energy automobiles which save energy and protect the environment, green buildings, energy-saving household appliances and renewable energy sources, domestic demands will be expanded and a green consumer market will be cultivated. As a result, Asia will be able to develop in a sustainable manner.

5.3.4 Development of renewable energy and new energy

Asia is rich in renewable energy resources. The hydroelectric technical potential in this region accounts for 40% of the global total and its development potentials of solar energy and wind energy represent over 30% and 20% of the global total, respectively. In addition to this, Asia has abundant biomass energy, ocean energy, and geothermal energy (UNESCAP, 2008). The development of low-carbon energies has offered Asia favorable conditions for the transformation of energy structure and the implementation of the green development strategy; it also gives Asia an opportunity to lead the world energy revolution. Today, Asian countries have made great progress in the development of renewable energy. China's installed hydroelectric capacity ranks 1st in the world and its installed wind power capacity ranks 2nd. The Philippines is successful in the development of terrestrial heat, which provides the country with 27% of the engery it needs and is a major contributor to its stable total primary energy consumption.

5.3.5 Increasing innovation capacity

Innovation is at the core of the development strategy of every country. Green innovation will be the direction of future innovations. Over the next 10 to 20 years, a new technology revolution and industry revolution featuring green, intelligence and sustainability (Lu, 2009) is highly likely to occur. Undoutedly, a new green technology revolution is a historical opportunity for Asia that cannot afford to be missed in order to achieve the goal of technological leapfrog and green emergence.

Asia has abundant human capital and the largest number of researchers and developers in the world. This has provided a strong personnel backup for Asia's green transition and green innovation. The remarkable economic growth in Asian countries in recent years, particularly the rise of new economies including China, India and Indonesia, has made Asia more attractive to talented people worldwide and Asia is becoming the world's gathering place of human capital.

Many Asian countries have increased their investment in research and development and their innovation capacity is expanding. At present, Asia's total spending in research and development has exceeded the U.S. and Europe. Its achievements in the research, development and application of Information and Communication Technology (ICT), biotechnology and nanotechnology are most striking. This has laid a solid foundation for Asia's green development.

Asia is becoming the world's leading region in ICT. Over the past several years, the progress it has attained in this field is most striking. The popularity and growth rates of the internet and cell phones have considerably surpassed the world average level. Some Asian information communication companies are beginning to play leading roles in the global market. The application of information technology, such as intelligent power grid, intelligent household appliances, intelligent buildings, intelligent transportation and improving energy efficiency, in the fields of green energy and energy-saving and emission-reduction, will open up new horizons for the growth of green intelligence in Asia and even in the whole world.

At the same time, Asia has made remarkable achievements in the research, development and application of some low-carbon technologies, providing corresponding technical reserve and support for Asia's green development, for example, Japan enjoys obvious advantages in energy-saving, environmental protection and green energy across the globe. With the expansion and rapid growth of domestic markets, Asian countries are expected to become innovation pioneers in electricity-powered vehicles and green power (Barton, 2010).

5.3.6 Opening-up policies and increasing regional cooperation

Opening-up, introduction of advanced technologies, learning of international knowledge, and development and utilization of the global market are strong factors that can enable Asia to maintain a rapid economic growth; they can also promote Asia's green transition and green development. With the development and speedy outreach of ICT, production factors including knowledge, information, technology and people are circulating, optimizing, restructuring and interacting in larger areas and to greater extents in the world. In these processes, innovation is always playing a conducive role. This has offered possibilities and opportunities for Asia to introduce advanced green technology and knowledge, learn from experiences, work out a solution that takes into account both the environment and development, reduce the cost of green transition, and fill the gap between Asia and the West in green technology.

In addition, various forms of regional cooperation in Asia are underway. In comparison with the past, the geographical boundaries of cooperation are being pushed further away and sub-regional cooperation is evolving into regional cooperation. The original economic cooperation is evolving into an all-round cooperation covering economy, technology, culture, resources and the environment. This gives Asia new strength and a strong guarantee in its joint efforts to promote green development and deal with regional and global resource and environmental problems, providing favorable conditions for the establishment and improvement of bilateral and multi-lateral environmental cooperation mechanisms, for the construction of energy infrastructure, and also for technical cooperation in the fields of resources and environment.

5.3.7 Best practices of sustainable development in Asia

The Asian countries have created different models of balancing environmental sustainability and economic growth according to their own actual conditions, and have accumulated many successful experiences in the process of promoting sustainable development. These case studies are related to various areas such as Energy Conservation and Pollution Reduction, new energy development, water management, integrated use of mineral resources, renewable energy management, and circular economy, which provide concepts and approaches that can be learned for the Asian developing countries to realize green transition and sustainable development.

5.3.7.1 Strategies and actions of Energy Conservation and Pollution Reduction in China

China's economy has been rapidly expanding since the 1980s. However, similar to many other Asian countries, its fast economic growth has been achieved at the expense of high input, high energy consumption and high emission. This kind of extensive development model is undoubtedly unsustainable. For example, the energy consumption per-unit GDP in China is well above the world average level. In 2000, the overall energy consumption for 14 products of eight industries (e.g., electric power, iron and steel, nonferrous metal, petrochemical, building material, chemical, light industry, and textile) in China was 40% more than the global advanced level.

Under such context, the Chinese government has developed mandatory targets on Energy Conservation and Pollution Reduction during the Eleventh Five-Year Plan period (2006-2010) to ensure the future energy security, improve environmental quality and address climate change. It is expected that by 2010, its energy consumption per-unit GDP will be reduced by 20% compared to 2005, and the major pollutants (COD and SO_2) be reduced by 10%. To achieve this objective, the Chinese government has implemented a series of policies and measures, including:

①Developed such laws as Renewable Energy Law and Circular Economy Promotion law; revised Energy Conservation Law, adopted the legal document of "the Decision of Actively Addressing Climate Change", and promulgated a number of regulation and rules including the Accountability System on Energy Conservation Target in order to define the legal justification.

②Established the National Leading Group to Address Climate Change, Energy Conservation and Pollution Reduction, with the Premier of the State Council as the team leader; set up the management institution on addressing climate change, enhanced capacity building and established a sound system on energy statistics.

③Prepared a number of plans such as the Medium to Long-term Renewable Energy Development Plan, the Medium to Long-term Nuclear Power Development Plan, Comprehensive Work Plan on Energy Conservation and Pollution Reduction, and the National Plan of Addressing Climate Change; implemented a series of key programs on Energy Conservation and Pollution Reduction, including the Energy Conservation Action of Thousand Enterprises' and Ten Key Energy Conservation Projects.

④Adopted many administrative and economic tools to achieve the targets: the task of fulfilling the national target has been implemented at the provincial, sectoral and corporate levels to eliminate outdated industrial capacity, encourage science and technology (S&T) innovation and accelerate the economic restructuring.

⑤Other policies and measures included: implemented the Public Campaign on Energy Conservation and Pollution Reduction, raised public awareness on the knowledge and approaches on energy conservation and environmental protection, promoted new technologies and production on energy conservation, and advocated the concepts of green consumption and moderate consumption.

Thanks to these favorable policies, China has made significant achievements in implementing its strategy of Energy Conservation and Pollution Reduction. In 2007, the gap between China and the global advanced level in terms of the overall energy consumption for 14 products of eight industries in China was narrowed to 20% versus 40% in 2000. In 2009, the national energy consumption per-unit GDP declined by 14.38% compared to 2005, while the discharge of major pollutants such as SO_2 and COD was reduced by 13.14% and 9.66%, respectively. The installed wind power capacity grew by 100% annually for five consecutive years.

It is estimated that thanks to the implementation of a series of energy conservation measures, about 81.70 million tons of iron, 82.50 million tons of coke, 240 million tons of cement, and 6 million tons of paper of outdated capacity were eliminated respectively across China from 2006 to 2009. During the same period, the reduced energy consumption per-unit GDP in China equals 450 million tons of standard coal and 670 million tons of CO_2. It is expected that China can reduce CO_2 emission of at least 1.5 billion tons during the whole period of the Eleventh Five-Year Plan (2006-2010) (UNDP, 2010).

