Economic development and de-carbonization paths: Micro and macro perspectives from Indonesia

Dissertation

zur Erlangung des wirtschaftswissenschaftlichen Doktorgrades

der Wirtschaftswissenschaftlichen Fakultät der Universität Göttingen

vorgelegt von

Mohammad Iqbal Irfany

aus Bogor, Indonesien

Göttingen, 2014

Erstgutachter : Prof. Stephan Klasen, PhD
Zweitgutachter : Jun.-Prof. Dr. Jann Lay
Drittprüfer : Prof. Dr. Bernhard Brümmer

Tag der mündlichen Prüfung: 14.11.2014

Summary

The three essays of this dissertation associate topics on economic development and climate change. All essays discuss the general topic on how to link rising income level and environmental trade-offs, focusing on CO_2 emissions as the main source of greenhouse gas. The research offers insight on major drivers and distributions of CO_2 emissions as well as how economic growth, energy use and emissions interact.

The first essay measures household carbon footprints from their consumption decision, using Indonesia as an example. It analyzes the pattern, determinants, and decomposition of growing household emissions. This study found that fuel-light and transportation sectors are the most intensive emitters in Indonesia and found a significant disparity of household carbon emissions. It also found that rising income level is the main determinant of the household emission. The decomposition of emissions growth suggests that growing emission between 2005 and 2009 are primarily attributed to the rise in household affluence.

Household distribution may have direct implication in mitigating climate change as any emission reduction policy has more pronounce in a more equal society than in an unequal one. The second essay examines how unequal the households in their emission levels and decomposes emission inequality based on emission sources. Results found that there is an increasing inequality among households and greater portion of emission inequality is contributed by energy-transportation household consumption item.

The third essay investigates the causality nexus between emissions, energy use and economic development along with urbanization and investment employing a number of time series analyses for the Indonesian case. This study indicates the direction of Granger-causality running from output and energy consumption to emissions but not in the opposite direction from emission to output, suggesting the possibility of reducing emission without impeding growth. Energy use could take

a role as an intervening variable linking output and emissions. Urbanization and capital formation could be carbon-neutral if the country in question has an appropriate urbanization and energy policy dealing with climate change mitigation.

Each essay contributes to the literature on how economic activities (from rising consumption) causes rising emissions as one of main externalities of human development. In the opposite direction, environmental degradation (and/or its mitigating strategies) could also impede further development of human well being. Appropriate policies to stimulate consumption towards less emission intensive expenditures could be implemented although it might be very difficult particularly in developing countries which are struggling with energy efficiency, carbon intensive energy system, insufficient green infrastructures, urban management and public transport systems, as well as high (and not well targeted) fuel subsidies. Those issues could then have substantial relevance not only to Indonesia as a developing economy but also to global debates on how to decarbonize development paths.

Zusammenfassung

Die drei Essays dieser Dissertation verbinden Themen der wirtschaftlichen Entwicklung und des Klimawandels. Alle Essays erörtern die allgemeine Frage wie steigende Einkommen und Austauschbeziehungen in Umweltfragen verbunden werden können und konzentrieren sich dabei auf CO_2 Emissionen als Hauptverursacher von Treibhausgasen. Die Forschungsarbeit beleuchtet die wesentlichen Treiber und Verteilungswege von CO_2 Emissionen und zeigt wie wirtschaftliches Wachstum, Energieverbrauch und Emissionen interagieren.

Im ersten Essay wird am Beispiel Indonesiens der ökologische Fußabdruck von Haushalten durch ihre Konsumentscheidung aufgezeigt. Es werden Muster, Determinanten und die Aufschlüsselung der steigenden Emissionen der Haushalte analysiert. Die Arbeit konnte zeigen, dass die Sektoren mit Leichtöl und im Transportwesen die intensivsten Emittenten in Indonesien sind und ein signifikantes Ungleichgewicht der Karbon-Emissionen zwischen Haushalten besteht. Sie konnte zudem darlegen, dass ein steigendes Einkommen die wichtigste Determinante der Haushaltsemissionen sind. Die Aufschlüsselung des Emissionswachstums legt nahe, dass die steigenden Emissionen zwischen 2005 und 2009 hauptsächlich auf den steigenden Wohlstand der Haushalte zurückzuführen sind.

Eine gerechtere Haushaltsverteilung besitzt -wie jedes Emissionsreduzierungskonzept- einen größeren Effekt zur Abschwächung des Klimawandels in einer Gesellschaft mit weniger Ungleichheit als in einer Gesellschaft mit verstärkter Ungleichheit. Im zweiten Essay wurde die Ungleichheit von Haushalts-Emissionen und die Aufschlüsselung der Emissionsungleichheiten in ihre Ursachen untersucht.. Die Studie zeigt einerseits eine steigende Ungleichheit unter den untersuchten Haushalten als auch dass Energie-Transport hauptsächlich für höhere Emissionsungleichheit verantwortlich ist.

Der dritte Essay untersucht kausale Zusammenhänge zwischen Emissionen, Energieverbrauch und wirtschaftliche Entwicklung gemeinsam mit Urbanisierung und Investitionen im Falle von Indonesien unter Verwendung von Zeitreihenanalyse. Diese Studie zeigt eine Granger-Kausalität von Output und Energieverbrauch hin zu Emissionen, aber nicht in die entgegengesetzte Richtung von Emissionen zu Output. Dies weist darauf hin die Möglichkeit Emissionen zu reduzieren ohne Wachstum zu hemmen. Damit könnte Energieverbrauch die hauptsächlich verändernde Variable zwischen Output und Emissionen sein. Urbanisierung und Kapitalformation können CO_2 neutral sein, wenn das betreffende Land nachhaltige städtische Entwicklung, grüne Investitionen und Energieeffizienz zur Entschärfung des Klimawandels fördert.

Jeder dieser Essays trägt zu der Literatur dazu bei, wie ökonomische Aktivitäten (wie steigender Konsum) steigende Emissionen - eine der wichtigsten Externalitäten menschlicher Entwicklung - bedingen. Andersherum könnte Umweltzerstörung (und/oder entschärfende Maßnahmen) weitere Entwicklung menschlichen Wohlbefindens erschweren. Passende Politikmaßnahmen, der Konsum in Richtung von weniger emissionsintensiven Ausgaben stimulieren, könnten implementiert werden. Aber insbesondere in Entwicklungsländern, die mit Energieeffizienz (CO_2 intensive Energiesysteme), ungenügend grünen Infrastrukturen, Städteplanung, öffentlichem Nahverkehr und hohen (und ungünstig gezielte) Treibstoffsubventionen zu kämpfen haben, könnte dies schwierig werden. Diese Themen könnten dann nicht nur für Indonesien als entwickelnde Ökonomie sondern auch bei globalen Debatten dazu beitragen, wie Entwicklungspfade weniger kohlenstoffintensiv gestaltet werden können und damit substantielle Bedeutung erlangen.

Acknowledgements

I am grateful to the assistance from a number of people. First and foremost, I owe the greatest intellectual debt to my supervisor, Prof. Stephan Klasen, PhD, for the guidance, encouragement, patience, and giving me opportunities during the course of my PhD research. His support, trust, and understanding have kept me strong until the end of my dissertation. I cannot imagine a better and more intelligent supervision than him. Special gratitude is also extended to Jun-Prof. Jann Lay as the second supervisor for his valuable comments including at the project meetings and presentations. I further wish to express my sincere thanks to Prof. Bernhard Brümmer for volunteering to be my third supervisor and his quick insights during discussions.

I must also express my special thanks to Experts I Erasmus Mundus for the PhD grant, without their funding this research would not have been possible. I would also like to thank to the Göttinger Graduiertenschule Gesellschaftswissenschaften (GGG), which provided a further assistance during the last months of my dissertation.

I would like to thank my colleagues in the project of “Low Carbon Development Paths” (EntDekEn), Dr. Nicole Grunewald, Moises Neil Serino, and Sebastian Renner. With them I presented the preliminary findings in various international conferences, seminars, workshops, and expert meetings. My appreciation also goes to the member of the project on “Long-term Land Use, Poverty Dynamics and Emission Trade-offs in Sulawesi and Jambi” (CRC 990, C04).

I would like to extend my sincere thanks to Dr. Felicitas Nowak-Lehmann Danzinger, who has helped me with the econometric analysis. I would also like to acknowledge to all members of the Chair of Development Economics, especially Syamsul H. Pasaribu, Bumi Camara, Deniey A. Purwanto, Junaid Ahmed, Rivayani, Dewi Nur Asih, Radjius Idzalika, among others for valuable discussions during PhD courses towards the final day of dissertation, to the students and IT assistants who have supported me with academic, technical and administrative works. To Jennifer Phillips, I am grateful for her excellent English proofreading.

Furthermore, I would like to express a big thanks to all people who directly and indirectly supported me with writing this doctoral thesis as well as living in Göttingen and numerous people who I cannot explicitly mention here.

Back home, this work is attributed to my beloved mother Hj. Iyah Sulasiah, for her love and praying, and to the big family of Nurul Hidayah and Uqon Bulqoeny descendants. Finally, my work and life in Göttingen would not have been written without the encouragement, spirit, practical supports and happiness from my small family: Rosa Samrotul Fauzah, and our sweetest children, Salwa and Haqqi. This is dedicated to all of you.

Table of Contents

Lists of Tables

Lists of Figures

Lists of Abbreviations

ADF	Augmented Dickey-Fuller
AIC	Akaike information criterion
BPS	Badan Pusat Statistik (the Indonesian Central Board of Statistics)
CO_2	Carbon dioxide
CUSUM	Cumulative sum
CUSUMSQ	Cumulative sum square
DLNCO2CP	First difference in logarithm of per capita CO_2 emissions
DLNECP	First difference in logarithm of per capita energy use
DOLS	Dynamic ordinary least squares
ECM	Error correction model
EKC	Environmental Kuznets Curve
Exp.	Expenditure
GDP	Gross Domestic Product
GHG	Green house gases
GTAP	Global Trade Analysis Project
GTAP-E	Global Trade Analysis Project - Environmental account
HH	Household
HHSize	Household size
HQ	Hannan-Quinn information criterion
IEA	International Energy Agency
IO	Input output
IRF	Impulse response function
kg	Kilogram
LMDI	Logarithmic mean divisia index
LNCO2CP	Natural logarithm of per capita CO_2 emissions
LNECP	Natural logarithm of per capita energy use
LNK	Natural logarithm of capital formation
LNU	Natural logarithm of urban population
LNYCP	Natural logarithm of per capita output
LR	Log likelihood criterion
Obs.	Observations
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least square
OPEC	Organization of the Petroleum Exporting Countries
Rp	Rupiah (the official currency of Indonesia)
SC	Schwarz criterion
Susenas	Survey Sosial Ekonomi Nasional (National Socioeconomic Survey)

UK	The United Kingdom
UN	The United Nation
UNFCCC	United Nations Framework Convention on Climate Change
US	The United States
USD	The United States Dollar
VAR	Vector auto regressive model
VECM	Vector auto correction model
VED	Variance error decomposition
WDI	World Development Indicators

Introduction and Overview

"Green is a process, not a status. We need to think of 'green' as a verb, not an adjective." (Daniel Goleman)[1]

The environmental trade-off of development is one of the pressing challenges of the global world, particularly since the industrial revolution. While income growth is a reflection of rising welfare and one of main dimensions of human development, reducing environmental damage is problematic as it could be associated with hampering economic growth and long-run welfare. Formulating a roadmap towards a low carbon economy that cuts the climate-change trade-off without impeding economic growth is one of biggest tasks both in academic discourses and in practices.

Green house gas (GHG) emissions, of which 81% was CO_2 emissions in 2009 (UNFCCC, 2010), are regulated based on its country of production (e.g. WDI reports from World Bank, 2012). However, though they are produced in one country they are often consumed elsewhere. Consumers thus partially contribute to the emissions. Given this fact, apart from the production side, the demand side analysis of growth and emission trade-offs is also important in order to account for the real emissions' contribution and to analyze the drivers of rising emissions that are important in climate change mitigations.

Numerous studies (e.g. Wier et al., 2001; Kok et al., 2006; Tukker and Jansen, 2006; Hertwich and Peters, 2009) fall into this nexus, especially in measuring GHG emissions from household consumption. While relatively abundant investigations have been done for developed countries (e.g. Kenny and Gray, 2009; Girod and de Haan, 2010; Murthy et al., 1997; Parikh et al., 1997), less research has been done regarding developing countries. Hypothetically, increasing

[1] "Ecological Intelligence: How Knowing the Hidden Impacts of What We Buy Can Change Everything" (New York: Broadway Books, 2009; available at goo.gl/dnjmwV. Accessed: September 2014).

standards of living is accompanied by changes in consumption patterns that then cause higher CO_2 emissions from burning fossil fuels (oil, gas, and coal) for household activities, transportation, and other energy-related expenditures. In other words, socio-economic development has been closely related to energy consumption, as it is an important element in the transition from traditional to modern economy (Schäfer, 2005; Kok et al., 2006). While transitions from traditional to modern sources of energy are intended to improve efficiency, such improvements are also compensated by higher energy requirements that are closely related to lifestyle changes (Pachauri, 2004; Pachauri and Jiang, 2008).

As witnessed in macro level (cross-country) studies, similar empirical evidence can be found in the differences between consumption-related household carbon footprints. Such studies typically indicated the significant heterogeneity of household carbon emissions based on their characteristics. For instance, in the UK case, Druckman and Jackson (2009) found that carbon footprints differ widely between the richest subgroups (called 'prospering suburbs'), which have almost two-thirds of total CO_2 emissions, and the poorest group (called 'constrained by circumstances'). Other similar studies such as Wier et al. (2001) investigating Danish households, Kerkhof and Moll (2009) in the UK, the Netherlands, Sweden, and Norway; Bin and Dowlatabadi (2005) and Weber and Matthews (2008) in the US case; found that household emissions widely differ depending on different characteristics, and that income has been found to be the single most important determinant of rising household carbon footprints (Murthy et al., 1997; Parikh et al., 1997; Weber and Matthews, 2008). For developing economies, studies done for households in China (e.g. Pachauri and Jiang, 2008), India (Parikh et al., 1997; Pachauri, 2004; Lenzen et al., 2006), and Brazil (Lenzen et al., 2006), also find remarkable heterogeneity within those countries.

Apart from the lifestyle and consumption changes which are likely to raise CO_2 emissions as households become more affluent, for some developing countries, including Indonesia, the method of energy production (renewable energy sources) as well as green infrastructures and technology (including energy subsidy regimes) may also play a role in widening the emission disparities across household groups. The differences in carbon footprint between household groups in developing countries even tend to be more obvious than in richer countries, as Pachauri (2004) found in the Indian case. Taking fuel subsidies as an example for the Indonesian case, the inappropriate subsidy allocation allows for increasing households' incomes (ability to consume) to easily translate (both directly and indirectly) into consuming high carbon intensive expenditure items provided by the subsidies. The study of emission and income inequality within household groups and the emission inequality decomposition based on expenditure/emission source is also fruitful. The main idea is to capture how much the level and distribution of household affluence and the consumption of emission intensive items affect overall emission inequality.

Last but not least, the above household level analysis should be reconciled with the historical macro perspective of how the income-emissions relationships were developed. Apart from the comparison, one of central ideas deals with how the uni-direction causality assumption does not satisfy the evidence, rather it is necessary to look at the Environmental Kuznets Curve (EKC) hypothesis in examining the growth-emissions relationship (e.g. Coondoo and Dinda, 2002; Dinda and Coondoo, 2006; Soytas et al., 2007; Zhang and Cheng, 2009; Tiwari, 2011). Among the main debates in this discourse is that the uni-directional causality assumption could be over-simplistic, given the fact that emissions may affect both consumers' wellbeing as well as income creation leading to further consumption and output. Another point of interest is that the conventional assumption does not distinctively highlight the dynamic process of change, which is also essential in the context of growth-emissions relationships. Hence, it is valuable to employ causality tests to determine the relationship direction between income and emissions using two or more series of variables. For the policy perspective, understanding this causality will allow us to know whether efforts to reduce emissions can further impede economic growth.

Addressing those issues will allow us to identify the determinants, distribution, and (direction of) causality in the growth-emission relationship, which may have great relevance to Indonesian and global debates on reducing the carbon intensity of development paths, both for the methodological and policy perspective. From the analytical perspective, this research could allow us to understand the factors, contributors to, and distribution of emissions from the in-depth micro level analysis as well as contribute to further research on green growth. From a policy perspective, it could allow us to examine, monitor, and formulate appropriate low-carbon development policy interventions.

As briefly mentioned, this thesis consists of three chapters that cover research on the determinants of the rising household carbon footprint, patterns and sources of inequality in the micro level analysis, and a macro level analysis of the direction of causality (mainly) between economic growth and emissions.

Chapter 1, titled **Affluence and emission trade-offs: Evidence from the Indonesian household carbon footprint,** analyzes the pattern and the determinants of the growing household carbon footprint in Indonesia. To measure the household emissions, it combines the national input-output GTAP's emission database to generate sectoral CO_2 emission intensities and matched these intensities with two waves of national expenditure surveys from 2005 and 2009. We then use this household CO_2 emissions level information for investigating the drivers of the rise in emissions from the micro perspective. Comparing CO_2 intensities, the results show that the 'fuel-light' and transportation sectors are the most intensive emitters in Indonesia. We also found a significant difference of household carbon emissions when comparing between affluence level, region, and education. The regression analysis suggests that income is the main determinant of the household carbon footprint. Although other household characteristics determine the variation in emissions, it is shown that varying affluence levels differ significantly in terms of their carbon footprint. The decomposition analysis confirms that changes in emissions are primarily due to the income effect. The analysis of expenditure elasticities suggests that the rise in household emissions is mainly caused by a general volume increase in overall household consumption, and not by shifting the share of expenditure amongst the consumption baskets.

Chapter 2, titled **Inequality in emissions: evidence from Indonesian households,** using the same generated database as **Chapter 1**, investigates the distribution in per capita CO_2 emissions by employing various measures of inequality and then comparing the differences between the emission and expenditure inequality indices. It also decomposes emission inequality based on household affluence level, socio-demographic characteristics as well as sources of emissions to assess the patterns and drivers of inequality. First, disaggregating emission inequality into any particular within group inequality based on different household characteristics assumes that different characteristics would have different within-inequality measures in emissions. Second, decomposing inequality by emission sources aims to measure the contribution of emission shares and to study the marginal effects of changes in different emission sources on the change in overall emission inequality. Results from the first case show that as per capita expenditure increases, within inequality in emissions tends to decline until the middle quintiles where it then increases in expenditure level and worsens emission inequality until the richest households. Results from the decomposition of inequality suggest that energy-transportation is the dominant contributor to overall emission inequality.

Chapter 3, titled **Examining causality between economic development, energy consumption, and emissions in Indonesia,** is a macro level and multivariate time series analysis that investigates the causality nexus between emissions, energy use and economic performance along with urbanization and capital formation (investment activity). It employs various time-series econometric techniques ranging from single equation ECM, VECM, and DOLS to investigating the presence and direction of long-run causality between the three variables. When adding urbanization and capital formation, we employ a modified (augmented) VAR as suggested by Toda and Yamamoto (1995) given the different order of integrations among variables. Various cointegration analyses reveal consistent findings suggesting long-run causality amongst variables. We also find that the direction of long-run Granger-causality is running from output and energy consumption to emission but not in the opposite direction from emission to output in the long-run, suggesting the possibility of reducing emissions without impeding growth. In the short-run, the Toda-Yamamoto approach generally suggests similar indication of uni-directional Granger causality running from output to emission but not in the opposite direction, indicating that clean growth is also possible in the short-run. The empirical evidence of a uni-directional causality from urbanization and capital formation to energy uses but not from urbanization to emission indicates that urbanization and capital formation will increase energy use but could be carbon-neutral if the country in question has a sustainable urban management and energy system. Results also show that the greater variations in emissions in the longer period are mainly due to Indonesia’s rising economic performance.

Each essay contributes to the literature on green growth and provides a basis for substantial investigations using Indonesia as an example. The essays might have a significant relevance not only to Indonesia itself but also to global debates on how to de-carbonize development paths and how to make development compatible with environmental sustainability.

For future research, these studies recommend using different approaches, as well as utilizing other emission sources (production and land use changes). Incorporating other possible relevant (or country/regional specific) variables as control variables could also be fruitful on how to analyze the link between economic development and emission both from a micro and macro level analysis.

Chapter 1 : Affluence and emission trade-offs: evidence from Indonesian household carbon footprint

Affluence and emission trade-offs: evidence from Indonesian household carbon footprint

Abstract

This study estimates the Indonesian household emissions that are attributed from their expenditures in 2005 and 2009 to analyze the pattern, distribution, and drivers of the household carbon footprint. Employing Input Output-Emission-Expenditure analysis, we found that fuel-light and transportation are the two most intensive emitting expenditure categories in Indonesia, and found a significant difference in household carbon emissions between different affluence levels, regions, and education levels. We also found that the income level is the main determinant of household emissions. The decomposition analysis confirms that changes in emissions are mainly due to the income effect between the two periods, while expenditure elasticities analysis suggests that the rise in household emissions is mainly caused by the overall volume rise in total household expenditure, and not by shifting consumption shares amongst consumption baskets.

Keywords: carbon footprint, household, Indonesia

1.1 Introduction

Climate change is one of the pressing challenges of the world, including Indonesia. In this emerging economy, the middle-income group has been growing and consuming more goods and services, causing households to directly and indirectly contribute to the rising emissions. However, quick glances at the literature on household carbon footprint show that most analyses were conducted in the developed countries compared to developing countries (e.g. Kenny and Gray (2009), Girod and de Haan (2010), Parikh et al. (1997), Murthy et al. (1997)). With that in regard, this study will fill in that gap by estimating the average household carbon footprint of Indonesia as one of the emerging economies.

In order to calculate the environmental consequences of household activities, Lenzen (1998a) analyses energy and green house gas (GHG) in the case of Australian households. It was found that the direct expenditure of fuels and electricity represent of about 30% (17%) of the overall energy expenditure (the overall GHG expenditure), the remainder of which was indirectly spent on non-energy commodities. Bin and Dowlatabadi (2005), using the US Consumer Lifecycle Approach to energy use and associated CO_2 emissions, estimates that more than 80% of the energy used and the CO_2 emitted in the US are a consequence of consumer demands and their supporting activities. Kenny and Gray (2009) show that the total CO_2 emissions of Irish households are associated with home energy usage (42%), transportation (35%), air travel and other fuel intensive leisure activities (21%). Moreover, using the Swiss household expenditure database, Girod and de Haan (2010) found that the most important consumption categories are living, transportation, and foods, which together account for almost 70% of overall GHG emissions.

Apart from just emissions measurement, there are several studies that investigate the determinants of the household carbon footprint using various methods. Taking an example of a cross-country perspective, Lenzen et al. (2006) focused on the investigation of the Environmental Kuznets Curve (EKC) hypothesis, which proposes an inverted U-shaped relationship between per capita output and environmental degradation, at the household level. However, their findings do not support the EKC hypothesis. They argue that household energy use monotonically rise due to rising consumption and show that no turning point is observed.

Household emission patterns may differ due to differences in household characteristics, including their incomes. Income portfolios and levels as well as the related patterns of consumption and production are considered as the important determinants. Findings show that income is the main driver of carbon footprints (Murthy et al., 1997, Parikh et al., 1997; Li and Wang, 2010). For instance, Parikh et al. (1997), for the Indian case analyzed expenditure patterns by income groups as well as what the CO_2 consequences were. Their approach is based on an input-output (IO) analysis, which uses an expenditure database examining the direct and indirect CO_2 emissions from household expenditure items. They found that carbon emissions were attributed to private consumption (of about 62%), direct household consumption (12%), and the remaining to indirect consumption of intermediates. It is also indicated that the rich have a more carbon-intensive lifestyle than the poor. Apart from income, numerous studies found that household characteristics also matter as driver of their emissions, such as household size, education, age of household head, and other demographic factors (e.g. Li and Wang, 2011, Wier et al., 2001). Additionally, another study from Pachauri and Spreng (2009) also suggest household energy requirements, increasing emission intensity in food and agricultural sectors are among other drivers.

This study attempts to answer the following issues. First, what are the characteristics of CO_2 emissions of households in Indonesia? How do they differ in terms of affluence and other household characteristics? Second, what are the main determinants of the growing carbon footprint in a fast growing emerging country, and which consumption categories are the most carbon intensive? Third, how will carbon emissions develop over time when household incomes increase?

Our findings can be summarized as follows. We found that fuel-light and transportation expenditures are the two most carbon intensive items. This study also indicates the variations of household carbon footprint in terms of their affluence level as well as other household characteristics such as urbanity and educational attainment. Household income (proxied by expenditure) is found as the main driver of the household carbon footprint, which is confirmed by the decomposition of emission growth between 2005 and 2009 suggesting that rising emissions are mainly attributed to the income effect. The expenditure elasticity of emissions proposes that the surging increase in household carbon footprint is mainly due to the overall volume rise in expenditure, and not to the shifting consumption shares of the consumption basket.

1.2 Data and methodology

We use numerous databases including sectoral emissions from the Global Trade Analysis Project-Environmental Account (GTAP-E), the Indonesian Input Output (IO) table, and the Indonesian household expenditure survey (Susenas) from the 2005 and 2009 database. The GTAP-E includes CO_2 emissions from fossil fuels combustion (coal, oil, gas, petroleum products) and cement production, but does not include emissions from land use change, which is also important for the Indonesian case (PEACE, 2007). We combine the IO analysis with GTAP-E and Susenas to calculate the indirect and direct carbon emissions of households. This approach is appropriate to analyze the environmental impact with respect to different household characteristics (Kok et al., 2006). Expenditure amounts on consumption items in Susenas are multiplied with the corresponding value of the emission intensity. Each consumption item in the expenditure survey is categorized into a specific economic sector.

1.2.1 Measuring emission intensities and deriving the household carbon footprint

This study only focuses on CO_2 emissions since it represents the largest share of GHG emissions (UNFCCC, 2010)[2]. To estimate an Indonesian household's

[2] Also, the emissions associated with land use changes cannot easily be attributed to households particularly since much of the land use change is associated with cash crop production for exports (such as palm oil, rubber, or cocoa).

carbon footprint, we follow Lenzen (1998)'s approach, which computed carbon embedded in an Australian household's final consumption. We basically trace the CO_2 emitted by the final consumption element back to its intermediates and factor both the direct and indirect emissions that occur from household expenditure. Applying the expenditure approach, **Figure 1.1** shows how CO_2 intensities of goods and services in a given economy can be traced using IO analysis.[3]

In the first step, CO_2 intensities of each Indonesian IO sector (in the local currency unit, Rp) were estimated. We assume the Single Region Model, which suggests that emissions of both imported and domestic products are not estimated differently assuming that they are produced by the same technology. One can argue that products in the developed world are produced more efficiently and may have lower emission intensities. On the other hand, imports require transport that might increase emissions. However such issues are beyond the scope of this study[4]. In this study, the CO_2 emission intensities were derived using the Leontif inverse of the IO table multiplied by the carbon intensities derived from GTAP.

---

[3] There are three available methods in accounting the environmental load of GHG emissions released by household consumption which are primarily from IO analysis, including the basic approach, the expenditure approach and the process approach (Kok et al., 2006). First, 'the basic approach' is a pure top-down approach as it simply utilizes national accounts to calculate energy requirements (emissions). One particular drawback of this approach is that it does not consider the possibility that the price of energy may vary between sectors. Second, 'the expenditure approach' combines IO-energy/emission account with the expenditure database. Here, the consumption database is more disaggregated as it is taken from household expenditure surveys instead of the consumption database from the IO table. Third, the 'process or hybrid approach' combines the IO-energy/emission account with process analysis, which proposes that lifecycle process of any product (consumption item) is denoted in physical terms (e.g. energy use per unit materials or energy use per transport distance, etc.). Although it could be more accurate as it avoids truncation errors, this process is more time consuming. In this study, the expenditure approach is utilized since we will use a national household expenditure database.

[4] There is also another version of input-output table called World IO Data (http://www.wiod.org) that has a set of synchronized use and supply tables, along with international trade database. However the dataset are quite aggregated with just only consists 38 industrial sectors as well as final household consumption sector. This study does not employ it partly to allow more flexibility to construct emission intensities. In this regard, the fact that the Indonesian IO table has 175 sectors allows us to have the more disaggregated sectoral emission intensities to be matched with consumption items in Susenas.

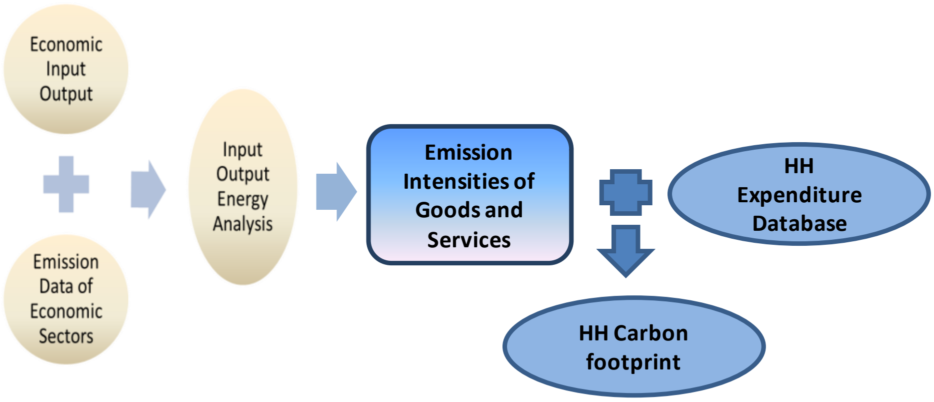

Figure 1.1 Emission Analysis - Expenditure Approach

Source: modified from Kok et al. (2006).

In the second step, the CO_2 emission intensities of each economic sector were matched to their household expenditure category. We refer to the Susenas questionnaire and GTAP sector classification (Huff et al., 2000) to match these sectors. Consumption expenditures from Susenas are then multiplied to the derived CO_2 emission intensity, and then by summing them up we get the household carbon footprint[5].

As the Single Region Model assumes that the domestic energy and environmental technologies used in production are the same as abroad, we just calculate emissions from direct and indirect CO_2 emissions from final demand of industrial sectors. First, the direct CO_2 emission intensities from final demand, CO_2^{fd}, are expressed by the following:

$$CO_2^{fd} = c'E^{fd}y \tag{1.1}$$

where c', E^{fd}, and y represent the inverse of the emissions coefficient vector, the matrix of energy use, and the vector of final demand.

[5] The overview of data matching scheme of the IO sectors with the household expenditure categories via the GTAP energy intensity is outlined as follows. There are 175 economic sectors in Indonesia, which were mapped using the GTAP sectors and aggregated into 57 sectors (Huff et al., 2010). The data on household expenditure is rather disaggregated, consisting of around 340 expenditure categories.

Second, the indirect emissions, CO_2^{ind}, can be divided into three sources of emissions: (a) from domestic production of domestic final demand; (b) from imported intermediates; (c) from imported products for domestic final demand (excluding exports). Then, the sectoral CO_2 emission intensity can be estimated by multiplying each sector's final demand, y, the transposed emissions coefficients, c′, the matrix of industrial energy use, E^{ind}, and with the domestic Leontief inverse $(I-A)^{-1}$, as follows:

$$CO_2^{ind} = c'E^{ind}\left[(I-A)^{-1}y_{\neq exp} + ((I-A_{tot})^{-1} - (I-A)^{-1})y_{\neq exp} + (I-A_{tot})^{-1}y_{imp_{\neq exp}}\right] \quad (1.2)$$

where $A_{tot}=A+A_{imp}$, and $y_{tot}=y+y_{imp}$.

$y_{\neq exp}$ and I represent domestic final demand and identity matrix, while A indicates the matrix of technical coefficients that reflects the intermediates' contribution to one unit of final output.

Hence the direct and indirect CO_2 emission intensities can be calculated as follows:

$$CO_2 = CO_2^{fd} + CO_2^{ind} \quad (1.3)$$

$$CO_2 = c'\left\{E^{fd}y + E^{ind}\left[(I-A)^{-1}y_{\neq exp} + ((I-A_{tot})^{-1} - (I-A)^{-1})y_{\neq exp} + (I-A_{tot})^{-1}y_{imp\neq exp}\right]\right\} \quad (1.4)$$

Finally, the above carbon intensities (in kg CO_2/Rp) of each sector are multiplied with the household consumption recorded from Susenas (in Rp) for the respective category and then the products from all categories are summed up for each household. The carbon footprint CO_2^{hh} (in kg of CO_2) for each household is calculated by the following equation:

$$CO_2{}^{hh}{}_i = \sum_i^j \left(CO_{2_j} * Exp_{ij}\right) \quad (1.5)$$

where i and j denote household and expenditure item, respectively.