5.3.7.2 The model of collaborative development of electric cars in Japan

Since the 1970s, the Japanese government has been committed to the development of low-emission cars using new energy, in particular the electric cars, to ensure energy security, reduce oil dependency and enhance its international competitiveness. During this process, the Japanese government focuses on enhancing coordination and cooperation with the companies to improve the industrial efficiency and quality in Japan.

The Japanese central government worked closely with the major auto and parts manufacturers, industry associations and research institutions to develop and revise the electric car R&D and commercialization development plan. It is aimed to define the vision, goal and objective at each stage (generally 10 years), and effectively integrate and coordinate the inputs and actions in terms of electric car development of various stakeholders such as the central and local governments, auto and parts manufacturers, and research institutions. During the planning process, all the stakeholders work together to identify the major technical and market barriers, and ask the relevant organizations or companies to address these challenges by conducting joint technical R&D, revising relevant laws and regulations, developing industry standards and building necessary infrastructure.

To further promote the technological development of the battery and the whole electric car, the Japanese government and the auto industry have jointly implemented a series of R&D projects. These projects generally last 5-10 years, in which the government, business and research institutions are all involved. The government and the private sector share their different responsibility in funding the R&D. Every new technological project often covers three stages: initial study, prototype test and commercialization. At the initial study, the government's funding accounts for 90%-100% of the total investment. As the new technologies are mature and meet the stage of commercialization, the share of the private sector's funding will increase as previously agreed. In addition, the

Japanese government also encourages the initial market application of electric cars by granting consumption subsidy, directly purchasing and promoting the development of special use markets.

Thanks to the ongoing efforts of the Japanese government, the electric car was launched to the market in Japan in 2000 and has been growing rapidly. In 2009, approximately 300,000 electric cars were sold in Japan (mainly HEV), representing 7% of the total car sales in that year. It is expected to grow about 14% annually in the future. The major Japanese auto manufacturers, including Toyota, Honda, Nissan and Mitsubishi, have also taken a leading role not only in the local market, but in the global electric car market. They have introduced more than 20 models of commercialized electric cars, and achieved an outstanding result of selling over 600,000 units globally in 2008 alone. Meanwhile, infrastructure test and construction projects on electric cars have also been implemented in many cities and regions in Japan (The Climate Group, 2010).

5.3.7.3 The model of water demand side management (DSM) in Israel

Over the recent years, water DSM has emerged as an advanced international water management concept and model. It is a systematic action involving water administrators, users and operators, which is mainly aimed to control the increasing water use conflict, ecosystem damage and reduced water environmental capacity due to the rising water demand, promote the equal and wise allocation and efficient, sustainable use of water resources through the comprehensive use of legal, administrative, economic, S&T, and publicity tools. Israel is known as the first country that conducted analysis on water demand and enhance water DSM (Tao et al., 2006).

Israel is an arid country suffering from water scarcity, with a per capita water use of only 271 m^3, and the area of deserts accounting for 67% of the total land area in the country. Amid the pressures from growing population, rising living standards and expanding agricultural production, the total amount of water use has successfully remained unchanged over the last half century. A highly value-added agricultural production and trade system has also been made available in the country, demonstrating the best practice of water saving and water use in arid zones.

Since the second half of the 20^{th} century, Israel has been implementing the demand side management focusing on water saving. Eight tools are mainly used to achieve the national water DSM targets. These tools include developing laws, pricing and economic policies; sewage and wastewater reuse; water resources protection and enhancing its use efficiency; distribution of water resources in agricultural and industrial production; urban water use metering, replacing the old pipelines, electronic monitoring and reconstruction of water use facilities; virtual water policy; internal and external water market; and desalinization.

So far, the water resources recycling rate in Israel is the highest one in the world, with a wastewater reuse rate of up to 75%. The agricultural water use efficiency in the country reached 70%-80% with the help of drip irrigation method, as the highest one worldwide. In addition, it boasts the world's largest seawater reverse osmosis desalinization plant. It is expected that 20% of the water use in Israel will come from the desalinization plants by 2010.

5.3.7.4 The three-dimensional comprehensive development model of agriculture, forestry and fisheries in South China

Mulberry-embankment fishpond is a unique, three-dimensional comprehensive development model of agriculture, forestry and fisheries, in South China (Figure 5.1) (Zhong, 1993).

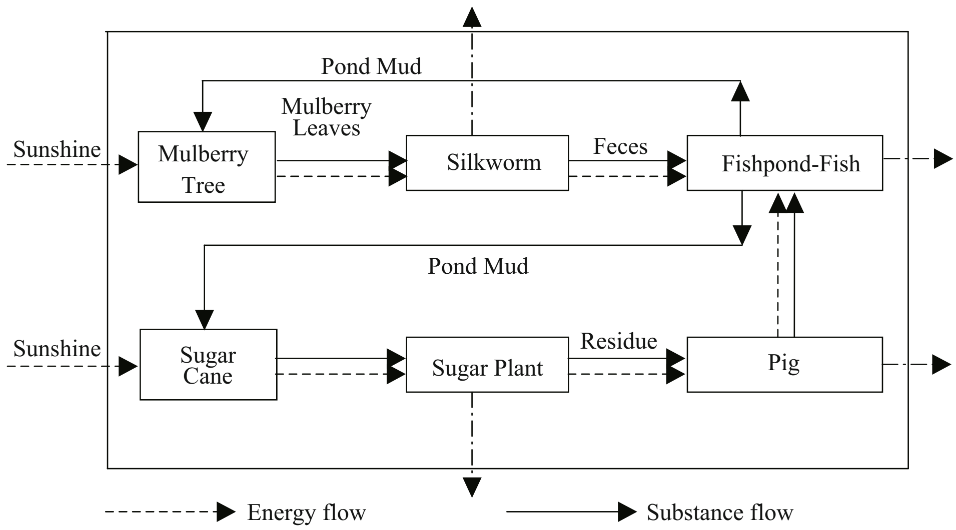

Figure 5.1 Typical mode of mulberry-embankment fishpond

The system of mulberry-embankment fishpond emerged in Taihu Lake Basin in the 9th century, and has begun to flourish since the 14th century. This three-dimensional model was a result of the increasing conflict between the rising population and limited land resources. This model can not only help generate more economic benefits by creating more jobs, but maintain a relatively strong capacity in fighting against natural disasters and establish a highly-efficient production system. In addition, it highlights the role of watershed forests in water conservation and in maintaining farmland ecosystem (Luo et al., 1995).

The system mainly consists of embankment and fishpond. According to the principle of metabiosis and syntrophism, the local farmers can establish a field-fishpond ecosystem. They firstly dig pond to raise fish and plant mulberry trees along the dike. The mulberry leaves are used to grow silkworm, whose excrement will then be used to feed fish. The pond silt including the fish feces will then be returned to the dike as manure. In this way, the silkworm-raising industry and the aquaculture depend on each other and establish the mulberry-embankment fishpond system, an eco-agriculture that is based on the positive cycle of terrestrial and aquatic systems (Chen et al., 1995).

The model has also been improving. For instance, biogas is introduced into the model to transfer the traditional agricultural structure of growing "mulberry-silkworm-fish" into a new one of producing "mulberry-silkworm-biogas-fish". Meanwhile, the mulberry-embankment-fishpond is converted into different types of sugar cane-embankment fishpond, fruit-embankment fishpond, forage-embankment fishpond, flower-embankment fishpond, and fishpond with the embankment growing with mixed forage, vegetable and crops.

5.3.7.5 The model of eco-industrial park in China

Although the circular economy is still at its pilot stage in China, a group of companies or industrial parks that promote clean production and integrated recycling and reuse of resources have already emerged.

Guangxi Guigang National Eco-Industrial (sugar-making) Demonstration Park, as the first eco-industrial park that has been approved to be established by the central government, adjusts and optimizes the original structure of sugar-making industry in Guigang City, Guangxi. Based on the former eco-industry of Guitang Group, it has expanded the scale of integrated resource use from the originally corporal level to the overall sugar eco-industrial pattern. The structure of the industrial eco-chain in the park has been improved with 12 key projects, including water saving, bio-alcohol, green pulp-making and cogeneration of heat and power, so as to diversify the product structure, enhance the scientific and technological factors and added value of the products, and strengthen the market competitiveness and risk-resistant capacity, and ultimately grow into the largest sugar, paper and alcohol production base in China.