1.2.2 Drivers of the household carbon footprint

This section will investigate the emission implications, household characteristics and their consumption decisions. The linkage between the expenditure choices and the carbon footprints will be determined from the carbon intensity of particular items consumed in Indonesia. From the list of consumption items in Susenas, we will analyze the determinants of particular carbon-intensive consumption preference, including choices related to household operations such as fuel-light and transportation. The empirical analysis is postulated as follows.

$$\ln CO_{2\ \ i}^{hh} = \alpha + \beta_1 \ln EXP_i + \beta_2 X_i + \varepsilon_i \qquad (1.6)$$

The ordinary least square (OLS) method will first be employed to regress the log of household carbon footprint CO_2^{hh} on log of household expenditure, lnEXP, as a proxy for income, and a range of control variables X, including *region, household members, education, gender and age of household head.* To apprehend the nonlinearity effect on household emissions, a squared term for the expenditure, household size, and age will be incorporated as well.

As we derived CO_2 emissions from expenditure, one can argue that our expenditure variable could have high correlation with CO_2 computed emissions by construction. Dealing with this issue, we can proxy expenditure with expenditure quintile dummies[6], Q, then regression (1.6) could be split into two stages, as follows:

$$\ln CO_{2\ \ i}^{hh} = \alpha + \beta_q \sum_{q=1}^{5} Q_{qi} + \varepsilon_i \qquad (1.7)$$

and

$$\varepsilon_i = \alpha + \beta_1 X_i + \gamma_i \qquad (1.8)$$

where ε_i is the residual from the regression (1.7).

In other words, we regress emissions on the expenditure quintiles in (1.7) then regressing its residuals on other control variables (i.e. household characteristics

[6] Household affluence quintiles are constructed based on per capita expenditure.

excluding expenditure) in (1.8). This approach could reveal the true effect of characteristics of households on their emissions. Of particular objectives are to understand the drivers of the heterogeneity of the household emissions, and to identify possible policy implications to reduce emissions without compromising the well-being of households.

In addition, we will also apply quantile regressions in the analysis to account for the possibility that the household emissions distribution is highly skewed. In this case, compare with the OLS regression, the quantile regression could be more robust to outliers partly given the assumption that it does not assume that the variables are normally distributed. Another reason is that we will be allowed to analysis the effect of the right-hand side variables on the location and the scale parameters in the model. Technically, while OLS minimizes the residuals sum of squared, $\sum e_i^2$, the quantile regression minimizes the sum that gives penalties of about $(1-q)|ei|$ for over-prediction and of about $q|ei|$ for underprediction (Cameron and Trivedi, 2010).

Our analysis assumes that the impact of income and control variables for lower carbon emitting households is different from the households with a high carbon footprint. With this in regard, the quintile regression estimates the effect of a one-unit expenditure change on a particular quintile q of our dependent variable (household emissions). Technically, by linear programming, the q_{th} quintile regression minimizes over βq:

$$Q(\beta_q) = \sum_{i:y \geq x\prime\beta}^{N} q\left|y_i - x'_\beta\right| + \sum_{i:y \leq x\prime\beta}^{N} (1-q)\left|y_i - x'_\beta\right|. \qquad (1.9)$$

We can choose q (0 < q < 1) that uniquely estimates the value of β. Suppose choosing q=0.9, instead of q=0.1, indicates that more weight is to be assigned on the estimation for observations with $y_i \geq x'_i\beta_q$.

1.2.3 Decomposing the changes in the carbon footprint

Another important issue in comparing household emission changes from two periods is determining what the drivers are of these changes. If one considers emissions to be an output of the process, we could argue that it is a product of driving forces. One approach is given by Kaya (1990) who provides an intuitive approach to the interpretation of the historical trend of CO_2 emissions. This method, which is widely known as the Kaya Identity, suggests that the total emissions level can be found by calculating the changes in four inputs, i.e. population size, per capita income, energy use per unit of GDP, and CO_2 emissions per unit of energy used. Using this decomposition technique, we can then directly link CO_2 emission levels to the population effect, and level of economic affluence (measured by per capita expenditure), carbon emission intensity (per energy use) and energy intensity (per output)[7]. Finally we can find the main driving forces of changes in emission levels in the periods observed.

In macro analysis, the Kaya Identity suggests that CO_2 emission levels are the product of: (i) the carbon intensity of the energy supply, (ii) the energy intensity of the economic activity, (iii) the economic per capita output, and population. However, since we do not have the data for energy intensities, in our analysis the Kaya Identity is modified as follows:

$$CO2_i = HHsize_i * \frac{EXP_i}{HHSize_i} * \frac{CO2_i}{EXP_i} \qquad (1.10)$$

where the household CO_2 emissions level is a function of household size, HHsize, per capita expenditure, EXP/HHsize, and emission intensity, CO_2/EXP.

In other words, we set up an emission equation to calculate and decompose the growth of CO_2 emissions into the population effect, per capita expenditure effect (Rp/capita), and carbon intensity effects (CO_2/Rp), and express the result as a percentage of the base line CO_2 emissions level. Following Ang (2005), our decomposition will be employed using the Logarithmic Mean Divisia Index

[7] In terms of policy, the CO_2 intensity of output generally focuses on the promotion of low (or zero) carbon sources of energy.

(LMDI), which has several advantages apart from it being consistent in aggregation, it also gives a perfect decomposition as the results will not contain unexplained residuals. The LMDI approach is modified (1.10) to construct the following formula:

$$\Delta CO2_i = C^T - C^0 = \Delta CO2_{HHsize} + \Delta CO2_{\frac{EXP}{HHsize}} + \Delta CO2_{\frac{CO2}{EXP}} \qquad (1.11)$$

where

$$\Delta CO2_{HHsize} = \sum_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln\left(\frac{HHsize_i^T}{HHsize_i^0}\right)$$

$$\Delta CO2_{EXP/HHSize} = \sum_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln\left(\frac{(\frac{EXP}{HHsize})_i^T}{(\frac{EXP}{HHsize})_i^0}\right)$$

$$\Delta CO2_{CO2/EXP} = \sum_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln\left(\frac{(\frac{CO2}{EXP})_i^T}{(\frac{CO2}{EXP})_i^0}\right)$$

where $\Delta CO2_{HHsize}$, $\Delta CO2_{EXP/HHSize}$, and $\Delta CO2_{CO2/EXP}$ represent changes in CO_2 emissions because of population, expenditure, and the carbon intensity effect, respectively.

1.2.4 Expenditure elasticites of emission

The demand analysis is generally utilized to measure the change in demand for any particular good due to the change in income. This demand function is originated from the consumers' utility maximization equation, which depends on the prices of goods and individuals' income (Deaton and Muellbauer, 1980). We modify this demand theory by replacing the demand for goods with CO_2 emissions given the consumption of the respective goods. By applying this, we can analyze the responsiveness of CO_2 emissions of any household consumption category to a change in household income, which is proxied by household expenditure.

As suggested by the conventional Engel curves, we should include price as one of the independent variables. However, since there is no price data in Susenas, we will estimate the expenditure elasticites of emission without using prices, meaning that the response of CO_2 emissions will only be dependent on the expenditure amount and socio-economic level of the households. We will estimate the following model:

$$sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij} \quad (1.12)$$

where $sCO2_{ij}$ represents the share of CO_2 emissions of j-th consumption category to total CO_2 emissions by the i-th household, $\ln EXP_i$ is the natural logarithm of household i expenditure. X_i represents a vector of household characteristics and ε_{ij} is error terms[8].

1.3 Results and discussions

1.3.1 Descriptive analysis

Susenas 2005 and 2009 consist of a large data on household expenditures of more than 257,000 and 291,753 Indonesian households, respectively[9]. **Figure 1.2** provides an overview on the allocation of household expenditure in 2005 and 2009. In general expenditure increased by 72.27% (nominal) and 24.83% (deflated). We also indicate that the large differences of the expenditure share between households living in urban and rural areas. Compared to urban households, households in rural areas have unsurprisingly a larger expenditure share on foods and a much smaller share on services, recreations, rents and taxes. In general, comparing two surveys we find that food expenditure declined as expected. Moreover, the shares of telecommunication, transportation, health,

[8] One might argue that there is a potential endogeneity problem due to the fact that our CO_2 emissions are derived from expenditure. We could apply the instrumental variables estimation using (for instance) the households‘ asset index as an instrument for household expenditure. However, due to data limitation this is beyond of our scope of study.

[9] For both surveys, the consumption is disaggregated to around 300 consumption items. In 2005 (and 2009), about 62.57% (64.64%) of households were located in rural areas. About 12.12% (13.61%) of households were headed by a woman. The households consisted of about 4.08 (3.96) members which 81.36% (83.30%) of them had a maximum 5 household members. On average, household heads' years of schooling was 6.1 (6.49) years. The annual household expenditure equaled to Rp 11.90 million (Rp 20.50 million). Urban households spent about Rp 16.50 million/year (Rp 27.70 million/year) compare to Rp 9.13 million/year (Rp 16.60 million/year) in urban area.

education, and taxes have been increasing both in the rural and urban areas. The share of beverage goods has been increasing in urban areas as oppose to in rural areas where it has been decreasing. In contrast, the share of income that has been spent on housing and durable expenditures has been increasing for households in rural areas as oppose to household in urban areas where it has indeed been decreasing.

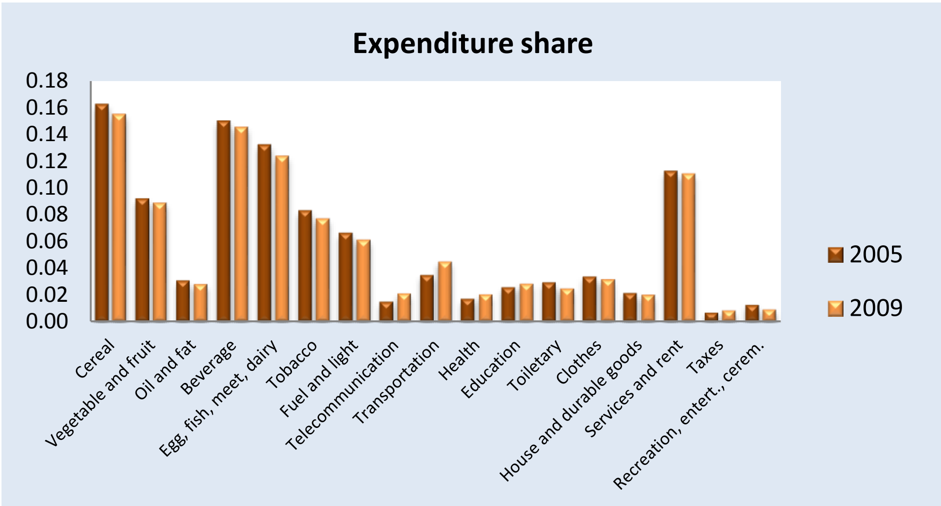

Figure 1.2 Expenditure share per consumption category
Source: Author‘s computation based on Susenas (2005 and 2009)

Before we begin the computation of the carbon footprint, it is very important to point out the coverage of Susenas compared to the private consumption database based on the macro perspective. If we compare the two databases, we indicate that the expenditure computation from Susenas will be significantly less than the national account (this underestimation measure can be also found in other studies e.g. Yusuf, 2006; Mishra, 2009). The deviation between the two measures is partly because of the computations in the national accounts that were constructed from the supply side’s economy while Susenas expenditures were taken from representative sample surveys. In addition, national accounts also include the consumption by non-households.

Table 1.1 portrays the calculations of household expenditure using the national account and Susenas. Given the difference in the measurements from Susenas, which accounted for around 42-49% of the national account measurements, we scaled up the computation of household emissions by dividing household consumption by the percentage of Susenas to total expenditure based on national accounts when we computed the carbon emissions (Mishra, 2009). However, the fact that the aggregate from Susenas expenditures falls short from the national account (including in our calculation with the scaled up household emissions) would not imply anything about the distribution of the expenditures across households hence that we assume that the discrepancy between expenditure items are more or less at the same amount across households.

Table 1.1 Estimate private consumption: Susenas vs. National Account (Rp)

Year	Susenas	National Accounts	Percentage of Susenas to National Accounts
1996	210,507	460,297	45.73
1999	499,435	1,051,483	47.50
2002	760,003	1,557,099	48.81
2005	983,032	2,167,979	45.34
2009	1,695,220	4,031,541	42.05

Source: Author's computation based on the monthly household expenditure (Susenas, BPS) and the monthly private (household) consumption (WDI, World Bank), various series.

In the next step, by incorporating the Indonesia input-output table and GTAP's energy use matrix, we extract the CO_2 emission intensity level of the 175 economic sectors[10]. The CO_2 emission intensity is measured in terms of kilotons per million rupiah (or gram CO_2/Rp), which captures the amount of CO_2 released from the production of goods and services in the Indonesian economy. **Table 1.2** presents the 10 most and least CO_2 intensive sectors. It can be seen that sectors that emit CO_2 intensively including: electricity, gas, cement, non-metallic minerals, glasses and their products, ceramics and clay products. In addition to those electric and manufacturing sectors, all transportation services are also very carbon intensive.

In contrast, the least CO_2 intensive sectors in Indonesia are associated with agricultural crops sectors, including fiber crops, grains, sweet potato, fruits, and

[10] We follow Huff et al. (2000) using concordance matrix between GTAP's emission data and all IO sectors.

beans. These figures reflect the fact that these products do not use much energy in production compared to manufacturing and transportation sectors[11]. In addition to the agricultural sectors, service sectors also have a lower CO_2 intensity, which include such industries as film and distribution services, building and land rent. In general, agricultural related activities emit less CO_2 compared to manufacturing sectors.

Table 1.2 CO_2 intensity of economic sectors: top 10 and bottom 10

Number on list	Sectors	gram CO_2/Rp
Top 10		
1	Electricity and gas	1.04962
2	Cement	0.44619
3	Other items of non-metallic materials	0.39552
4	Glass and glass products	0.38542
5	Ceramics and building materials from clay	0.37331
6	Ceramics and items made of clay	0.36825
7	Air transport services	0.20421
8	Railway services	0.17156
9	Marine transportation services	0.16338
10	River and lake transport services	0.16153
Bottom 10		
10	Other nuts	0.00380
9	Other animal products	0.00374
8	Soybean	0.00287
7	Cassava	0.00280
6	Vegetables	0.00266
5	Beans	0.00218
4	Fruits	0.00185
3	Sweet potato	0.00102
2	Grains and other foodstuffs	0.00078
1	Fiber crops	0.00031

Source: Author's computation based on IO 2005 and GTAP-E 2005. Note: For more detail sectors, see **Appendix Table A.1**.

The derived CO_2 emission intensities were then matched with the consumption categories in the Susenas 2005 and 2009. There are around 340 consumption items in the expenditure survey and this was aggregated to represent the major household expenditures. **Figure 1.3** shows the average CO_2 emissions (in kg) from major expenditure categories. It is observed that CO_2 emissions vary based on the consumption item. The lowest CO_2 emissions were observed from the consumption of cereals, medical services, telecommunication services and recreation. On the other hand, the highest CO_2 emissions were observed from the consumption of transportation as well as fuel and light.

[11] But note that emissions from land use change are not considered here.

From 2005 to 2009, emissions from fuel-light expenditures accounted for 1,688 kg to 2,768 kg, growing about 19% (real). Meanwhile, emissions from transportation, the second highest emission source, account for 183 kg to 401 kg (real growth of about 59%). Emissions from food related expenditures grew (real) around 30%. We also indicate that health, transportation, tax and redistribution are among the fastest growing emission sources (around 50%).

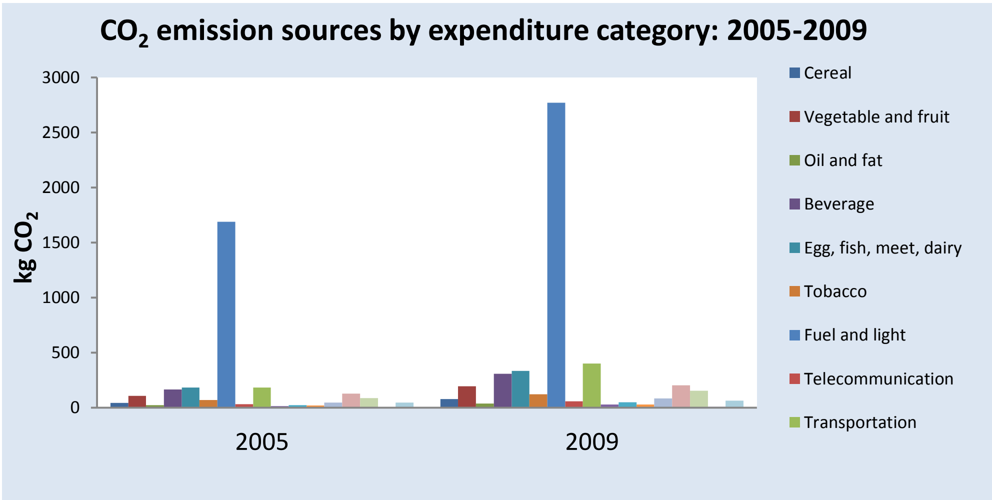

Figure 1.3 Emissions in Expenditure Subgroup (2005 and 2009)

Source: Author's computation based on Susenas 2005-2009, IO 2005, GTAP-E 2005

The disaggregation of the CO_2 emissions into regions and income levels is presented in **Figure 1.4**. It is found the large differences in CO_2 emissions with respect to household affluence level. Moreover, we found a variation in the carbon emission levels of households of different educational attainments. In more detail, the household emissions from the 5th affluence quintile is 4.6 times higher than the household emissions from the lowest quintile, and still about 2.6 times as high as the level from households in the third quintile (middle income group)[12].