The park, with Guitang Group as the core, adopts a framework comprising six systems: sugarcane field system, sugar-making system, alcohol making system, paper making system, heat & power cogeneration system and environmental comprehensive treatment system (Figure 5.2). Products are generated within each system, and different systems link each other through the intermediate products and waste exchange, thus forming a relatively complete and closed eco-industrial network. As a result, the resources within the park can be optimally deployed, the waste efficiently reused, and environmental pollution minimized to balance the economic growth and environmental protection (Ji, 2004).

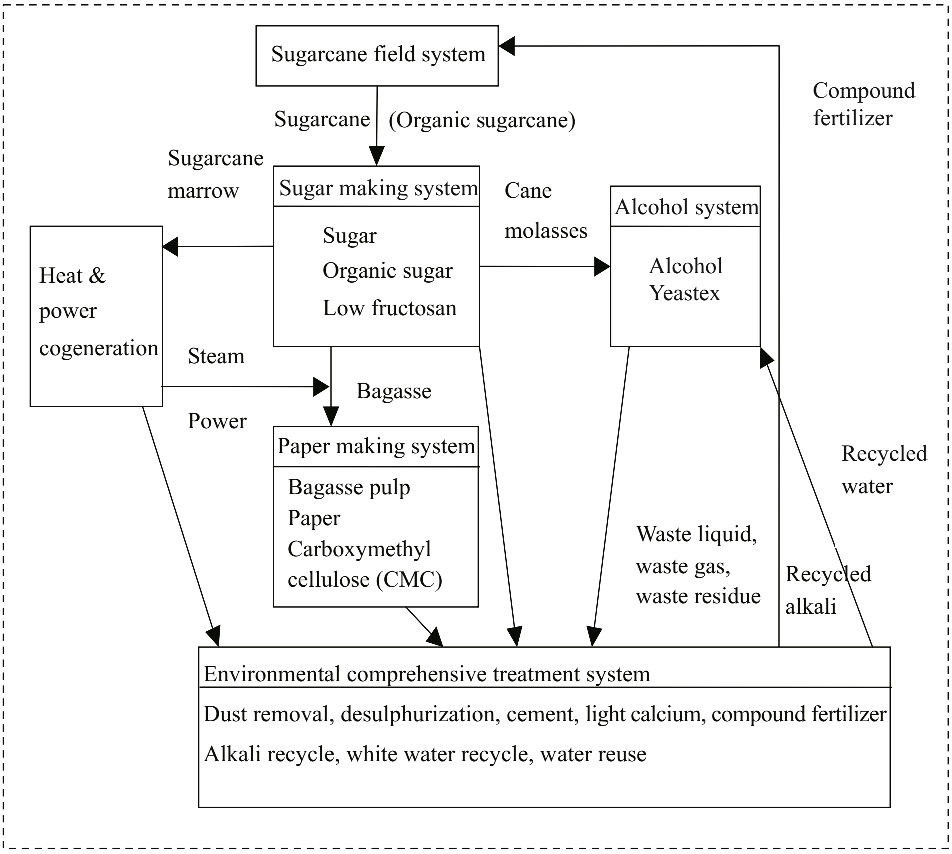

Figure 5.2 Guigang National Eco-Industry (Sugar Making) Demonstration Park—framework
(Source: Ji, 2004)

5.4 Promoting green development in Asia: principles, strategic framework, focus and priorities

Given the current development stage of various countries in Asia, as well as the advantages and disadvantages they are facing, we have proposed the following basic principles, strategic framework and priorities for Asia to facilitate its green development.

5.4.1 Basic principles

5.4.1.1 Reaching consensus

Asian countries need to gradually reach consensus on the connotation of green development and its role in the next one to two decades, and implement the concept of green development in the practice of sustainable industrialization and urbanization through individual efforts and extensive cooperation to achieve green transition.

5.4.1.2 Making policies based on area differentiation

Due to the differences of natural endowment, social, economic and technological conditions, as well as the forms and seriousness of the environmental problems, the objectives and focuses of Asian countries in green development should also vary in all respects.

5.4.1.3 Seeking for innovation-driven transition

A principle of innovation-driven transition should be followed in Asia's green transition, integrating incremental and radical innovation. It includes technological, institutional, organizational, social and cultural dimensions.

5.4.1.4 Pushing forward pragmatic cooperation

Promoting Asia's green transition goes beyond the capacity and physical boundaries of its various countries. In particular, these countries need to work closely to address the regional and global issues. It is necessary to establish an innovative bilateral and multilateral cooperation mechanism, coordinate and integrate the actions among different countries and promote the practical cooperation so as to achieve win-win situation and jointly advance the sustainable development in Asia and the world at large.

5.4.1.5 Promoting inclusive Growth

Promoting the green development in Asia will not only help Asia achieve its objectives in economic growth, environmental protection, and more importantly in social development (such as narrowing the gap between the rich and poor, eliminating poverty, and ensuring the equitable sharing of the development benefits by the whole community).

5.4.1.6 Combining centralization and decentralization

It is hardly possible for the environmental agencies and professional environmental administrations alone to address the environmental problems due to their diversity and complexity. While fully leveraging the governments' role, it is also essential to fully involve the participation of various stakeholders, constantly improve the local governance capacity and engage the general public in this process.

5.4.2 Strategic framework of promoting green development in Asia

On the basis of OECD Green Growth Strategic Framework (2010), we have proposed the Strategic Framework of Promoting Green Development in Asia, as shown in Figure 5.3.

(1) Leading green transition: mainstream green development into the national strategy, action plan and the governments, sectors or industries' plans at different levels, and implement these plans.

(2) Supporting green transition: create and improve the green development institutional framework that combines incentive and control measures, develop a technical innovation system that eliminates the obstruction of resource and environment, establish sustainable infrastructure, create a green

production, consumption and urbanization growth model that fits in with the resource and environmental carrying capacity in order to fully promote the green transition in Asia.

(3) Adapting to green transition: develop an education and training system, a labor supply and skills structure, a social security system for the vulnerable groups, and the social service system in consultation, transaction and financing that adapt to green transition.

(4) International cooperation in green development: innovate and improve the international cooperation mechanism, strengthen international collaboration, expedite the exchange in knowledge, information, products and technologies, create a multi-level international cooperative system.