[12] In per capita emission terms, the richest quintile households emit about 6.9 times as the lowest quintile, and about 3.1 times as the 3rd quintile (**Appendix Table A.4**).

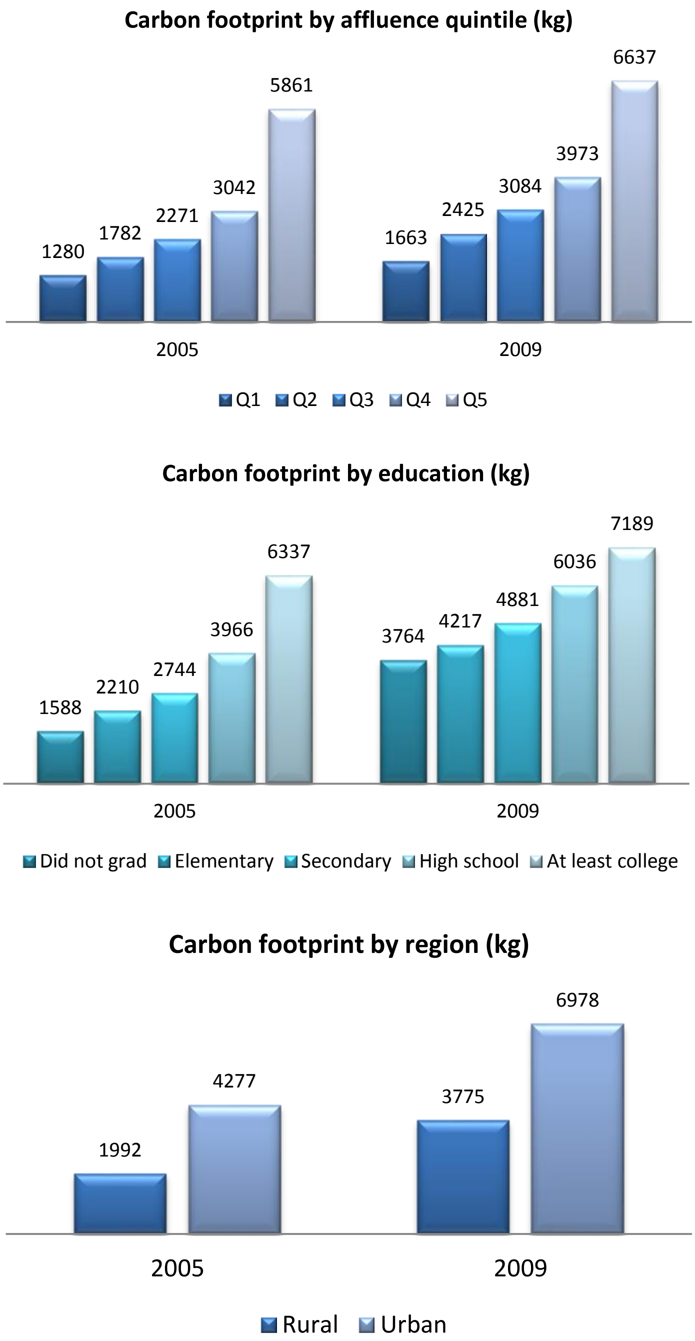

Figure 1.4 Carbon footprint by household affluence quintile, education attainment, and region (2005 and 2009)

Source: Author's computation based on Susenas 2005-2009, IO 2005, GTAP-E 2005

Looking at change from 2005 to 2009, we indicate that overall emissions grew on average from 2.8 tons in 2005 to 3.5 tons in 2009 (expenditure deflated, 2005 =

100)[13]. In 2005 households in the poorest quintile emitted of about 1.3 tons of carbon emissions (to 1.6 tons in 2009) while emissions from the richest households were about 5.8 tons (6.6 tons). The pattern of emissions with respect to educational attainment also has a similar story as the affluence quintile given that education could mirror income level, although the differences between are not as not as steep as affluence level. Last, based on location, both surveys indicated that the urban household emissions are about twice the amount of rural households. Rural households emit almost 2 tons in 2005 (3.8 tons in 2009), while urban households emit of about 4.3 tons (7 tons).

Comparing emission shares to expenditure shares (**Figure 1.5**), we indicate that the emission shares are somewhat lower than expenditure shares from the first to the third quintile. In contrast, CO_2 emission shares of households in the top two quintiles are higher than their emission shares. This picture indicates that affluent households in the top two quintiles have a more carbon intensive lifestyle than households in the first three quintiles. It also means that CO_2 emissions inequality is slightly larger than the expenditure inequality (See **Chapter 2** for more detailed analysis).

[13] On per capita term, the average per capita CO_2 emissions were about 0.70 tons (2005) and 0.90 tons (2009). Estimated per capita CO_2 emissions in Indonesia from IEA (2013) were about 1.48 tons (2005) and 1.61 tons (2009). Our calculation is relatively lower than the estimation provided by IEA (2013) partly because our focus is only on household consumption (around 340 items in Susenas) and not on all economic activities.

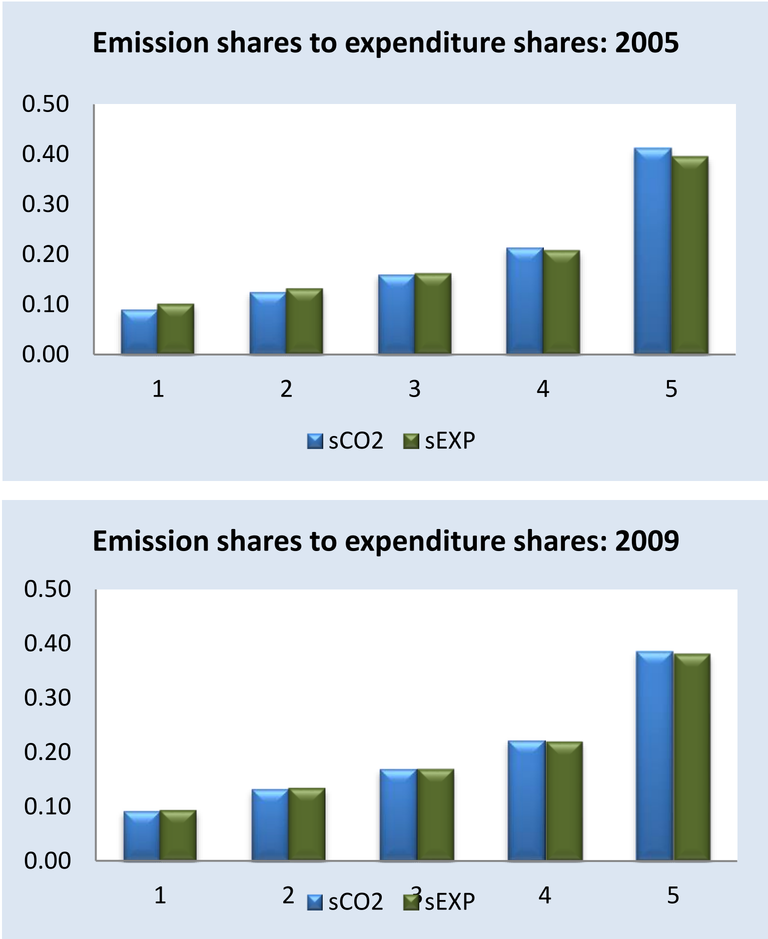

Figure 1.5 Emission shares to expenditure shares by quintile (2005 and 2009)

Source: Author's computation based on Susenas 2005-2009, IO 2005, GTAP-E 2005

1.3.2 Drivers of household carbon footprint

The regression analysis of the determinants of household emissions is presented in **Table 1.3**. Various model specifications were employed to analyze the drivers of the variation in CO_2 emissions. In Regression I and II, we regress the log of household emissions with log household expenditure and other control variables, including dummies for different household characteristics. In the third regression, we regress the carbon footprint with only income quintiles. Regression IV, V and VI use the residuals from the Regression III as the dependent variable and household characteristics as control variables.

Table 1.3 The determinants of household carbon footprint, 2005-2009

	I	II	III	IV Dep var: Residuals III	VI Dep var: Residuals III	VI Dep var: Residuals III
lnexp	1.045***	1.029***				
lnexp^2	-0.002***	-0.001**				
Expenditure quintile						
2			0.351***			
3			0.579***			
4			0.825***			
5			1.251***			
hhsize	0.004***	0.036***		0.345***	0.494***	
hhsizesq	-0.001***	-0.008***		-0.019***	-0.050***	
hhsizecub		4.12E-04***			0.002***	
age	0.005***	0.013***		0.008***	0.011***	
agesq	-3.47E-05***	-1.98E-04***		-5.77E-05***	-1.19E-04***	
agecub		1.05E-06***			4.12E-07***	
HH size (#)						
2						0.424***
3						0.700***
4						0.903***
5						1.054***
6						1.176***
7+						1.325***
HH-head age						
25-44						0.081***
44-64						0.133***
65+						0.148***
Urbanity	0.108***	0.109***		0.240***	0.240***	0.242***
Education						
Elementary	0.020***	0.020***		0.076***	0.073***	0.069***
Secondary	0.039***	0.039***		0.125***	0.121***	0.115***
High school	0.068***	0.067***		0.200***	0.196***	0.191***
At least college	0.068***	0.068***		0.298***	0.299***	0.298***
Married HH-head	0.044***	0.037***		0.055***	0.027***	0.010***
Female HH-head	0.053***	0.052***		0.036***	0.031***	0.030***
Survey year 2009	0.067***	0.067***	0.625***	0.019***	0.018***	0.019***
_cons	-9.139***	-9.158***	6.833***	-1.512***	-1.730***	-1.145***
Number of observations	549,659	549,659	549,659	549,659	549,659	549,659
R^2	0.828	0.828	0.505	0.417	0.422	0.420
Including province dummy	Yes	Yes	Yes	Yes	Yes	Yes

Source: Author's estimation. Note: In Regression I, II and III, the dependent variable is log of total household carbon footprint, while in Regression IV-VI, the dependent variable is residual from Regression III. * (**, ***) indicates significance at the ten (five, one) percent level.

From Regressions I and II, we find that all independent variables are statistically significant. In addition, expenditure has a nonlinear effect on the CO_2 emissions. This implies an inverted U-shaped pattern of the carbon footprint with respect to expenditure[14]. In other words, rising affluence leads to increasing CO_2 emissions, ceteris paribus, and turns to decline as household expenditure rises even farther. Furthermore, we also indicate that the larger the number of household members, the greater the age (of the household head), if the gender (of household head) was female, and if the region was an urban area, the more carbon was emitted. Moreover, the number of household members and age of the household head both have non-linear relationships with the carbon footprint. It is noticeable that survey

[14] The negative expenditure squared coefficient indicates an emissions decline after reaching a turning point. However, the calculated turning point is far beyond our sample, indicating there is still a progressively rising emissions with respect to rising affluence.

year dummy is still positive even though we already controlled for expenditure, indicating that apart from being affluence-driven, there has been other things that have pushed up emissions by 6.7% between two surveys controlling for other things.

In the Regression III, we regress household emissions with household affluence quintiles, which divide household into 5 equal parts by sorting the per capita expenditure out from lowest to highest. It is observed that households in the higher quintiles have a larger carbon footprint and the coefficients are statistically significant. Moving from the first to the second quintile increases the household emissions by 35% whereas moving from the first to the richest quintile increases household emissions by 125%.

We then utilize the residual from the Regression III as the dependent variable of Regression IV, V, and VI, and household characteristics as control variables. The idea is to drop the income interventions which would then reveal the effect of certain household characteristics on their emissions without compromising their well-beings. As indicated, it is not surprising that the coefficients of household characteristics (the control variables) are statistically significant and consistent with the previous specifications. In other words, household characteristics are among determinants of the household carbon footprint. Moreover, we include dummies for all of the provinces in all regressions. The estimated coefficients for all control variables with and without dummies do not change significantly. However, from the province fixed effects regression we indicate that the emissions of provinces in Java and Bali, Kalimantan Timur, Kalimantan Selatan, Sulawesi Selatan and Sulawesi Tenggara, were higher than the amount in other provinces[15].

Table 1.4 presents quantile regression estimates using q=0.1; 0.25; 0.50; 0.75; and 0.90. Apart from its advantages that quantile regression fits prediction over quintile that avoid sensitivity of the outliers with can dominate the regression if we just employ OLS, it will also estimate an equation expressing a quintile of

[15] The detailed estimations of the dummy coefficients are presented in **Appendix Table A.9**.

conditional distribution as well as allow as to investigate the effects of the independent variables to differ over quintiles. In our case, this might be sensible since that household affluence effect might have different effect for any different household groups.

Table 1.4 Quantile regression estimates[16]

	OLS		Q(0.1)		Q(0.25)		Q(0.50)		Q(0.75)		Q(0.90)	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
lnexp	1.045***	0.024	1.967***	0.039	1.525***	0.030	0.908***	0.025	0.358***	0.025	0.180***	0.033
lnexpsq	-0.002***	0.001	-0.028***	0.001	-0.016***	0.001	0.001*	0.001	0.017***	0.001	0.021***	0.001
hhsize	0.004***	0.001	0.067***	0.005	0.061***	0.003	0.051***	0.003	0.037***	0.002	0.025***	0.003
hhsizesq	-0.001***	0.000	-0.014***	0.001	-0.013***	0.001	-0.012***	0.000	-0.009***	0.000	-0.007***	0.001
hhsizecub			0.001***	0.000	0.001***	0.000	0.001***	0.000	4.78E-04	0.000	0.000***	0.000
age	0.005***	0.000	0.022***	0.001	0.022***	0.001	0.021***	0.001	0.017***	0.001	0.014***	0.001
agesq	-3.47E-05***	0.000	-3.35E-04***	0.000	-3.40E-04***	0.000	-3.22E-04***	0.000	-0.000***	0.000	-1.86E-04***	0.000
agecub			1.78E-06***	0.000	1.81E-06***	0.000	1.70E-06***	0.000	1.27E-06***	0.000	8.63E-07***	0.000
Urbanity	0.108***	0.001	0.210***	0.002	0.207***	0.001	0.177***	0.001	0.143***	0.001	0.122***	0.002
Married HH-head	0.044***	0.002	0.048***	0.004	0.053***	0.003	0.052***	0.003	0.045***	0.002	0.033***	0.003
Female HH-head	0.053***	0.002	0.055***	0.004	0.055***	0.003	0.050***	0.003	0.044***	0.003	0.031***	0.003
Elementary school	0.020***	0.002	0.044***	0.003	0.029***	0.002	0.018***	0.002	0.014***	0.002	0.005*	0.003
Secondary school	0.039***	0.002	0.051***	0.004	0.032***	0.003	0.019***	0.002	0.014***	0.002	0.004	0.003
High school	0.068***	0.002	0.081***	0.004	0.062***	0.003	0.047***	0.002	0.039***	0.002	0.029***	0.003
At least college	0.068***	0.002	0.086***	0.005	0.074***	0.004	0.065***	0.003	0.057***	0.003	0.042***	0.004
Survey year 2009	0.067***	0.001	0.045***	0.002	0.047***	0.001	0.048***	0.001	0.061***	0.001	0.079***	0.002
_cons	-9.139***	0.197	-17.869***	0.324	-13.654***	0.246	-7.905***	0.207	-2.702***	0.208	-0.716***	0.268
#Obs	549,659		549,659		549,659		549,659		549,659		549,659	
(pseudo) R^2	0.828		0.5538		0.55893		0.5639		0.5732		0.576	

Source: Author‘s estimation. Note: * (**, ***) indicates significance at the ten (five, one) percent level.

We found that those households who have less emissions seem have higher expenditure elasticites to emit of about 1.52 (at 25 % quantile), the magnitudes are then lower to 0.91 (at median quantile), and to 0.36 (at 75% quantile) and 0.18 (at 90% quantile). In other words, low emitter household groups seem to be more responsive to emit and then its effect decreases for those with higher emissions. Meanwhile, household with high carbon footprint have an expenditure elasticites to emit lower than one, indicating they might pass a saturation point that allows them to have rising consumption to become less-carbon intensive. Finally, similar to the OLS estimation, here we also indicate that other household characteristics also matter as the determinants of household carbon footprint[17].

[16] Quantile regression estimates without expenditure square are presented in **Appendix Table A.10**.

[17] We also found the estimated coefficients of squared expenditure are no longer negative for q=0.50; 0.75; 0.90, that could indicate the convex relationship of income-emissions of higher emitters. However, this convexity does not seem quite strong.

1.3.3 The decomposition analysis of emission growth

Figure 1.6 presents the decomposition of the growth of household CO_2 emissions from 2005 to 2009. From the perspective of contributors to CO_2 emissions growth, we can clearly show that rising expenditures is the largest contributor to the rise in CO_2 emissions in all quintiles. This rise in expenditures has the largest effect in the lowest quintile, which means that rising the per capita expenditure of households in this quintile will more greatly increase CO_2 emissions than the same rise in per capita expenditures of household in the upper quintiles would. Moving to affluent households, the expenditure effect then decrease gradually, but the effects in all quintiles remain positive.

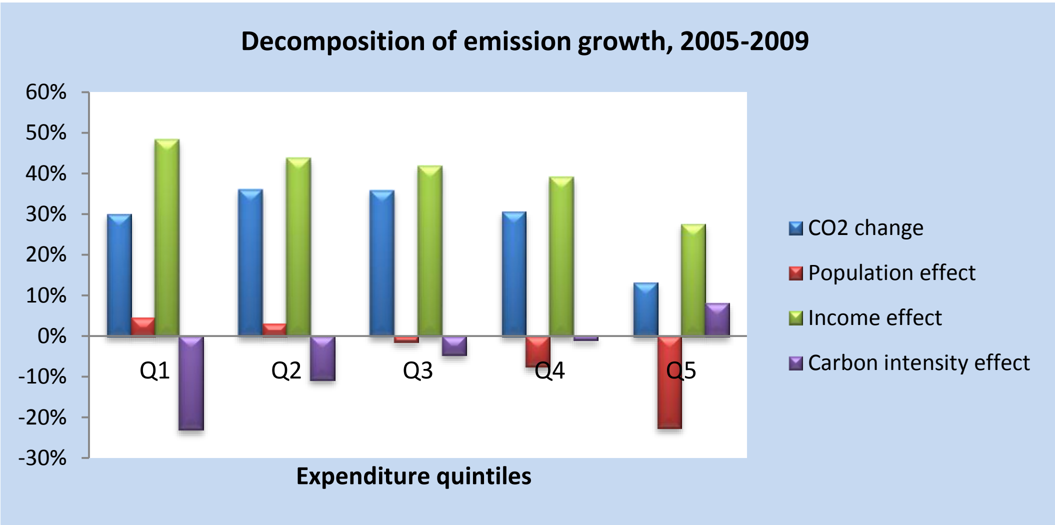

Figure 1.6 Decomposition of CO2 emission growth [18]
Source: Author's computation based on Susenas 2005-2009, IO 2005, GTAP-E 2005

Moreover, moving from the lowest to highest household, we can clearly identify that the population effect has a decreasing pattern, which has a positive effect on the first two quintiles, and has a negative effect on the third to the highest quintile. Finally, the CO_2 intensity effect (measure as kg CO_2/Rp) has the largest negative contribution to CO_2 emissions risings in the lowest quintile. This effect has a negative sign from the first until third quintile and has a positive sign in the highest quintile.

[18] Note: CO_2 emissions and total expenditure are deflated.

From the quintile perspective, it can be seen that the rise in CO_2 emissions between 2005 and 2009 in the first and second quintiles is mostly a result of the positive income (expenditure) effect, followed by the (negative) CO_2 intensity effect and the positive population effect. In the third and fourth quintiles, the rise of CO_2 emissions is a result of the positive effect of rising expenditures, but the effect is not as strong as it was in the first two quintiles. They are also affected by the negative contribution from carbon intensity and population effect. In the richest quintile, the expenditure effect is not as strong as it was in the lower quintiles, however it is still the largest contributor to the change in household emissions. This effect was strengthened by the carbon intensity effect that only had a positive contribution in this quintile, but was weakened by the larger negative population effect. Increase in energy expenditure share (mainly transportation) to overall consumption in 2009 is considered as the driving factor of this positive carbon intensity effect among the richest household group (or falling in the lower income groups)[19]. To sum up, the richer households have lower emissions growth because their population (household size) effect has fallen, but this is partly offset by choosing carbon intensive goods due to rising affluence.

1.3.4 Expenditure elasticities of emission

Due to the fact that expenditure is the most important driver of the household carbon footprint, we conduct an analysis of expenditure elasticities of CO_2 emissions that measure the responsiveness of CO_2 emissions (as a share of total household emissions) to a change in expenditure. There are some important issues to be taken into consideration for our analysis. First, dealing with the potential endogeneity problem, one could have a valid instrument for total expenditures, say for the instance asset index, and employ the instrument in a two-stage least squares procedure. However, our database unfortunately does not provide sufficient candidates as valid instruments for total expenditure, as we do not have sufficient data on assets in Susenas. Second, in addition to the national estimation,

[19] See for instance **Appendix Table A.8.**

we will also analyze expenditure elasticities for both rural and urban areas, as well as computing expenditure elasticities by household quintiles.

As the demand theory suggests, the negative coefficient of expenditure elasticities accounts for a decreasing share of any particular expenditure group due to rising affluence, and vice versa. Our results on expenditure elasticities on CO_2 emissions generally have the same direction as the conventional Engle curve. **Table 1.5** reveals some important findings. We found that inferior goods, such as vegetables and cereals, have negative signs that mean that rising expenditure will reduce their share of CO_2 emissions of these consumption categories. In the opposite direction, luxury goods such as health expenditures, housing, durable goods, transportation, services and rent have positive value, meaning that the rising of household affluence tends to contribute a higher share of CO_2 emissions to the total household emissions. Specifically, the transportation expenditure is carbon intensive that a 1% increase of household expenditure will increase the share of CO_2 emissions from transportation by about 0.03% (both in 2005 and 2009). Fuel and light consumption, another carbon intensive category, has a negative elasticity, which means a 1% increase in household income will reduce the share of CO_2 emissions from these consumption items by about 0.07% in 2005 (008% in 2009).

Table 1.5 Expenditure elasticities of emission

	Overall observation		**Rural**		**Urban**	
Share of CO_2 emission	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Cereal	-0.0169	-0.0095	-0.0185	-0.0076	-0.0080	-0.0052
Vegetable and fruit	-0.0088	-0.0066	-0.0084	-0.0060	-0.0095	-0.0074
Oil and fat	-0.0044	-0.0029	-0.0054	-0.0032	-0.0033	-0.0024
Beverage	0.0045	-0.0006	0.0070	0.0023	0.0021	-0.0048
Egg, fish, meat, dairy	0.0033	0.0143	0.0074	0.0159	-0.0011	0.0122
Tobacco	0.0023	0.0046	0.0048	0.0089	-0.0005	-0.0011
Fuel and light	-0.0686	-0.0916	-0.0740	-0.1045	-0.0639	-0.0741
Telecommunication	0.0065	0.0068	0.0041	0.0064	0.0091	0.0073
Transportation	0.0277	0.0334	0.0304	0.0379	0.0250	0.0272
Health	0.0022	0.0021	0.0023	0.0019	0.0021	0.0024
Education	-0.0011	0.0047	-0.0004	0.0045	-0.0019	0.0048
Toiletry	-0.0012	-0.0007	-0.0014	-0.0008	-0.0009	-0.0007
Clothes	0.0000	0.0024	0.0003	0.0031	-0.0003	0.0013
House and durable goods	0.0349	0.0263	0.0391	0.0282	0.0306	0.0240
Services and rent	0.0087	0.0077	0.0045	0.0056	0.0136	0.0105
Taxes	0.0007	0.0010	0.0005	0.0008	0.0009	0.0012
Recreation, ceremony	0.0071	0.0057	0.0079	0.0066	0.0062	0.0047

Source: Author's estimation ($sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij}$). Note: all estimated coefficients are significant at one percent level, estimations for different quintiles are mentioned in **Appendix Table A.12**.

Conducting a simulation of a 10% increase in income (**Table 1.6**), we indicate that some of the priorities of households, if they were more affluent, would be to have more housing and durable goods, transportation, and services and rents. For instance, in the hypothetical case where a household has double the total expenditure, i.e. a rise of about 100%, the CO_2 emissions for consuming durable goods and transportation increase by 3.4% and 2.7%, respectively[20].

Table 1.6 Share of CO_2 emission and changes once total expenditure increases

Emissions from consumption category	Share from overall emission (%) before expenditure rise		Change in share (%) once 10% expenditure increase		Emission share (%) after expenditure rise	
	2005	2009	2005	2009	2005	2009
Cereals	2.468	2.317	*-0.169*	*-0.095*	2.299	2.222
Vegetables and fruits	4.956	4.855	*-0.088*	*-0.066*	4.867	4.789
Oil and fat	1.108	1.003	*-0.044*	*-0.029*	1.064	0.974
Beverage	6.545	6.801	*0.045*	*-0.006*	6.590	6.794
Egg, fish, meat, dairy	7.603	7.290	*0.033*	*0.143*	7.636	7.433
Tobacco	3.249	3.052	*0.023*	*0.046*	3.272	3.098
Fuel and light	57.330	55.927	*-0.686*	*-0.916*	56.644	55.011
Telecommunication	0.572	0.903	*0.065*	*0.068*	0.637	0.971
Transportation	5.028	7.011	*0.277*	*0.334*	5.305	7.345
Health	0.466	0.579	*0.022*	*0.021*	0.488	0.600
Education	0.702	0.893	*-0.011*	*0.047*	0.691	0.940
Toiletry	0.759	0.672	*-0.012*	*-0.007*	0.747	0.664
Clothes	1.862	1.826	*0.000*	*0.024*	1.862	1.849
House and durable goods	2.837	2.683	*0.349*	*0.263*	3.186	2.946
Services and rent	2.833	2.880	*0.087*	*0.077*	2.920	2.957
Taxes	0.089	0.117	*0.007*	*0.010*	0.096	0.126
Recreation, ceremony	1.593	1.194	*0.071*	*0.057*	1.664	1.252

Source: Author's estimation

Last but not least, most of the estimated expenditure elasticities coefficients are generally very small, but generally the directions of these expenditure elasticities to CO_2 emissions have the same signs as the conventional Engle curve. However, they have different sensitivities due to the different CO_2 intensities of the consumption categories. The small size of the expenditure elasticites indicates that the household emission change can mainly be attributed to a general volume increase in overall expenditure, and not by shifting the expenditure shares within the consumption basket. These findings support the previous results on the decomposition of emission growth that suggests that the emission growth is mainly due to rising income (expenditure) level.

[20] However, it is noticeable that there could be a different response to expenditure rises in different household characteristics. See for instance the expenditure elasticites to emission share by household affluence quintile can be shown in **Appendix Table A.13**.

1.4 Conclusion

The objectives of this study are to analyze the household carbon footprint pattern in Indonesia and to analyze the determinants of the growing carbon footprint in this emerging economy. Of particular relevance is identifying possible trade-offs between increasing incomes (which are in line with poverty reduction) and the carbon intensive behavioral choices of households from the consumption side as in the transition economy, household consumption (particularly associated with energy expenditures) is an important element. This study combines national input-output, and the GTAP emission database to compute CO_2 emission intensities for all input output sectors in Indonesia. These intensities were then matched with two waves of national expenditure surveys from 2005 and 2009 to calculate the carbon footprint for every household in the surveys. We further use this household CO_2 emissions information in investigating the drivers of the rise in emissions from a micro-cross sectional perspective.

Comparing CO_2 intensities, the results show that the fuel-light and transportation consumption categories are the two most CO_2 intensive emitting sectors in Indonesia. These expenditures are also the main sources of overall household emission. In contrast, food or agriculture-related expenditures post the lowest CO_2 intensities as well as carbon emission levels. In terms of numbers, we found that there was an increase of households' carbon footprint from 2005 to 2009 by about 72.36% (or 24.90% if we deflate CO_2 and expenditure). Dividing households into per capita expenditure quintiles, we showed emission disparities between household quintiles as the richest household emit almost 5 and 3 times compare to the first and third quintile (7 and 3 times based on per capita emission terms). In addition, we found there is a significant difference of household carbon emissions between different income levels, regions, and education levels.

To understand the drivers of the variations in the household carbon footprint, we apply various regressions of household CO_2 emissions on household characteristics such as income, education, region, household population, and gender and age of the household head. We found that rising household expenditures is the main determinant of rising household emissions. It is clearly shown that varying income levels differ significantly in terms of their carbon footprint. Other household characteristics also contribute to the variation in emission levels. Urbanity, large household size, more educated, older and female household head, as well as households in Java provinces, all have a higher profile of CO_2 emissions. Quantile regression indicates that low emitter household have stronger magnitude to emit as income increasing, while household with high carbon footprint have an income elasticites to emit lower than one, indicating that they might have passed a saturation point allowing their rising expenditure towards less-carbon intensive. Last but not least, the results of the decomposition analyses also show that changes in household emission levels are due primarily to the income (expenditure) effect, between household levels and over the two periods. The expenditure elasticities analysis suggested that the rise in household emissions is mainly caused by general increases in overall household expenditure, and not by shifts in the consumption basket.

Back to the EKC hypothesis that proposes the income-environmental degradation relationship depends the scale, composition and technology effects (see Grossman and Krueger, 1995; Torras and Boyce, 1998), from the micro perspective, on the one hand our findings indicate that growing household affluence is remarkably compensated by higher emissions (the scale effect). On the other hand, we indicated little evidence of a transformation in behavioral choices of the households towards sustainable consumption patterns, although there is evidence of declining emission intensity as income rises.

Finally, our study could motivate some possible policy implications. As Indonesian per capita income grows, the future emissions will undeniably rise but there would be potential way outs that the household emissions could grow more slowly. In this regard, transformation towards less carbon-intensive consumption would play a role. This issue might be reinforced by a number of supporting policies such as developing energy efficiency, low-carbon energy system, green technology and infrastructures including sustainable transport system, along with a gradual (well-targeting) reduction of fuel subsidies. Taking those strategies together would allow rising affluence could be translated towards consumption patterns that might minimize the scale of the emission trade-offs of development and thus promote low-carbon development paths. All of the above issues could have significant relevance to Indonesian as well as to global debates on how to reduce the carbon intensity of development paths.

Chapter 2 : Inequality in emissions: Evidence from Indonesian households

Inequality in emissions: Evidence from Indonesian households

Abstract

Although the literature on emission inequality is abundant, this study will differentiate itself by focusing on emission inequalities at the household level. We further separate measures on emission inequality based on household characteristics as well as decompose it into sources of emission. The results show that as per capita expenditure increases, within-group emission inequality tends to decline until the middle-income group but then further increases in expenditure level and worsens emission inequality until the richest household group. The decomposition of inequality based on emission sources suggests that energy-transportation dominantly contributes of the overall emission inequality.

Keywords: carbon footprint, household, inequality, Indonesia

2.1 Introduction

Human activity is one the leading contributors to the rise in global emissions, particularly since the industrial revolution. The idea of the relationship between economic development and environmental degradation is suggested by the Environmental Kuznets Curve (EKC) hypothesis, which proposes that in the early stage of development environmental degradation surges until reaching its peak, then a further increase in economic affluence would lead to a decline in environmental degradation. For that reason, the investigation of the driving forces as well as the evolution of CO_2 emission levels are important and thus have been becoming of great interest to both research and policy perspectives.

However, different levels and patterns of development in countries or groups of economic actors lead to a disparity in the figures of environmental degradation. Of particular relevance is the fact that the inequality in emissions across countries (or regions) is enormously huge. For instance, the World Bank (2013) reports that in the 1980s developing countries in East Asia emitted only 1.27 tons of CO_2 per capita compared to the European countries that emitted about 5.75 tons/capita. In 2009 however there was a huge change in the emission disparity as the CO_2 emission per capita in East Asia jumped to 4.59 tons while Europe increased to just around 7.22 tons of CO_2 emissions.