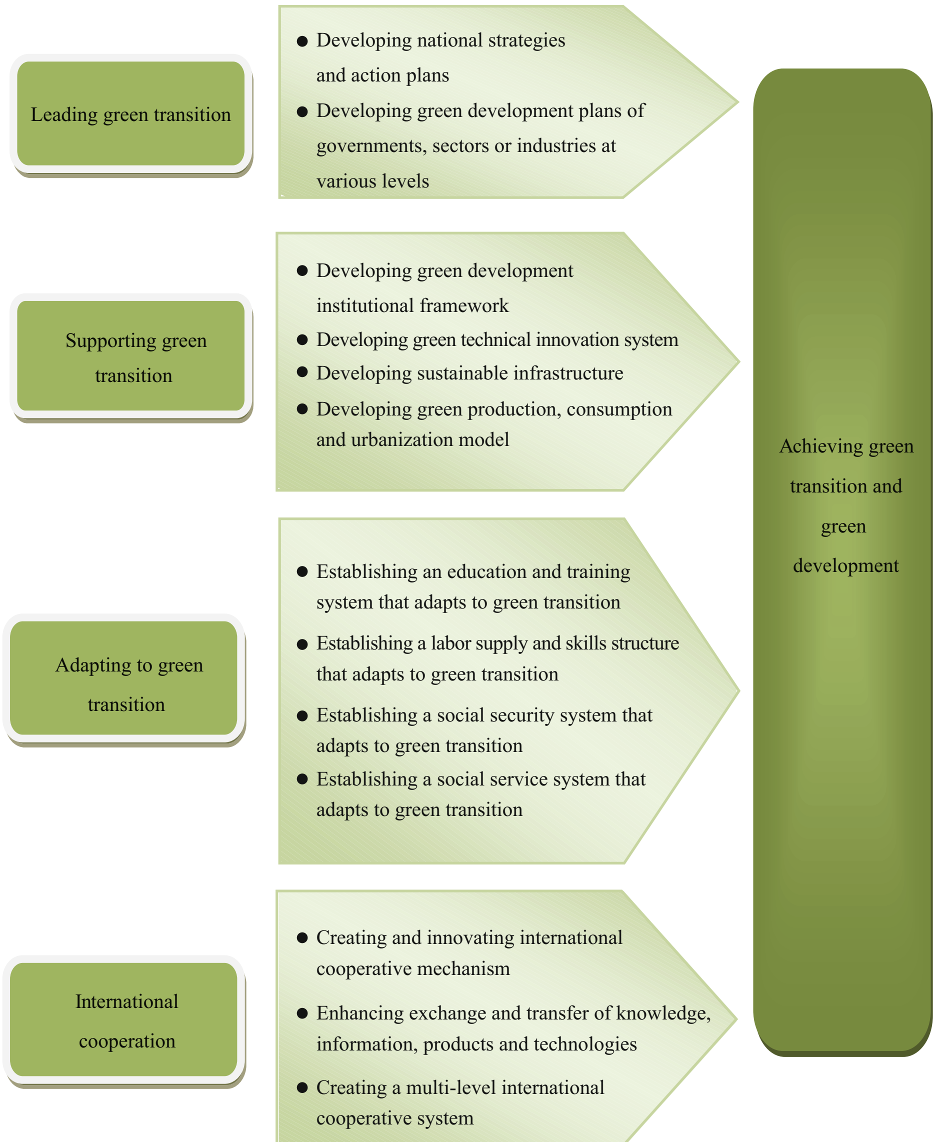

Figure 5.3 Strategic framework of green development in Asia

5.4.3 Strategic focus and priorities of promoting green development in Asia

The actual conditions, development objectives and issues of different countries in Asia need to be taken into account in the following path of green development. Efforts should be focused on specific areas to minimize the economic and social costs, and gradually greenize the national economy. In general, Asia should focus on the following strategic areas and priorities in the course of implementing green development:

(1) Priority should be given on addressing the resource and environmental problems of various countries in terms of achieving green development in Asia. The developed economies need to focus on controlling the per capita and total amount of resource consumption and pollutants discharge, while the developing and transitional economies should highlight improving the resource and environmental performance (i.e., enhancing the energy and resource use efficiency), and constantly improving the quality of development.

(2) Focus should be made on the fast growing industrialization and urbanization process, expanding the production capacity and carrying out infrastructure construction (in particular the power plant, building, transportation, water supply and sanitation facilities) to avoid the technological lock-in effect of fixed-asset investment, with the benchmark of high-input, low-energy consumption, low-emission, resource and environmental performance as the measuring criteria by depending on institutional and technological innovation.

(3) The development strategy of greening the sectors and companies with high energy consumption and high emissions (e.g., energy, chemical, steel, metallurgy, and building material) should be adopted to promote the development and extensive application of green, low-carbon and environment-friendly technologies, transform the growth model and achieve green transition of the industries and enterprises.

(4) Great efforts should be made to develop highly-efficient technologies and renewable energy, and gradually achieve low-carbon energy transformation. Priority needs to be given on developing energy-efficient technologies to promote the clean use of coal, improve the efficiency of oil and gas, and ensure energy security; focus should also be made on exploring optimal renewable energy deployment model in line with the actual conditions and future trend of clean and renewable energy of various countries in Asia, establishing a sound, diversified energy supply system, gradually transforming the energy structure, improving energy service and increasing the percentage of commodity energy for the rural areas and poor people; R&D and pilot projects on Carbon Capture and Storage (CCS) technologies should also be carried out.

(5) While improving the people's living standards, the Asian countries should also actively explore and establish sustainable consumption models that meet the actual conditions of different countries. Moreover, efforts should also be made to strengthen demand side management, guide and adjust

consumption through such tools and measures as green taxation, energy efficiency labeling, and public education, in order to minimize the pressure of consumption structure upgrading onto the environment.

(6) A new green development approach based on poverty alleviation should be explored for Asia due to its large poor population. The clean, safe, easy-to-use technologies that are affordable to the poor people need to be developed and applied in the region to promote its economic growth, reduce poverty and protect environment.

5.5 Policy recommendations on promoting green development in Asia

(1) Develop national strategies and action plans on green development, and steer and promote green transition.

①Asian countries should consider mainstreaming green development into the national socio-economic development strategies and integrate the concept of green development into various plans and policies.

②Develop long-term goals and objectives on green development, define the roadmaps and priorities for green development.

③Establish long-term and stable incentive mechanism and institutional arrangement, gradually decouple the economic growth from resource and environmental pressure, promote the development of economic growth model and social system that are on resource saving, environment-friendly and low-carbon basis, and advance economic development and create more jobs mainly through green development.

(2) Promote green development through institutional innovation and innovated policy-making.

①Develop a mechanism that integrates environmental and economic policy-making, break the barriers between/among different sectors, enhance coordination, and create a good governance structure. In particular, a strategic environmental impact assessment system needs to be established to fundamentally prevent and control the environmental pollution and ecological damage.

②Give top priority on establishing an appropriate pricing mechanism for resource, energy and environmental factors so that the price can truly reflect the scarcity of resources, market demand and supply, as well as the external costs of pollutants discharge; while developing incentive policies for renewable energy to promote the low-carbon and environmental protection efforts.

③Gradually promote the process of “greening” the taxation and establish a green taxation system through the pilot projects of levying environmental, resource, energy and carbon taxes.

④Consider developing the industry benchmark system for resource and environmental performance, market access system for energy-intensive and high-polluted industries and products, producers' responsibilities extension system, as well as the green purchase system according to the actual conditions of various countries so as to enhance environmental regulation, promote the industry green transition and foster a green consumption market.

(3) Invest in green technologies and construct a green technology innovation system.

①Implement key S&T plans on green development. Efforts should be made to develop an S&T roadmap on green development, coordinate the existing energy conservation, environmental protection and low-carbon R&D projects. Focus should be made on developing key green technologies and technical clusters, implementing the commercialization pilot projects and engaging more enterprises in this process.

②Provide more financial and policy support for R&D of green technologies. Such favorable measures as credit, taxation and subsidies should be taken to encourage and involve the enterprises to invest in R&D and promotion of green technologies and products, contribute to the introduction, absorption and re-innovation of green technologies and equipment, as well as the improvement of energy, water and material-saving technologies.

③Engage the private sector in the R&D of green technologies through Public-Private Partnership to establish a diversified, multi-source, green technologies investment system that integrates the government, enterprises and the public.

④Focus on developing and deploying low-cost, Energy Conservation and Pollution Reduction technologies and renewable energy technologies that are suitable to be expanded in the developing countries in Asia.

⑤Enhance regional R&D cooperation, and jointly develop high and new technologies that benefit energy conservation and environmental protection.

(4) Accelerate the development of green and emerging industries that feature energy conservation and environmental protection.

①Develop green and emerging industries that meet the actual conditions of Asian countries, establish new economic growth area, enhance the industry competitiveness in environmental protection and low-carbon development, and create new jobs, such as new energy, electric cars and environmental protection industries.

②Define the industry development target and spatial distribution and guide the industries to select appropriate technical pathway by developing industry development planning in order to avoid malicious competition and overcapacity and ensure the healthy development of emerging industries.

③Strengthen the policies on developing green, emerging industries, by expanding the investment and financing channels, regulating the standard systems for industries and products, improving the corporate S&T standards, and developing favorable policies in terms of taxation, credit and subsidies.

④Advance the development of green service industries, such as green financial service, emission right trading service, and corporate carbon management consulting.

(5) Implement proactive policy on population control, reduce the number of poor people and develop human resources.

①Develop forward-looking population policy that fits in with the Asian countries' actual socio-economic conditions and takes into consideration the population growth and future aging trend, so as to promote the family planning, control the population number and reduce the adverse effect of the population growth on resource and environment.

②Take various measures to reduce the poverty and achieve the MDGs.

③Further develop human resources, improve the skills of the population and labor force to provide human capital for green development.

④Eliminate the gender discrimination, safeguard the rights and interests of women and children, provide more education opportunities for and improve the education level of women and girls, and reduce the pressure of population growth onto resource and environment.

(6) Strengthen the innovation of education and training model to develop new employment and skills structure that adapts to green transition.

①Develop plans and policies on labor re-training and re-employment according to the needs of green transition, expedite the transfer of labor force from outdated industries and enterprises to emerging ones, and wisely deploy the labor force.

②Reform the existing education and training system to nurture professional talents and skills that are urgently needed by green transition and emerging industries.

③Help the education & training institutions and the labor force to establish partnership.

(7) Explore green consumption model that adapts to the resource and environmental conditions.

①Advocate the long-standing tradition of being thrifty in Asian culture, and disseminate the idea of respecting nature and living in harmony with nature.

②Fully leverage the roles of media (e.g., TV, network and radio) in publicity through education, training and public participation to raise the awareness of the government, business and the general public on greenness, energy conservation, low-carbon development and environmental protection, promote the living habits and consumption behavior that contribute to energy conservation and environmental protection, and provide a favorable social background for the development of green technologies.

③Guide the consumption and promote green consumption by strengthening demand side management, establishing green consumption markets and developing relevant policies and regulations.

④The government agencies should take the lead in implementing actions on Energy Conservation and Pollution Reduction to promote the green consumption model.

(8) Innovate the cooperation mechanism and build a multi-level international cooperation system.

①Enhance dialogue, communication and cooperation in energy, resource and environmental protection areas, define the obligations and responsibilities according to each country's advantage, and jointly conduct R&D on green technologies and resources.

②Establish appropriate technical transfer mechanism, and expedite the process of green technical transfer within Asia. Special attention should be paid to learn from international best practices and introduce advanced green technologies to improve the resource and environmental performance in the region.

③Strengthen the capacity building of resource and environmental monitoring system, early-warning system and emergency system in Asia, develop an information sharing platform, jointly crack down illegal deforestation, trading of wild endangered species and trans-boundary transfer of electronic wastes, and establish an emergency cooperation mechanism on addressing the cross-border pollution incidents.

④Expand the communication network between and among different government agencies and NGOs within Asia, establish a regular communication mechanism and constantly improve the governance capabilities.

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Appendix A

Spatial scope definition and sub-regional categorization of 'Asia' in this report

The spatial scope under this report is stipulated as follows: 1) 'Asia' in this report covers 49 countries and 52 economies (including Hong Kong, Macao and Taiwan of China); and it is divided into five sub-regions, i.e. East Asia, West Asia, South Asia, North Asia and Central Asia, as shown in the following table. 2) Due to limited accessibility and availability of some data and information, the report uses the data of the Asia-Pacific region to approximately reflect the situation in Asia at some cases. In this report , the categorization criteria of UNESCAP is used to describe Asia-Pacific Region, which mainly includes East Asia, South Asia, Central Asia, North Asia (i.e. Russia), Oceania, and the islands in the Pacific Ocean. All the data and information in this report are compiled according to the above-mentioned standards , unless otherwise noted.

Table Scope of 'Asia' in this report and its sub-regional categorization

East Asia	South Asia	Central Asia	West Asia	North Asia
Brunei Darussalam	Afghanistan	Kazakhstan	Armenia	Russia
Cambodia	Bangladesh	Kyrgyzstan	Azerbaijan	
China Mainland	Bhutan	Tajikistan	Bahrain	
Hong Kong, China	India	Turkmenistan	Cyprus	
Macao, China	Maldives	Uzbekistan	Georgia	
Taiwan, China	Nepal		Iran	
Indonesia	Pakistan		Iraq	
Japan	Sri Lanka		Israsel	
Malaysia			Jordan	
Mongolia			Kuwait	
Myanmar			Lebanon	
DPR of Korea			Oman	
Lao PDR			Palestine (West bank and Gaza)	
Philippines			Qatar	
Singapore			Saudi Arabia	
Rep. of Korea.			Syrian Arab Republic	
Thailand			Turkey	
Timor-Leste			United Arab Emirates	
Vietnam			Yemen	

Appendix B

Reports of the Workshops of AASA SDA Project

1. Report of the First Workshop of AASA SDA Project

- Date: 25-26 February 2008
- Venue: Beijing, China
- Host: Chinese Academy of Sciences (CAS)
- Sponsored: Association of Academies of Sciences in Asia (AASA), CAS

The first workshop of AASA Project on Sustainable Development in Asia (SDA) in Asia was hosted by CAS and held in Beijing during 25-26, February 2008. Twenty-three experts from ten different countries participated in the workshop.

The workshop was chaired by Prof. Namık K. Aras, AASA secretary general and Prof. Yi Wang from the Institute of Management and Policy of CAS.

Prof. Jinghai Li, AASA president and Vice President of CAS made welcoming remarks to all the participants on behalf of AASA and CAS. He briefly introduced AASA and the context of the SDA project to all the participants.

Prof. Namık K. Aras gave a presentation on the details of the SDA project and Prof. Yi Wang made an introduction to the outline of the project.

Twenty experts made great presentations respectively of their research and country portfolios of sustainable development of their fields and all the participants shared their wisdom on the design and management of the SDA project in the future during this workshop.

Thematic group discussions commenced on Feb. 26. In the morning experts were divided into four groups to make topic discussions and prepare recommendations for the afternoon session.

During the summary and closing session, Prof. Jinghai Li announced the resolutions and arrangements according to recommendations proposed by each group:

Four study groups were established, with group coordinators identified as follows:

Energy:
Prof. Seung Mo Oh from Rep. of Korea,

Prof. Luguang Yan from China.
Environment:
Prof. Woojin Lee from Rep. of Korea,
Prof. Congbin Fu from China,
Prof. Gensuo Jia from China.
Natural resources: [1]
Prof. Cahit Helvacı from Turkey,
Prof. Lei Shen from China.
Social development and culture:
Prof. Andrei V. TABAREV from Russia,
Prof. Mehmet Özdogan from Turkey,
Prof. Baichun Zhang from China.

The workshop also recommended the co-chairs for the project, they are Prof. Yi Wang from China and Prof. Mehmet Özdogan from Turkey.[2]

The group coordinators will be responsible to arrange flowing up workshops, necessary coordination among group experts as well as relevant experts from other countries beyond AASA members. Each group will work out roadmap for accomplishing the report in their topic. The final report should be with global vision and focused on Asian specific features as an emphasis.

An agreed framework or outline will be the priority task for each group. Experts in each group will be requested to provide necessary scientific input for adapting the context. The group leader will call additional experts from AASA member academies to join the group work if there is the necessity.

The co-chair of the project will be responsible to negotiate the sub-reports from each group to form a single study report. It would be the role of the co-chair to provide comments on the framework of the sub-report of each group to make sure that they are in common manner.

To facilitate the communication between AASA and the project co-chairs and study groups, Prof. Namık K. Aras was appointed to work as a facilitator for the implementation of the project on the AASA side. A project office will also be set up in the institute of policy and management of CAS to provide necessary backup support for the project.

The progress of AASA project will be posted to other relevant international organizations like InterAcademy Panel (IAP) and InterAcademy Council (IAC) and AASA member academies as well, to help to generate extra financial support if possible.