More importantly, many studies, such as Heil and Wodon (1997) and Clarke-Sather et al. (2011), proclaim that the inequality in emissions between developed and developing countries has been one of the huge challenges hampering the process of forging international agreements towards reducing green house gas (GHG) emissions. One particular reason for this is that developed countries believe that restraining their emissions will disrupt their economy. Conversely, developing and emerging economies argue that their growth should not be limited by any climate mitigation policies, as their historical levels of carbon emissions have been lower (Heil and Wodon 1997; Duro and Padilla, 2006). These contradictory arguments challenge the mitigation of global climate policies.

Notwithstanding the fact that the emission inequality problem is somewhat global or regional, it could be also relevant to investigate the issue at the micro level across households within country. Given this, this study tries to measure the CO_2 inequality and its decomposition from the household/micro perspective that could be valuable in the discourse on climate change. The measure and degree of inequality in CO_2 emissions across households show what degree of "responsibility" of emitters and emission sources from the household perspective within a country.

Some particular motivations of this study are: to discover whether the apparent stability in household (cross-sectional) emissions could coincide with the unequal expenditure distribution, as well as to investigate the drivers of its distributions. Similar to the emission inequality in the macro analysis concerning household distribution, we apply several measures of inequality to synthesize the amount of inequality at the household level. In addition to determining the level of inequality, we will also disaggregate and decompose inequality into subgroups of observations as well as into sources of emission. Among the major reasons to decompose household emission inequality are: (i) allowing us to identify whether the change in emission inequality is fueled by a reduction in the emission gap between household affluence, or whether its difference is due to the homogeneity of households' lifestyles within the same group; (ii) allowing us to understand which subgroups (and source of emissions) dominantly contribute to the overall emission inequality. Finally, regarding the comparison between expenditure and emissions, we analyze the inequality measures as well as decomposition of the two variables into the drivers and sources of such inequality.

2.2 Literature reviews

A number of studies have been conducted to investigate emission inequalities that are mainly focusing on the international (e.g. Heil and Wodon, 1997; Hedenus and Azar, 2005; Padilla and Serrano, 2006; Cantore and Padilla, 2010) as well as the regional level (e.g. Alcantara and Duro, 2004; Padilla and Duro, 2013; Clarke-

Sather et al., 2011). In general, these studies have taken into account the characteristics of the emission distribution and have dealt with the arrangement in international and national emissions inequality.

In an international context, Heil and Wodon (1997) analyze the CO_2 emissions inequality between poor and rich countries. Employing the Gini index, results found that the inequality in GHG emissions remained high during the period 1960-1990 and the between group component accounted for half of the per capita emissions inequality. Padilla and Serrano (2006) applied conventional applications of inequality to measure CO_2 emissions inequality, and employ the Theil index decomposition to investigate the contribution of four income country groups to the overall inequality in CO_2 emissions. They found that while the overall CO_2 emissions inequality lessens over time, the low-income countries experience an increase in inequality. Employing the concentration indices of emissions (cross country emission inequality ordered by increasing value of income, which was proposed by Kakwani et al. (1997)), they found it has diminished less than the conventional measure in emission inequality. Duro and Padilla (2006) decompose the Theil index of emissions by using Kaya factors to find what contribution the factors had on per capita CO_2 emissions, CO_2 intensity, energy intensity and per capita income. They found that the CO_2 emissions inequality was mainly attributed to the difference in per capita income levels. Recently, an investigation of the international inequalities in ecological footprint was conducted by Duro and Teixidó-Figueras (2013), that primarily suggested that the global emission inequality was largely explained by "between groups" inequalities rather than the "within group" component.

From the regional context, a study on the energy intensities inequality among OECD countries by Alcantara and Duro (2004) revealed that the decline in energy intensities differences was mainly due to "between-group component inequalities" rather than "within group inequalities". Similarly, Padilla and Duro (2013), who only focused on the European Union case, employed the same method of decomposing emission inequality of using the Kaya factor. They found that per capita output is the most important factor of emission inequality. In other words, evidence from the European Union is consistent with the global context. Furthermore, there was a significant decline in emission inequality, which is primarily due to the declining contribution of energy intensity inequality and the reduction of output inequality between country groups.

In the case of the provincial level analysis, Clarke-Sather et al. (2011) primarily intend to investigate whether the Chinese provincial-level of CO_2 inequality mirrors the international pattern. They found that global evidence of CO_2 emission inequality was not reflected in the provincial context, as the contribution of the “within group inequality” (i.e. intraregional inequality) was larger than the “between group” inequality component. This means that the variations of CO_2 emissions between regions in China are lower than the variation within any particular provinces.

Therefore this study could fill the gaps in analyzing inequality in emission and its decomposition from the household level perspective. As mentioned, although the above problem is global, it is also relevant to investigate it in local context. In that sense, a cross-country study on household-level emission inequality and how it relates to income is relevant. Specifically, the contributions of this study are as follows: (i) disaggregated household-level study on CO_2 emissions in a developing country using Indonesia as example, to understand the patterns of emission inequality from the micro level perspective; (ii) a study on the main contributors (drivers) of CO_2 emissions inequality at the household-level[21]; (iii) investigation on the internal dynamics of emission inequality at the household level, which remains an understudied dimension in mitigating climate change.

[21] Overall, it is hypothesized that if emission is more unequal than income, one could suggest that (richer) households should have more carbon intensive lifestyle. It is also hypothesized that if households are ordered based on income and under this circumtance emission inequality is dominated by between-group component; then the income is considered as important driver of emission inequality. This is also comparable with the case households are ordered based on non-income characteristics. For instance, in the case that most inequality is between group component (if households are ranked based on their income) and an opposite findings if they are ranked based on non-income characteristics; one could suggest that income has a strong influence on emission inequality. Finally, the decomposition of emission inequality by income source hypothesizes that apart from individual emission source inequality, overall emission inequality should be largely attributed to any emission (income) source that highly dominates to overall emission, and/or which highly correlated to overall emission inequality.

2.3 Methodology and data

2.3.1 Basic measures of emission inequality

Imagine we have a distribution of emissions, $e = (e_1, e_2, e_3, \dots, e_N)$, for N individuals which has the mean $\mu = \frac{1}{N}\sum_{i=1}^{N} e_i$. For this distribution, emission inequality can be defined as a I(e) function which determines how unequal this emission distribution is. Several methods are commonly applied to measure inequality, each of which possesses their own benefits and drawbacks. This study will utilize the Gini and the Theil index, which will be applied to find the level of inequality in the emission and expenditure distributions.

One of the most popular inequality measures, the Gini coefficient, is defined as the area between the absolute equality line and the Lorenz curve. It is easily and readily understandable as it has a value from 0 (means perfect equality) to 1 (means perfect inequality). We calculate the household Gini coefficient of household emissions using the following formula:

$$G(c) = \left(\frac{2\sum_{i=1}^{N} i * c_i}{N\sum_{i=1}^{N} c_i}\right) - \left(\frac{N+1}{N}\right) \tag{2.1}$$

N and c_i refer to the total number of households (observations) and per capita emissions, respectively.

The Theil index measures a weighted entropy index and can be fully decomposable into subgroups of observations or other factors. This decomposability is beneficial as it allows us to study the composition of the index by factors or sources. This index can be calculated using the following formula:

$$T(c) = \sum_{i=1}^{N} p_i \ln\left(\frac{\bar{c}}{c_i}\right) \tag{2.2}$$

where p_i is the proportion of individual i to the overall individuals in the (group) sample, $\bar{c}$ is the mean of per capita emissions. As mentioned, if our overall number of observations is divided into several groups (in our case, per capita expenditure quintiles, regions, educational attainment, number of household members, gender and age of household head), the overall emission inequality can be expressed as a sum of two terms called the 'within group inequality', $T(c)_w$, and the 'between group inequality', $T(c)_b$, as follows:

$$T(c) = T(c)_w + T(c)_b \tag{2.3}$$

The within-group inequality measures how much per capita emission inequality is due to the variations between the individuals in each of these groups, while the between group inequality quantifies to what extent emission inequality is due to the differences in the average emission amount of each subgroup. Equation (2.3) can be re-expressed as follows:

$$T(c) = \sum_{g=1}^{G} p_g T(c)_g + \sum_{g=1}^{G} p_g \ln(\frac{\bar{c}}{c_g}) \tag{2.4}$$

The first term, which represents the within group inequality, is a weighted sum of subgroup inequality values, while the latter term indicates the between group component of inequality. p_g is the household proportion in group g, $T(c)_g$ represents the internal Theil coefficient of household emission in group g, and c_g denotes the household emission in group g.

2.3.2 Emission concentration index vs. expenditure Gini

Intuitively, we can directly compare the amount of emission inequality to the amount of expenditure inequality just comparing their Gini indices. However, one particular drawback of direct comparison is a different ranking criterion since the emissions Gini index is basically computed using the ranks of individuals based on their emissions, while the expenditure Gini index is constructed using the ranks of households based on their expenditure rank. To solve this, we can apply another index, modified from Kakwani et al. (1997), which basically compares the concentration of emissions and expenditure using the same rank ordering based on expenditure. In other words, this can be regarded as emissions inequality conditional on expenditure. Among the previous studies that employed this similar method were Padilla and Serrano (2006) and Cantore and Padilla (2010).

We basically calculate the Kakwani index by subtracting the household expenditure Gini, $G(Exp)$ from the quasi-Gini index of CO_2 emissions, $qG(c)$, as follows.

$$G(Exp)_i = \left[\frac{2\sum_{i=1}^{N} i.Exp_i}{N\sum_{i=1}^{N} Exp_i}\right] - \sum_{i=1}^{N} i.c_i \quad (2.5)$$

where Exp_i is expenditure of i-th individual (which were ordered by their per capita expenditure).

$$qG(c) = \left[\frac{2\sum_{i=1}^{N} i.c_i}{N\sum_{i=1}^{N} c_i}\right] - \left(\frac{N+1}{N}\right) \quad (2.6)$$

where c_i refers to the emissions of the i-th individual, but ordered by per capita expenditure. The Kakwani index is then computed by the following formula:

$$K = qG(c) - G(Exp)_i \quad (2.7)$$

which measures the difference between the concentration of household emissions and household expenditure inequality. A positive number of K indicates that CO_2 emissions are more concentrated along the expenditure distribution (less equally distributed than expenditure), and vice versa.

2.3.3 Inequality decomposition into emission sources

Although the Gini index cannot be decomposed into ‘between’ and ‘within’ group, we can decompose this index into sources of emissions using the application suggested by Lerman and Yitzhaki (1985) and Stark et al. (1986), employing the following steps. We initially need to divide the overall amount of emissions by the number of households and then rank the households from the lowest to the highest emitter. Then we compute the Gini index of the overall emission, $G(c)$, using another expression as follows:

$$G(c) = \frac{2}{N\mu} Cov(c, r) \quad (2.8)$$

where c is the per capita CO_2 emissions, μ is the mean of per capita CO_2 emissions for all N observations (in kg of CO_2) from all emission sources, and r is the rank of the individual according to their emissions.

Modifying (2.8), the Gini index of the i-th source of emissions, $G(c)_i$, can be computed as follows:

$$G(c)_i = \frac{2}{N\mu_i} Cov(c_i, r_i) \qquad (2.9)$$

where c_i is the per capita emission amount in that particular expenditure category, μ_i is the average per capita emission amount of the i-th emission source, and r_i denotes the corresponding rank of the individual in that emissions source.

The overall Gini index of the overall per capita CO_2 emission amount can be derived from the above individual Gini index of emission source, as follows:

$$G(c) = \sum_i S_i R_i G(c)_i \qquad (2.10)$$

where $S_i = \frac{\mu_i}{\mu}$ is the share of a particular emission source in overall emissions, $R_i = \frac{Cov(y_i, r)}{Cov(y_i, r_i)}$, is the rank correlation ratio of the covariance between the amount of emissions from a particular emission source and the overall emission rank ($Cov(y_i, r)$) to the covariance between the amount of emissions in that particular source and the emission source rank, $Cov(y_i, r_i)$.

Therefore, we can then estimate what effect a small change has in a particular inequality has on the total inequality given the equation (10), which shows that the overall emission inequality is a product of the three terms, including (i) the share of the average emission amount of a particular source has in total emissions, S_i, (ii) the correlation between the i-th emission source and its rank in overall emission, R_i, and (iii) the emission source Gini, $G(c)_i$.

In addition, we can measure what marginal effect of a percentage change in the emission source has on the total emission inequality. This will allow us to calculate what kind of an effect a marginal change in a particular emission source will have on overall emission inequality. We modified the method proposed by Lerman and Yitzhaki (1985) and Stark et al. (1986). Suppose we have an exogenous change in i emission source by a factor, say h, such that $c_i(h) = (1 + h)c_i$, we can then capture the change as:

$$\frac{\partial G(c)}{\partial h} = S_i[R_i G(c)_i - G(c)] \tag{2.11}$$

Dividing (2.11) by $G(c)$ yields the following formula:

$$\frac{\frac{\partial G(c)}{\partial h}}{G(c)} = \frac{S_i R_i G(c)_i}{G(c)} - S_i \tag{2.12}$$

which implies that the relative effect (change) of a percentage in i emission source to the total inequality equals the relative contribution of i emission source to the overall emission inequality minus the relative share of emissions from source i in the total emission amount.

2.3.4 Data

As described in more detail in **Chapter 1**, we use the data on carbon emission from the Global Trade Analysis Project-Environmental Account (GTAP-E), which contains CO_2 emissions from energy and cement production but does not include emissions from land-use change, which is also an important factor for the Indonesian case. These emissions are then incorporated with the Indonesian Input-Output (IO) table, and the Indonesian household expenditure survey (Susenas) from the 2005 and 2009 survey. This method is convenient for describing and explaining the environmental impact of different household types (Kok et al., 2006).

We combine the IO analysis with GTAP-E to calculate the cumulative sectoral carbon intensities, which account for the direct and indirect emissions of any particular economic sectors. Expenditure amounts on consumption items in Susenas are multiplied with the corresponding emission intensity from the IO-

GTAP computation. Then by summing the CO_2 emissions from any particular consumption category we get the household carbon footprint.

Technically, the total households' CO_2 emissions can be computed by summing up the direct (c_{dir}) and indirect (c_{ind}) emissions, as follows:

$$c_{hh} = c_{dir} + c_{ind} \quad (2.13)$$

while the direct emissions consist of domestic energy consumption and transport, the indirect emissions account for emissions embodied in the consumption related to household operations, food expenditures, service-oriented goods and other expenditure items. The indirect emissions are calculated by tracing the emissions of a certain household expenditure item down to its intermediates in the IO table, employing the methods of IO analysis in estimating the embodied carbon emissions (e.g. Parikh, et al., 1997; Lenzen, 1998; Bin and Dowlatabadi, 2005; Kok et al., 2006). The sectoral CO_2 emission intensities, EI_j, can be computed by utilizing the following formula:

$$EI_j = e'(I - A)^{-1}y \quad (2.14)$$

EI_j is the carbon intensity of each economic sector in the IO table, e is a vector of carbon coefficients taken from the GTAP (Lee, 2008). A is the technical coefficients, while $(I - A)^{-1}$ is widely known as the Leontief inverse; y is the vector of final demand for commodities. We then match j carbon intensity (2.14) with the i consumption categories taken from household expenditure as follows:

$$c_{ind} = \sum EI_j . Exp_i \quad (2.15)$$

We found that the average Indonesian carbon footprint[22] in 2005 were 698 kg CO_2/capita and increased to 898 kg CO_2/capita in 2009 (expenditure deflated, 2005=1)[23]. When disaggregating across expenditure quintiles, there is a huge disparity in emissions across affluence quintiles (**Figure 2.1**), which indicates that there are large differences between the household carbon footprints across

[22] The CO_2 emissions are scaled up to national account expenditure.
[23] Per capita emission is about 1,239 kg (without deflated expenditure).

different household affluence level. For instance, the per capita emission amount of the richest quintile is almost seven times as high as the carbon footprint of the poorest quintile, and still about three times as high as the level of the third quintile (middle affluence group). Considering such large differences of household emissions, it is then sensible to analyze emission inequality of different household affluence as can be explained further in the following sections.