List of Workshop Participants

Jinghai Li, Chinese Academy of Sciences, China
Namık K. Aras, Turkish Academy of Sciences, Turkey

1 Prof. Gensuo Jia was confirmed as the only coordinator of the environment group from the Chinese side.

2 Prof. Yi Wang and Prof. Namık K. Aras were confirmed as the co-chairs of the SDA project.

Yi Wang, Institute of Policy and Management, CAS, China
Luguang Yan, Institute of Electrical Engineering, CAS, China
Changgang Huang, Institute of Electrical Engineering, CAS, China
Seung Mo Oh, Seoul National University, Korea
Andrei G. Korzhubaev, Siberian Branch of the Russian Academy of Sciences, Russia
Hassan Zohoor, The Academy of Sciences of IR Iran, Iran
Congbin Fu, Institute of Atmospheric Physics, CAS, China
Woojin Lee, Korea Advanced Institute of Science and Technology, Rep. of Korea
Moonsuk Seon, Korea Advanced Institute of Science and Technology, Rep. of Korea
Tamara V. Khodzher, Limnological Institute, Russia
Oktay Kerimov, Institute of Energetics, National Academy of Science, Azerbaijan
Jiyuan Liu, Institute of Geographical Sciences and Natural Resources Research, CAS, China
Lei Shen, Institute of Geographical Sciences and Natural Resources Research, CAS, China
Christopher C. Bernido, Research Center for Theoretical Physics, Central Visayan Institute Foundation, Philippines
H. K. Gupta, National Geophysical Research Institute, India
Cahit Helvacı, Geology Department, Dokuz Eylül University, Turkey
Baichun Zhang, Institute for the History of Natural Sciences, CAS, China
Kwang-Yoen Wohn, Korea Advanced Institute of Science and Technology, Rep. of Korea
Andrei V. Tabarev, Novosibirsk State Pedagogical University, Russia
Elena Gvozdeva, Siberian Branch of the Russian Academy of Sciences, Russia
Mehmet Özdogan, Turkish Academy of Sciences, Turkey
Michael Turner, Israel World Heritage Committee, National Commission for UNESCO
Saran Solongo, Mongolian Academy of Sciences, Mongolia
Yonglong Lv, Bureau of International Cooperation, CAS, China
Zhenyu Wang, Bureau of International Cooperation, CAS, China
Yan Zhuang, Bureau of International Cooperation, CAS, China

2. Report of AASA Workshop on Sustainable Energy Development in Asia

- Date: 17-18 November 2008
- Venue: Beijing, China
- Host: Chinese Academy of Sciences (CAS)
- Sponsored: CAS, InterAcademy Panel and InterAcademy Council

Background

As part of the AASA's "Sustainable Development in Asia (SDA)" project, "The AASA Workshop on Sustainable Energy Development" was held on 17-18 November 2008 in Beijing, China. The events were organized by AASA and CAS, hosted by Institute of Electrical Engineering of CAS and sponsored by InterAcademy Panel (IAP) and InterAcademy Council (IAC).

Participants include 30 representatives of 10 member academies and two observers. Ten member academies include Bangladesh, Iran, Rep. of Korea, Malaysia, Nepal, Philippines, Sri Lanka, Thailand, Turkey, and China. Two observers are Dr. Yee-Cheong Lee, Secretary General of the Federation of Asian Scientific Academies and Societies (FASAS) and Special Advisor on Sustainable Energy to IAC Co-Chair; Prof. H. K. Gupta, Raja Ramanna Fellow of National Geophysical Research Institute, India. Participants shared information about the energy situation in their own country and address the common challenge in Asia. Recommendations are also made on how to prepare a consultative report on sustainable energy development in Asia.

Discussion

Discussion was mainly on the content of the Final Report of the Sustainable Energy Development in Asia. The experts emphasize the following points:

• Each country provides its National Report, which is basic data for Final Report of the Sustainable Energy Development in Asia.

• What is Sustainable Development? We should provide a clear definition specific to "Sustainable Energy Development" along with the broader definition of "Sustainable Development". Define clearly the meaning of Sustainability from the point of view of AASA.

• There are many reports available but what is special about AASA report? This report will be written by AASA, hence it is an advisory. Based on the national reports and official statistic dates, the recent annual primary energy consumption, production, primary energy resource and structure, import and export situation for most countries will be collected and summarized, some forecast for the next 20-40 years will also be collected, as basis for detailed analysis and study.

• General energy situations: The template (form) to collect energy situation should make clear the time frame of data (say most up-to-date ones), the units and conversion factors, and source of data.

• The environment protection and climate change are still big problems for future energy development. Energy consumption should be within the environment and climate change allowable limits.

• The social and economic development needs to provide reliable and sustainable energy supply. Guarantee the energy supply security, especially the oil and gas in the near future.

• Develop the technologies for capturing and sequestering carbon from fossil fuels, particularly coal, to effectively manage the global CO_2 emissions.

• Continue long-term new energy research and development, including gas hydrates, hydrogen and nuclear fusion.

• Promote the South-South cooperation, i.e., developing country-developing country cooperation. Share experience in energy R&D.

• Look at those energy areas: hydrogen, fuel cell, solar cell, new materials for building, energy saving, continual use of fossil fuels, nuclear power generation, biofuel for transportation, energy-efficiency improvements, energy harvesting, new energy merging, energy storage and conservation, energy efficiency, etc.

List of Workshop Participants

Jinghai Li, Chinese Academy of Sciences (CAS), China
Namık K. Aras, Turkish Academy of Sciences, Turkey
Luguang Yan, Institute of Electrical Engineering, CAS, China
Liye Xiao, Institute of Electrical Engineering, CAS, China
Honghua Xu, Institute of Electrical Engineering, CAS, China
Yi Wang, Institute of Policy and Management, CAS, China
Shaofeng Chen, Institute of Policy and Management, CAS, China
Gensuo Jia, Institute of Atmospheric Physics, CAS, China
Lei Shen, Institute of Geographical Sciences and Natural Resources Research, CAS, China
Baichun Zhang, Institute for The History of Natural Science, CAS, China
Hongguang Jin, Institute of Engineering Thermophysics, CAS, China
Changgang Huang, Institute of Electrical Engineering, CAS, China
Yee Cheong Lee, FASAS, Malaysia
M. Shamsher Ali, Bangladesh Academy of Sciences, Bangladesh

H. K. Gupta, National Geophysical Research Institute, India
Hassan Zohoor, The Academy of Sciences of IR Iran, Iran
Mahmoud Yaghoubi, The Academy of Sciences of IR Iran, Iran
Seung Mo Oh, Seoul National University, Rep. of Korea
Muhammad Yahaya, Academy of Sciences, Malaysia
Er. Rishi K.B. Shah, Nepal Academy of Science and Technology, Nepal
Alvin B. Culaba, The National Academy of Science and Technology, Philippines
Indral K. Perera, Sabaragamuwa University of Sri Lanka, Sri Lanka
Bundit Fungtammasan, King Mongkut's University of Technology Thonburi, Thailand
Volkan S. Ediger, İzmir University of Economics, Turkey
Xavier Chen, BP China
Yunhan Xiao, Bureau of High-Tech Research and Development, CAS, China
Lucheng Ji, Bureau of High-Tech Research and Development, CAS, China
Xiaolei Zhang, Xinjiang Branch of CAS, China
Yuhuan Ma, Institute of Electrical Engineering, CAS, China
Zhenyu Wang, Bureau of International Cooperation, CAS, China
Yu Chen, Bureau of International Cooperation, CAS, China

3. Report of AASA Workshop on Agricultural Culture and Sustainable Development in Asia

- Date: 12-13 August 2009
- Venue: Beijing, China
- Host: Chinese Academy of Sciences (CAS)
- Sponsored: Association of Academies of Sciences in Asia (AASA), CAS

Workshop activities

The Workshop on Agricultural Culture and Sustainable Development in Asia, hosted by Chinese Academy of Sciences (CAS), sponsored by Association of Academies of Sciences in Asia (AASA) took place in Beijing Friendship Hotel from 12th to 13th August 2009. Nearly 20 speakers and scholars from CAS, Chinese Academy of Social Science (CASS), University of Toronto Canada, University of Nottingham UK, Osaka University of Economics, Pusan National University, Shaanxi Normal University, China Agricultural Museum, South China Agricultural University and Nanjing Agricultural University attended it.

At the beginning of the workshop, Prof. Yi Wang, deputy director-general of Institute of Policy and Management, CAS addressed congratulations to the workshop on behalf of Prof. Jinghai Li, vice president of CAS, and made presentation on the SDA project from aspects of its background, aims, outlines, schedules, and management. Prof. Baichun Zhang, deputy director of Institute for the History of Natural Science, CAS also made welcome address.

Each participant delivered opinions actively based on his research field and the workshop topics. Andrew M. Watson, Professor Emeritus of Economics, famous expert in History of Agriculture and sustainable development in West Asia presented two lectures with full and accurate data and precise textual research: "Agricultural Innovation in the Early-Islamic World. How, why did it happen? And how, why did progress end?"; and "Sustained and Sustainable Agriculture in West Asia: Past, Present and Future", which inspired each participant on the knowledge of History of Agriculture in West Asia. Presentation "Sustainable Agrarian Systems and the transformation of Japan in East Asia" by Prof. Mitsutoshi Tokunaga, Osaka University of Economics investigated the attitude of peasants to nature through fieldwork and historical document analysis, and expressed his perspectives on the future of agriculture in Japan.

Prof. Duk Kyung Choi from Pusan National University presented "The Legacy of Korean Farming Culture and its Sustainable Development", case study from "Korea Era", explored the features of Korean agriculture development and identified its future trends. Prof. Luling Wei, from South China Agricultural University addressed presentation "the Feature and Future of Indian Agriculture" based on her understanding of Indian agriculture and her work during her stay in India. Y L Nene, Chairman, Asian Agri-History Foundation, where he and coworkers had been conducting investigation on agricultural legacy and sustainable development over the last ten years, showed us some of his work in "Some Classics on Agriculture and Their Relevance Today in Cultivating Medicinal and Aromatic plants" and Prof. Gengpan Li, from CASS, presented "Chenfu Nongshu and the Evolution of Chinese Traditional Thinking of the Sustainable Agriculture" with profound comments on Chenfu Nongshu and Qi Min Yao Shu (Main techniques for the welfare of the people).

As member of the National Committee of the Chinese People's Political Consultative Conference (CPPCC), Prof. Chenggui Li, from CASS shared his lecture "Traditional Farming Culture of China and Its Adaptability to Contemporary Society" and put forward some new thoughts on famers' capacity-building, such as mastery of new technology, marketing and management. Prof. Xiongsheng Zeng, focusing his research in agricultural history of China and agricultural culture as well as organizer of the workshop from CAS, presented a report "Agro-biodiversity and Agricultural Development in China'. He argued "Agro-biodiversity", like intensive cultivation, had shown its positive effect against challenge of agriculture in China and did believe that "Agro-biodiversity" would be as important as Farmland Preservation in future agriculture. In his presentation "Dynamic Conservation Approaches to Agro-cultural Heritage", Prof. Qingwen Min, from Institute of Geographic Sciences & Natural Resources Research CAS, gave us the latest progress in the conservation of Agro-cultural Heritage in China. Prof. Wangsheng Xu, from China Agricultural Museum had a talk "On the Cultural Heritage and Sustainable Development of Agriculture: Rice-fish System in Paddy Fields as a Case" at the workshop. Prof. Huoqi Yan, from Nanjing Agricultural University, presented his talk "The Value of Local Knowledge: as the Case of Hani in China", in which traditional local knowledge of various ethnic communities was given the same priority as modern technology.

Lectures of Prof. Lingfu Li from Shaanxi Normal University and PhD student Bo Ren from University of Nottingham explored effects of water resource upon the agriculture. Prof. Li described "Evolution and Development of Zhengguo Irrigation Canal". Bo Ren presented her lecture "Comparison between Run-off Desert Agriculture in Israel and Low-lying Silt Filed in China" in cooperation with Dr. Jianting Yang from the Research Centre of the Song Dynasty in Hebei University. Mr. Yichao Wang, from capital Mountain Rural Development Research Center made a brief review on Eco-agriculture Construction in Liuminying over the last 30 years.

In the discussion part, every participant felt free to present his or her opinion. All participants agreed that this high-level international workshop provided a good platform for scholars to exchange ideas, expand and extend research fields, and start investigation on sustainable development in Asia based on an integrated and comprehensive perspective, which laid a good base for future cooperation.

List of Workshop Participants

Gengpan Li, Institute of Economics in Chinese Academy of Social Science (CASS), China

Yichao Wang, Capital Mountain Rural Development Research Center, China

Chenggui Li, Institute of Rural Development in CASS, China

Andrew Watson, Department of Economics, University of Toronto, Canada

Huoqi Yan, Nanjing Agricultural University, China

Yi Wang, Institute of Policy and Management, CAS, China

Lingfu Li, Shaanxi Normal University, China

Mitsutoshi Tokunaga, Osaka University of Economics, Japan

Qingwen Min, Institute of Geographic Sciences & Natural Resource Research, CAS, China

Duk Kyung Choi, History Department of Pusan National University, Rep. of Korea

Luling Wei, South China Agricultural University, China

Y L Nene, Asian Agri-History Foundation, India

Wangsheng Xu, China Agricultural Museum, China

Baichun Zhang, Institute for the History of Natural Science, CAS, China

Xiongsheng Zeng, Institute for the History of Natural Science, CAS, China

Bo Ren, University of Nottingham

Rongguang Huang, Institute for the History of Natural Science, CAS, China

Dongling Peng, Institute for the History of Natural Science, CAS, China

Xiaolei Shi, Institute for the History of Natural Science, CAS, China

Xinhao Du, Institute for the History of Natural Science, CAS, China

4. Report of AASA Workshop on Environment and Resources in Asia

- Date: 24-27 September 2009
- Venue: İzmir, Turkey
- Host: Turkish Academy of Sciences (TÜBA)
- Sponsored: InterAcademy Panel (IAP), Association of Academies of Sciences in Asia (AASA), Turkish Academy of Sciences (TÜBA)

Background

The Association of Academies of Sciences in Asia (AASA) is a non-profit organization, established in 2000, and comprising 26 Academies. The vision of AASA is to provide a forum to discuss and provide advice on issues related to science and technology and the application of technology for national development. Since the establishment, AASA held many symposiums, conferences and scientific meetings. Based on several proposals from member academies, it was decided in April 2007 to organize a new project entitled "Sustainable Development in Asia (SDA)". The new project covers four main topics or components: energy, climate change and environment, natural resources, and social/cultural development. The whole project is coordinated by Prof. Yi Wang from CAS and Prof. Namık K. Aras, projects coordinator of AASA, from Turkish Academy of Sciences (TÜBA). The science team for the component of climate change and environment is led by Prof. Gensuo Jia from China and Prof. Woojin Lee from Korea, while science team for the component of natural resources is led by Prof. Cahit Helvacı from Turkey and Prof. Lei Shen from China.

During 2008 two workshops were organized in Beijing. The first workshop was held from February 25 to February 26 and devoted to the whole project "Sustainable Development in Asia", including four groups of energy, environment, natural resources, social development and culture, 28 experts from 10 countries attended. on November 17-18, 2008 the second workshop on "Sustainable Energy Development in Asia" was held in Beijing, where 31 representatives from 10 AASA member countries contributed to the discussions. From the information exchange and discussion during the above mentioned workshops, it was decided to have the third workshop in the fall of 2009 devoted to environment and natural resources and the interactions among these two major issues in the context of sustainable development in Asia.

Objectives of the workshop

Asia is the most economically dynamic region in the world. In the last two decades, growth in industrial and agricultural production in Asian countries has outstripped global growth rates, and more people than any other continents have walked out of the shadow of poverty. However, economic progress has been achieved at a high price. Under combined pressure of climatic change and human disturbances, the natural environment in Asia has been steadily degrading, which compromises the future development and the livelihood of its 3.8 billion residents. Meanwhile, share of Asian developing countries to global GHG emissions is rising rapidly. Impacts of climate change are especially visible in Asia on various sectors including agriculture, forestry, biodiversity conservation, water resources, human health, air quality, energy security, etc. Impacts of climate change in Asia are already serious, and will very likely further worsen in the future. Environmental sustainability is under serious threat.

There is good opportunity of cooperation on the sustainable use of resources and environmental management in Asia. Strengthening the cooperation is a demand for resources security and environmental quality that guarantees sustainable development in all Asian countries. In this regard, AASA sponsored the workshop on "*Environment and Resources*" during the period from September 24 to September 27, 2009 in İzmir, Turkey.

AASA invited stakeholders with broad interest in environment and resources from its member countries to learn from concrete successful case studies of effective environmental management and sustainable use of resources as a guide to the development of better policy and practice, or implementation of some priority actions in the different jurisdictions of the Asian region.