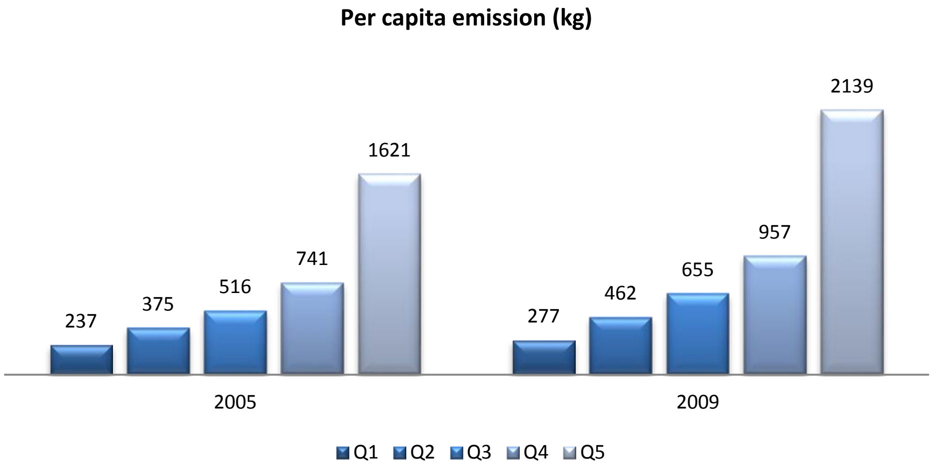

Figure 2.1 Per capita emission by affluence quintile (2005 and 2009)

Source: Author's computation based on Susenas 2005-2006, IO 2005, GTAP-E 2005

2.4 Results and discussions

2.4.1 Household characteristics and emission share

We begin with providing a simple measure of inequality by computing the share of per capita emission from the overall figures, as shown in **Table 2.1**. First, by classifying observations into five quintiles based on per capita expenditure, it is clearly shown that the average per capita emission contribution increased in line with the rise in expenditures. In the 2005 survey, the richest quintile contributed about 46% of total emissions (48% in 2009) compared to the fourth quintile at 21% (21%), the third quintile at about 15% (15%), the second quintile at about 11% (10%), and the poorest quintile at about 7% (6%). In other words, the individuals from the richest household emit more than 7 times (8 times) the amount that the first and the second quintile emit. In general, these figures clearly suggest similar patterns of the share of emissions among household groups in both surveys.

Table 2.1 Per capita emission and emission share

	Mean of per capita emission (kg CO_2)		Share of per capita emission (% of total emission)		Share of obs. (% of total obs.)	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**
Affluence						
Poorest	237	382	6.80	6.17	20	20
2nd	375	638	10.75	10.29	20	20
Middle	516	904	14.77	14.59	20	20
3rd	741	1,321	21.24	21.32	20	20
Richest	1,621	2,952	46.44	47.64	20	20
Location						
Rural	489	952	31.81	35.03	62.52	64.72
Urban	1,047	1,766	68.19	64.97	37.48	35.28
Education						
Did not grad	570	1,113	13.01	16.32	19.06	17.51
Elementary	577	1,114	13.17	16.34	43.34	41.91
Secondary	680	1,191	15.52	17.46	16.69	16.62
High school	940	1,468	21.45	21.52	16.62	17.98
At least college	1,615	1,934	36.85	28.36	4.30	5.98
If s/he is member of x persons HH						
1	1,408	4,767	24.51	38.28	1.31	1.53
2	1,035	2,336	18.02	18.76	5.98	6.79
3	830	1,589	14.45	12.76	15.91	17.03
4	733	1,242	12.76	9.97	24.55	25.03
5	656	1,010	11.42	8.11	21.04	20.83
6	581	850	10.11	6.83	14.4	13.57
7+	501	659	8.73	5.29	16.81	15.21
Gender						
Male	706	1,213	50.59	48.95	50.23	50.13
Female	690	1,265	49.41	51.05	49.77	49.87
Age						
<30	656	1,129	22.47	20.45	59.44	55.44
30-44	736	1,262	25.18	22.85	20.21	22.1
45-64	796	1,424	27.26	25.79	15.83	17.31
65+	733	1,706	25.09	30.90	4.52	5.15
Per capita emission (number of obs.)	**698**	**1,239**			**1,052,091**	**1,155,566**

Source: Author's computation based on Susenas 2005-2009, IO 2005, GTAP-E 2005

Comparing locations, in both surveys we can see that the per capita emission of urban households is more than double the amount of those who are living in rural areas. The contribution of urban households to overall emissions in 2005 was about 68% then decreased to 65%. Meanwhile the per capita emission of rural households had a slight increase in their contribution to total emissions.

Classifying observations according to educational attainment, the figure has a similar pattern to the affluence classification. The contribution of 'at least college' graduates was higher than lower educational attainments. Someone who had 'at least college' contributed about 38% in 2005 (27% in 2009), compared to elementary school graduate at about 13% (16%). Comparing the two years, we can see there was an increasing pattern in the share of emissions from 'did not graduate' to 'high school graduate', while 'at least college graduate' group has a decreasing emission share pattern.

Comparing emissions according to the number of household members, there have been decreasing patterns of per capita emission share from those who are a member of a small family to those who are a member of a large family. If s/he has 2 household members, for instance, per capita emission is about 18% (19%) compared to the share of per capita emission from an individual of 6 household members, which contribute of about 10% (7%) to overall emissions.

Comparing gender of household head, the emission share of those who are headed by a female is slightly lower than male-headed households. However, comparing between the two surveys, there was a slight increase in the emission contribution of female household heads, so the contribution to CO_2 emissions of female and male headed households are slightly more equal in 2009. Finally, when categorizing households by the age of the household head, we not-surprisingly found that there is an 'inverted U-shape' of the emission share of households, as the share increased until the age of 64 and then lowered after 65 years of age.

2.4.2 Emission inequality measure by household characteristics

This section will analyze the disparity in emissions among households through employing the Gini and Theil indices**.** Classifying observations by their affluence, the conditional Gini coefficient indicates that both in 2005 and 2009 the emission inequality within quintiles has a U-shaped pattern when moving from the lowest to the highest expenditure quintiles (**Appendix Table B.2)**. The poorest and the richest household groups are more unequal in their emission inequality than the middle income quintile (**Figure 2.2**). This implies that an increase in affluence at lower end of distribution has an equalizing effect on emission while at the upper end of the distribution an increase in income leads to a worsening carbon footprint inequality. The middle income groups are more homogenous in term of emission distribution. Of particular reason of this lower inequality within the middle income quintiles is due to the boundaries of those quintiles. Meanwhile, among all quintiles, the richest household group is the most unequal group in their emissions, which is expected due to their greater variations in lifestyle that the richest household group have a large range of expenditures (luxury effect). Comparing the two surveys, similar expenditure inequality, overall emission inequality in 2009 is higher than in 2005 (**Appendix Table B.2**). This means that rising household emission level overtime is still driven by rising emission among richer households. Furthermore, looking at the within and between inequality component, we indicate that overall emission inequality is largely attributed by the between group inequality component.

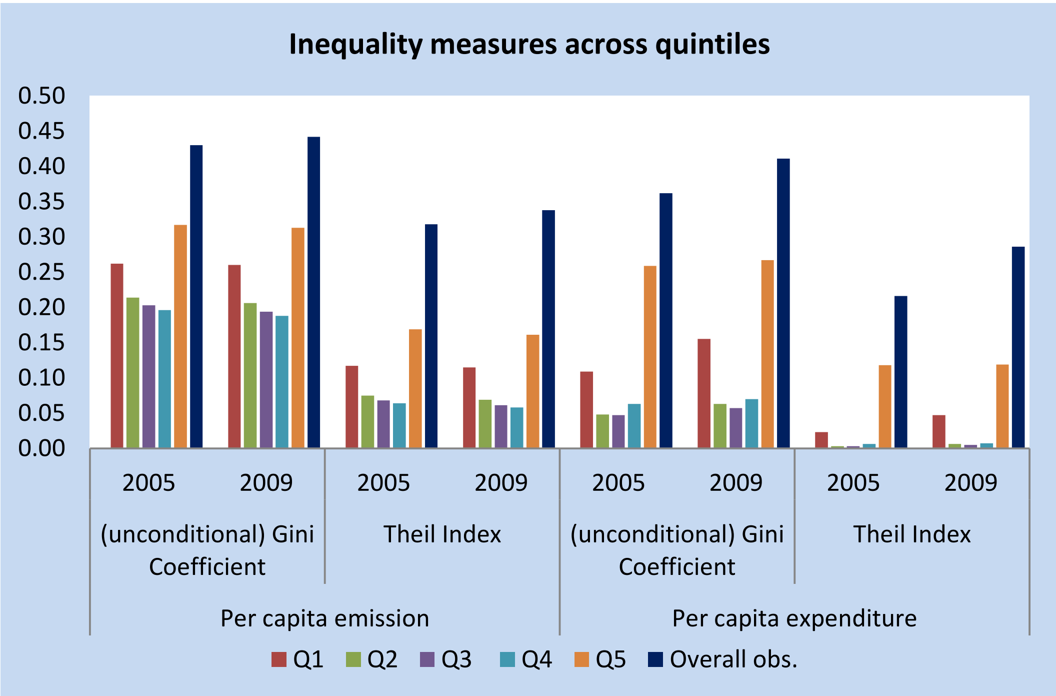

Figure 2.2 Emission inequality measures across quintiles

Source: Author's estimation

Based on location, we indicate that urban household group is slightly more unequal than rural household in both the 2005 and 2009 surveys. We also indicate that the inequality is mostly due to within-group inequality (**Appendix Table B.2**). One possible explanation is that urban household seems to have wide range of expenditure (source of emissions) that leads to make higher emission inequality measure than rural households. Based on educational attainment, we found that the most unequal group is observed amongst households headed with someone who has ‘at least college graduate’. Apart from decreasing inequality pattern from without formal education to elementary school graduate, there is an increasing pattern of inequality with respect to higher educational attainment. In addition, the Theil index decomposition indicates that the emission inequality is dominantly attributed to the within group component. The above figures could hint that formal education attainment does not likely change the consumption preferences towards less carbon intensive expenditure items. The more educated a household becomes, the greater the income attained and the more that is spent on carbon intensive consumption items.

Classifying observations based on the number of household members, we observe an U-shape pattern of emission inequality moving from the least to the biggest household size (**Appendix Table B.2**). There is a decreasing pattern of per capita emission inequality from group of one family member to three members, and it increase from 4 household member groups to the largest household size. A possible explanation could be that it is related to the sharing of resources (energy use) among household members. If a small household generally has a higher per capita energy use, then the emission inequality could be higher. In larger sized households, resources could be shared, thus lowering per capita energy use that would cause emission inequality to decrease. Finally, from the gender classification, we found that in both surveys the male-headed households were more unequal than the female-headed households. We also found an increasing pattern of emission inequality based on the age of the household head. Younger household heads have a lower emission inequality.

2.4.3 Emission inequality and its relationship with the expenditure distribution

We compare the inequality distribution of per capita emissions to the inequality distribution of per capita expenditure instead of solely analyzing the emission inequality itself. Comparing both figures allows us to evaluate whether the emission distribution is more or less equal than the expenditure distribution. This section compares the computation of emission inequality with the same measure and rank as the expenditure inequality. **Table 2.2** shows a descriptive analysis of the per capita emission contribution of all of the household affluence levels from both surveys.

In the 2005 survey, the richest quintile is responsible for about 46% (45% in 2009) of total emissions compared to the fourth quintile that contributes about 21% (21%), the middle affluence group contributes about 15% (15%), the 2nd quintile about 11% (12%), and the poorest group contributes about 7% (8%). In other words, the richest group emits (in per capita terms) more than 7 times (8 times in 2009) the amount of the poorest household. Similarly, the pattern of the per capita expenditure shares (to total expenditure) is comparable to the emissions. In 2005 the most affluent household quintile emitted about 48% of total emissions compared to the poorest household group at 6%. Finally, comparing the expenditure shares, in both surveys the emission shares were generally higher than the expenditure shares in the two richest groups, which is opposite from the three lowest quintiles. In other words, the emissions are more concentrated relative to the expenditure in the top two quintiles than the lower quintiles. It also means that in 2005 the emission inequality is larger than the expenditure inequality. In 2009, it appears the reverse figure that expenditure is slightly more unequal than emission.

Table 2.2 Per capita emission vs. per capita expenditure: contribution to total

	2005		**2009**	
	Per capita emission	**Per capita expenditure**	**Per capita emission**	**Per capita expenditure**
Poorest	6.80	7.75	6.17	5.98
2nd	10.75	11.51	10.29	10.30
Middle	14.77	15.20	14.59	14.64
4th	21.24	20.98	21.32	21.26
Richest	46.44	44.56	47.64	47.83
Gini index	0.430	0.362	0.442	0.411
Theil index	0.318	0.216	0.338	0.286

Source: Author’s calculation

In addition to the application of the 'conventional' Gini index, we can also measure emissions inequality by employing the concentration index of CO_2 emissions, which is modified from Kakwani et al. (1997). This method basically measures the inequality in emissions by employing the Gini index, but we ranked household CO_2 emissions in the distribution according to their expenditures, which is widely called quasi-Gini or the concentration index. We then compared this emission concentration index with the expenditure Gini index. The Kakwani index measures to what extent the distribution of emissions is greater than the distribution of expenditure. It also measures what degree of rich households emit than poor households. Applying this index, we can measure the level of 'regressivity' or 'progressivity' of the emission distribution across observed subgroups (Padilla and Serrano, 2006).

Table 2.3 Concentration of CO_2 emissions vs. expenditure Gini

	Unconditional Gini index of per capita emissions (A)		**Quasi Gini Index of per capita emissions (B)**		**Gini index of per capita expenditure (C)**		**Kakwani Index (D = B-C)**	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Poorest	0.262	0.260	0.129	0.142	0.109	0.155	**0.020**	**-0.013**
2nd	0.214	0.206	0.056	0.063	0.048	0.063	**0.008**	**0.000**
Middle	0.203	0.194	0.053	0.059	0.047	0.057	**0.006**	**0.002**
4th	0.196	0.188	0.070	0.071	0.063	0.070	**0.007**	**0.001**
Richest	0.317	0.313	0.257	0.264	0.259	0.267	**-0.001**	**-0.003**
Overall	0.430	0.442	0.390	0.409	0.362	0.411	**0.028**	**-0.002**

Source: Author's computation. Note: Quasi Gini Index is based on Concentration Index of CO_2 emissions, i.e. Gini index of CO_2 emissions ranked by household expenditure (Kakwani et al.,1997).

Table 2.3 portrays the concentration index of per capita emissions versus the Gini index of per capita expenditure. Overall, emissions are similarly unequally distributed as expenditure. Comparing two years for the overall households surveys in 2005 and 2009 tell a different story. In 2005, the overall Kakwani index had positive sign, which indicates that CO_2 emission inequality surpasses income inequality. In contrast, the Kakwani index of the 2009 survey has a negative value (but the sign is quite small), which indicates that the CO_2 emission distribution conditional on expenditure is slightly less concentrated than the expenditure distribution. From 2005 to 2009, results also show that rising emission inequality is lower than rising emission inequality, indicating that un-equalizing emission inequality seems less pronounced than un-equalizing income.