The objectives of this workshop are to bring researchers together and high-level managers to discuss regionally the major problems presently faced by managers and how science can contribute to the overcoming of these problems. The workshop main topics are:

- Earth's Life Support Systems: climate change impacts, adaptation and mitigation, resources' efficent and sustainable use
- Successful experiences on environment protection and resources use in all Asian countries
- Improvement, protection and integrated management of water and coastal resources, delta wetland, land and mineral resources conservation
- Management and policy for sustainable use of resources and environment

Workshop activities

"The AASA Workshop on Environment and Resources in Asia" was held from 24 to 27 September, 2009 in İzmir, Turkey, as a part of the AASA "Sustainable Development in Asia" project.

A preparatory meeting was held at Dokuz Eylul University on May 14, 2009, attended by Prof. Gensuo Jia, Prof. Lei Shen, CAS, Prof. Cahit Helvacı, Prof. Alper Baba, IYTE, Prof. Namık K. Aras, TÜBA. During this one-day meeting the overall frame of the meeting was decided.

This workshop was organized by AASA and TÜBA, hosted by Turkish Academy of Sciences and Dokuz Eylul University (DEU), sponsored financially by InterAcademy Panel (IAP), InterAcademy Council (IAC), Turkish Academy of Sciences (TÜBA), Association of Academies of Sciences in Asia (AASA), InterAcademy Panel (IAP), Dokuz Eylul University (DEU), İzmir Institute of Technology (IYTE) and Turkish Chamber of Geological Engineering (JMO).

The workshop committee received 20 contributed papers that cover wide topics on regional climate change, environment, and natural resources from 12 AASA member countries. Those papers were reviewed, edited, and published in the workshop proceedings prior to the workshop.

Participants of the workshop include 34 representatives of 10 member academies and one observer. The 10 member academies is Azerbaijan, Bangladesh, China, Georgia, Iran, Israel, Rep. of Korea, Philippines, Pakistan, Turkey. The one observer is Mrs. Anna Stabrawa, Regional Coordinator for Asia-Pacific Division of Early Warning and Assessment (DEWA), United Nations Environment Programme (UNEP) based in Thailand. A group photo of the participants is given below.

Participants shared information about the environment and resources situation and the interlinks between these two issues in their own country and addressed the common challenges in Asia. Recommendations were also made on how to prepare a consultative report on sustainable use of natural resources and the environment in Asia.

Discussion

At the last session of the workshop a lengthy and very constructive discussion was held among the attendees. The experts emphasized the following points:

• Science and technology are useful in establishing what we *can* do. However, neither of them, or both, can tell us what we *should* do. The latter requires the application of *evaluative thinking* and *value judgment* by socially responsible, reflective, and active participants in relevant societal, technological, economical and/or policy-related discourses in the environmental context.

• Resource efficiency is cross-cutting and applicable to the use of all resources. Therefore it needs to be investigated in all resources contexts.

• Identifying the key environment and resource issues and what are the scientific gaps that need further research are among the major issues that need urgent attention.

• The policy relevance of all research is critical to addressing the issues roused. Scientists should be encouraged to include this in their work. Also what are the emerging environmental issues which might need attention in the future should be discussed.

• Water availability with appropriate quality and water use efficiency in the region are among the key issues in Asia and should be given high attention.

• Impact of climate change on agricultural production and food security and food safety should be given high priority. Strong support should be given to research in genetic engineering to increase the production of rice, wheat and corn.

• Under the economic globalization and regional economic integration as well as urbanization and industrialization, the landscape of natural resources use in Asian countries has changed dramatically. The protection, development, processing and consumption of natural resources, and the economic, social and environmental issues associated with them have aroused great concern in countries in Asia and/or even the whole world. There is no doubt that natural resources have placed devotion to the economic development of countries in Asia, and economies of many countries highly depend on the development and utilization of natural resources. However, the over-exploitation and over-consumption of some resources, resulting in environmental damage, social instability, single economic structure, are all the facts that cannot be ignored. In that case, the major topics requiring to be paid urgent attention and studied in this report include the status, the existing problems, the sustainability of Asia's natural resources and the measures might be taken by each country in Asia.

• Global warming is a major issue of concern worldwide and effort for cutting down the Greenhouse Gas (GHG) is vigorous everywhere. Emission control facilities are important industrial infrastructure and it is also critical for the mitigation of climate change.

• Establishment of technology and information-sharing platform and mechanism would contribute to the advancement of the collaboration and sustainable development in resources utilization in Asia. The establishment of the Asia resources technology sharing networks and domestic resources technology communication mechanism may facilitate this development.

• Promoting environmental concern and knowledge of society using proper training methods in primary, secondary high schools, universities and through national mass media especially radio and television and NGOs is greatly recommended. All university students must take at least one environmental course and the main content of these courses should be the environmental values and natural resource protection and the methods of social, economical and constructional activities without environmental damage. However, the importance of "readiness" must be emphasized in order to activate the public awareness.

• Population control, the unbalance population growth with ecosystems potential in the past has imposed a great pressure on environmental resources. Therefore, the population increase should be kept in the agenda as of high priority issue.

• Geothermal resources have a great potential for providing heating and alternative power generation in some Asian countries. It also has great potential for reduction of GHG emissions and climate change mitigation. Asian countries that have experience in geothermal resources should be encouraged to share their knowledge in terms of know-how and technology transfer with those who have geothermal potential that might be available for development.

• Coal mining and the consumption are two of the core issues that concern the natural resources management, environmental quality, and climate change. Problem-solving oriented projects should be promoted and cooperation between member countries should be supported.

• Environmental technologies should consider both removal efficiency and CO_2 emissions reduction.

• Increasingly frequent and extent and intensified extreme climate event and the related natural disasters posed major threat to the regional economy and the sustainability. Sensitivity and vulnerability of Asian countries to climate change should be studied in specific hydrologic basins.

• Resources should be mobilized for the installation and use of renewable energy sources to minimize the adverse effects of the conventional energy sources.

• About 60% of the coastal areas of the world are in the Asia-Pacific region. However, coastal resources have not been effectively developed. Coastal resources should be explored and sustainably managed for socio-economic development. Coastal resources should include energy production from seas and oceans as well as food production and biological resources.

• Resources and environment are linked on the basis of all types of ecosystems. Maintaining the biodiversity in Asia is of vital importance for sustainability not only in the continent but also in the world. Therefore, a holistic and integrated approach should be applied in research and application projects aiming at effective use of natural resources. Additionally, strong support should be given to research on extracting drugs and medicine from plants and marine life before they become extinct.

• International and interdisciplinary cooperation in research targeting specific problems of food production, energy demands and environmental protection should be highlighted in the reports to national governments. The role of multidisciplinary approach and the value of the public and NGOs participation should be promoted more actively.

• Governments should come together for a common or regional policy to mitigate the conflict between the environmental protection and resource development. Capacity building in the area of environment is essential. The member countries should cooperate and share expertise. Future direction for Asia wide cooperation should be established.

• Priorities should be given to the fields of monitoring and assessing the impact of the resources management on the ecosystems and environment in Asia, focusing on semi-arid, mountainous, and coastal regions. Establishing and sharing a database is of major importance and creating a platform to provide a regular forum for scientists within the member countries of AASA might be very useful in this context.

Future Work

During the workshop all participants also discussed follow-up activities and important future work that ensure continue progress after the workshop. The following future work is highlighted:

(1) After the workshop the project coordinators will gather the committee to further evaluate the outcomes of the workshop and write a draft report "Environment and Resources in Asia" to be submitted to AASA. The report will be organized to provide important inputs to the AASA SDA project, together with the reports and outcomes of the previous relevant workshops.

(2) The project coordinators and science team leaders will continue dialogues with workshop participants to seek for their valuable comments and suggestions on the draft reports of climate change/environment and natural resources as parts of final reports for the AASA SDA project.

(3) A participant's mailing list and an online forum will be established to serve as platforms for scientific communications and data exchange. Emerging issues in science and technology related to environment and resource and decision-making for sustainability will be highlighted in addition to the importance of developing short-term and long-term action plans in the context of sustainable development.

(4) A homepage of the workshop has been developed prior to the event (http://www.fbe.deu.edu.tr/AASA2009). The homepage will be continuously maintained and frequently updated for follow-up activities.

(5) Participants will share successful local practices for solving regional natural resources and environmental problems via online forum. Those local knowledge based best practices could be used as prototypes for solutions under similar conditions in Asian countries.

List of Workshop Participants

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