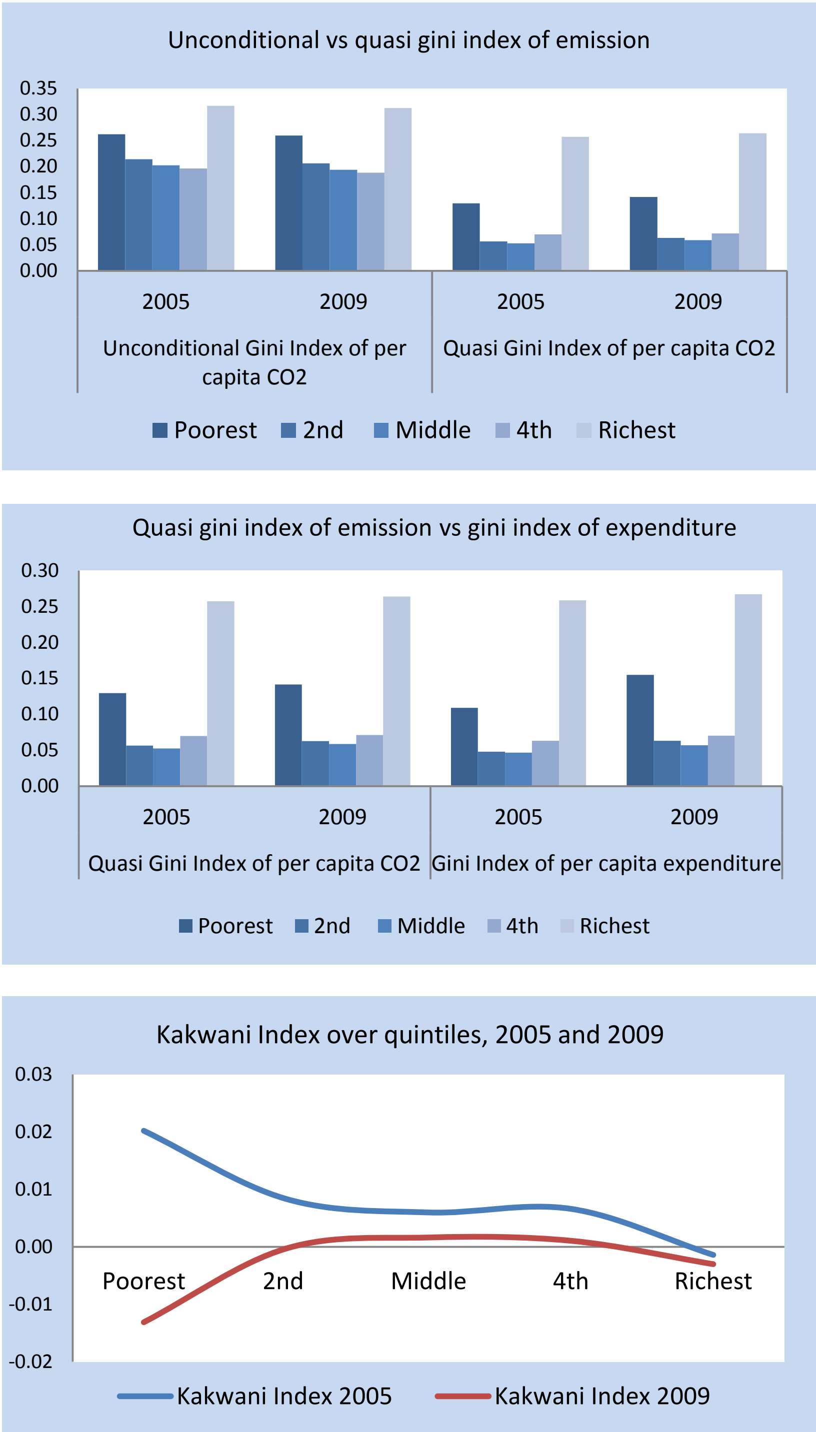

Figure 2.3 Emission vs. expenditure inequality

Source: Author's computation

2.4.4 Decomposition and simulation of CO_2 inequality by emission sources

This section provides the decomposition of emission inequality into emission sources (expenditure categories) to determine how they contributed to changing the inequality in emissions as well to see the drivers/contributors of such inequalities and to see the marginal effects of a percentage change in emission sources that will determine the overall emission inequality. It is noticeable from **Table 2.4** that fuel-light contributes of about 59% in 2005 (56% in 2009) to overall emissions, followed by transportation, which accounts for 6-8% of the overall emissions. This clearly suggests that these two emission sources (expenditure groups) enormously contributed to the overall emission level. In addition, fuel and light and transportation are highly correlated to total emissions of about 95-96% and 77-79%, respectively. Therefore, changing people's preferences of them could mainly contribute to the behavior of overall emissions. This also means that the distribution of household emissions can be largely traced from the composition of household consumption of these two carbon intensive categories.

Table 2.4 Gini decomposition by emission sources

Emission source	Share of emission source (Sk)		Gini of emission sourcea (Gk)		Correlation to total emissions (Rk)		$Share = \frac{S_k G_k R_k}{G}$		$\%\ change = \frac{S_k G_k R_k}{G} - S_k$	
	2005	2009	2005	2009	2005	2009	2005	2009	2005	2009
Cereal	0.015	0.016	0.261	0.379	0.013	0.403	0.000	0.005	-0.015	-0.010
Vegetable and fruit	0.038	0.040	0.381	0.434	0.637	0.711	0.021	0.028	-0.016	-0.012
Oil and fat	0.007	0.007	0.343	0.402	0.379	0.547	0.002	0.004	-0.005	-0.004
Beverage	0.058	0.063	0.509	0.551	0.733	0.736	0.050	0.058	-0.008	-0.005
Egg, fish, meat, dairy	0.064	0.068	0.487	0.551	0.610	0.707	0.044	0.060	-0.020	-0.008
Tobacco	0.024	0.025	0.578	0.623	0.314	0.448	0.010	0.016	-0.014	-0.009
Fuel and light	0.593	0.564	0.469	0.468	0.956	0.951	0.618	0.568	0.025	0.004
Telecommunication	0.011	0.012	0.882	0.736	0.844	0.795	0.018	0.016	0.008	0.004
Transportation	0.064	0.082	0.721	0.659	0.771	0.790	0.083	0.096	0.019	0.015
Health	0.005	0.006	0.757	0.774	0.582	0.599	0.005	0.006	0.000	0.000
Education	0.008	0.010	0.783	0.775	0.575	0.623	0.008	0.011	0.000	0.001
Toiletry	0.007	0.006	0.460	0.474	0.737	0.769	0.005	0.005	-0.001	-0.001
Clothes	0.016	0.017	0.509	0.532	0.627	0.708	0.012	0.014	-0.004	-0.003
House and durable goods	0.045	0.042	0.881	0.889	0.760	0.753	0.069	0.063	0.025	0.022
Services and rent	0.030	0.031	0.634	0.635	0.789	0.786	0.035	0.035	0.005	0.004
Taxes	0.001	0.002	0.844	0.817	0.754	0.753	0.002	0.002	0.001	0.001
Recreation, ceremony	0.016	0.013	0.854	0.904	0.523	0.544	0.017	0.014	0.001	0.002
Per capita CO_2			0.430	0.442						

Source: Author's computation

Applying the modified methods of Lerman and Yitzhaki (1985) and Stark et al. (1986), we compute the decomposition of the Gini coefficient, which allows us to estimate the marginal effects of each of the consumption categories on the overall emission inequality. A positive (negative) marginal effect indicates that an increase in any emission source leads to un-equalizing (equalizing) total household emissions, ceteris paribus. We found that from the household cross-sectional analysis, it is noticeable that a 1% increase in the emissions of fuel-light leads to an increase the total emission inequality to about 0.25% in 2005 (0.04% in 2009). In other words, a rise in the share of emissions from this category will increase the overall emission inequality (i.e. the distribution of CO_2 emissions become more unequal). In contrast, an increase in emissions from cereals will have an equalizing effect of emissions.

In terms of direction, we found that emissions from food, toiletry, and clothes-related expenditures have an equalizing effect on the distribution of overall emission inequality. On the other hand, an increase in emissions from fuel-light, transportation and services will have a worsening effect on emission inequality. This finding is consistent with the fact that as income rises; the food-related expenditure share decreases, causing people to spend more on durables and services. When households become affluent, they tend to consume more energy, services and durables goods, which leads to an increase in the inequality level of emissions from these sources, contributing to more unequal emissions (particularly in the richest group).

Table 2.5 Gini decomposition by per capita expenditure category

Expenditure category	Share of expenditure (Sk)		Gini of expenditure category (Gk)		Correlation to total expenditure (Rk)		$Share = \frac{S_k G_k R_k}{G}$		$\%Change = \frac{S_k G_k R_k}{G} - S_k$	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Cereal	0.126	0.123	0.255	0.376	0.247	0.588	0.022	0.066	-0.104	-0.057
Vegetable and fruit	0.082	0.079	0.379	0.432	0.712	0.771	0.061	0.064	-0.021	-0.015
Oil and fat	0.025	0.023	0.343	0.402	0.520	0.650	0.012	0.015	-0.013	-0.008
Beverage	0.146	0.142	0.451	0.499	0.816	0.818	0.148	0.141	0.002	-0.001
Egg, fish, meat, dairy	0.132	0.126	0.452	0.513	0.768	0.805	0.126	0.127	-0.006	4.0E-04
Tobacco	0.077	0.073	0.576	0.622	0.468	0.569	0.057	0.063	-0.020	-0.010
Fuel and light	0.064	0.057	0.469	0.468	0.769	0.785	0.064	0.051	0.000	-0.006
Telecommunication	0.028	0.029	0.882	0.736	0.853	0.812	0.058	0.042	0.030	0.013
Transportation	0.046	0.054	0.721	0.659	0.757	0.785	0.069	0.068	0.023	0.014
Health	0.020	0.024	0.759	0.775	0.653	0.665	0.027	0.030	0.007	0.006
Education	0.032	0.035	0.783	0.775	0.545	0.684	0.037	0.045	0.006	0.010
Toiletry	0.028	0.024	0.460	0.474	0.735	0.794	0.026	0.022	-0.002	-0.002
Clothes	0.034	0.032	0.509	0.532	0.664	0.766	0.031	0.032	-0.002	-3.0E-04
House and durable goods	0.036	0.031	0.881	0.889	0.778	0.745	0.068	0.050	0.032	0.019
Services and rent	0.134	0.127	0.614	0.604	0.856	0.841	0.194	0.157	0.060	0.030
Taxes	0.010	0.011	0.822	0.792	0.760	0.757	0.017	0.017	0.007	0.005
Recreation, ceremony	0.015	0.011	0.854	0.904	0.563	0.559	0.020	0.013	0.005	0.002
Per capita expenditure			0.362	0.411						

Source: Author's computation

It is also fruitful to compare the figure of the emission inequality decomposition with the inequality decomposition of expenditure sources as shown in **Table 2.5**.

Here we indicate that fuel-light expenditures no longer have a large contribution to overall expenditure inequality (only about 6%). The biggest portion is services, beverage and egg-fish-dairy products.

We further aggregate the emission source and expenditure sources as shown in **Table 2.4** and **Table 2.5** into four major emission (expenditure) categories, namely food, energy and transportation, housing operation and durables, and services[24]. We then compute the same application to get a deeper understanding of the sources of inequality in emissions and expenditure. The results are summarized in **Figure 2.4**.

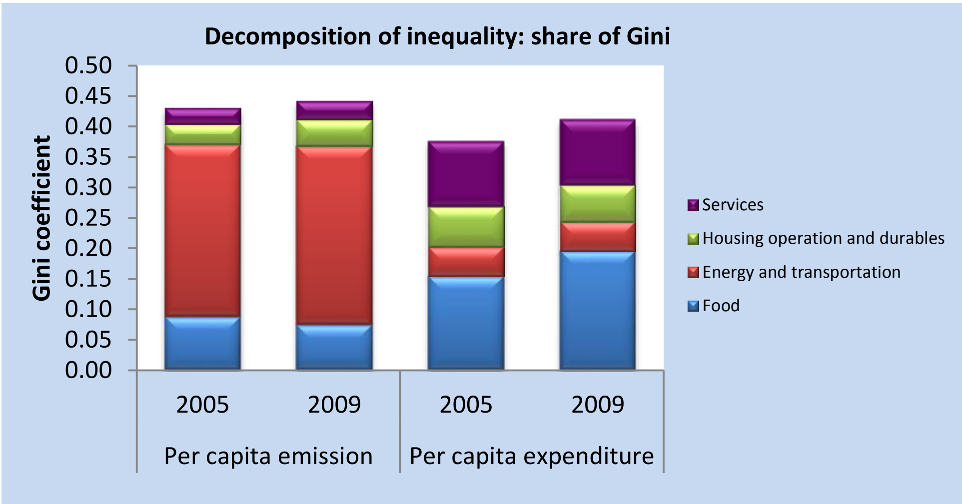

Figure 2.4 Sources of inequality: emission vs. expenditure
Source: Author's computation based on share of Gini

We indicate that there was an increase in the emission and expenditure inequality measure from 2005 to 2009. However, we observed a different story about the contributors to the inequalities in emissions and expenditure. For the emission inequality contributors, it is noticeable that in both years, energy-transport is responsible for more than two-thirds of the overall emission inequality, followed by services and household operations, so if we get rid of the disparity in the energy-transport emissions, then the overall emission inequality will reduce by the

[24] "Food" refers to emissions from cereals, vegetables and fruits, oil and fats, eggs fish, meat and dairy, and tobacco; "Energy and transportation" captures the emissions from fuel-light and transportation; "Housing operations and durables" represents emissions from house operation and durables, toiletry, and telecommunication; "Services" represents emissions from health, education, services sectors and rent, tax and redistribution, and recreation and ceremony.

same amount. For expenditure inequality, we found that the main contributors to inequality are food (mainly beverages) and services.

2.5 Conclusion

This study investigates the dispersion in per capita CO_2 emissions by employing various measures of inequality and then comparing the differences between the emission and expenditure inequality indices. We also decompose emission inequality based on household affluences, socio-demographic factors as well as sources of emissions to assess the patterns and drivers of inequality. Disaggregating emission inequality into any particular within-group inequality based on different household characteristics assumes that different characteristics would have different within-inequality measure in emissions. And decomposing inequality by emission sources aims to measure the contribution of emission shares and to study the marginal effects of changes in different emission sources to the change in overall emission inequality.

We found that as household affluence increases, emission inequality tends to decline until the middle household affluence group, but then increases and worsens emission inequality until the richest group, which is the most unequal group in terms of the within group inequality measure of emissions. This evidence could hint that the variation in consumption preferences (lifestyle), particularly toward emission-intensive items, determines overall emission inequality. As the inequality measure based on household affluence, the emission inequality figure based on educational attainment has a similar pattern. Classifying observation according to the number of household members, we observe an U-shaped pattern of inequality figures from the smallest to the largest household size group. Based on location, the per capita emissions in urban areas are observed to be more unequal than the figure from rural households. Based on gender, we found that the group of male-headed households is more equal than the female-headed group. Based on the age of household head, we found younger household head groups have a lower emission inequality. In addition, dividing observation based on their affluence, we found a dominant contribution of “between group” component of inequality compare to between-group component. However, classifying based on non-expenditure characteristics, we found that "within-group inequality" dominates overall inequality.

The decomposition analysis of inequality based on emission sources suggests that in both years, energy-transport emissions were responsible for more than two-thirds of the overall emission inequality. It is then noticeable that the change in overall emissions can be reflected by dominant contribution of energy-related emission source and to some extent attributed to a rise in the share of emissions from services, durable goods and luxury. The decomposition of the emission and expenditure inequality suggests a different story about the contributors to inequalities in emission and expenditure. While the largest contributor to emission inequality is energy-transport (followed by services and household operations), food (mainly beverages) and services are the largest contributors to the expenditure inequality.

Although there are only a limited number of empirical studies related to household emissions inequality, we could compare this study to international (cross-country), national and regional perspectives to investigate whether our household level analysis mirrors the results from more macro perspectives. One piece of evidence suggests that emission inequality is dominantly explained by the between-affluence component, which is reasonably consistent with Clarke-Sather et al. (2011) for a provincial-level analysis in China. Other studies (e.g. Padilla and Serrano, 2006; Levy et al., 2009; Duro and Padilla, 2006) report that inequality between groups of different income levels largely explains the overall emission inequality. Our findings then suggest that the level of affluence dominates the emission inequality, although non-income characteristics might also contribute to the overall emission inequality.

Finally, the improvements in the standard of living of poor households may initially promote a declining the emission inequality, as indicated by the decomposition of inequality across affluence quintiles. Yet a balanced development has to be sought out as growth in the higher quintiles, particularly the two richest quintiles will then push emission inequality wider. Therefore, rising environmental awareness from the demand side could be taken in line with providing households with greener consumption items, green infrastructure, and sustainable (public) transport system. A carbon tax could be also introduced in line with a gradual reduction (and better targeting of) fossil fuel subsidies. Another important strategy in reducing emission inequality is the effort towards the improvement of energy and carbon efficiency allowing households, at any level of affluence, to consume carbon-efficient consumption items that will not merely reduce the emission level but also reduce the emission inequality.

Chapter 3 : Examining causality between economic development, energy consumption, and emissions in Indonesia

Examining causality between economic development, energy consumption, and emissions in Indonesia

Abstract

This chapter investigates the causality nexus between emissions, energy use and economic performance along with urbanization and capital formation (investment activity) taking Indonesia as a case study, employing single equation ECM, VECM, DOLS, and the augmented-VAR approach to investigate the presence and direction of long-run and short-run causality amongst variables. We found the direction of long-run causality running from output and energy consumption to emissions but not in opposite direction from emissions to output and energy consumption, suggesting the possibility of reducing emissions without impeding growth. The short-run augmented-VAR approach found similar evidence of a unidirectional Granger causality running from output to emissions but not in the opposite direction, indicating that green growth could be also possible in the short run. Urbanization and capital formation will unsurprisingly increase energy consumption but could be carbon-neutral if energy efficiency, sustainable urban development and green investment are promoted. Results also indicate that the greater variations of emissions in the longer period are mainly due to rising economic performance.

Keywords: economic growth, emission, energy use, causality

3.1 Introduction

Over the last two decades Indonesia has come a long way in its socio-economic development with relatively fast and stable economic growth. Although there was a deep recession during the Asian economic crisis at the end of 1990s, since that period the economy emerged significantly growing at about 5-7% per year. The pace did not change even with the recent global crisis in 2008; while the United States and European Union countries have been experiencing a recession, Indonesia has been growing above the country averages. The Indonesian government even has set for itself the ambitious target of becoming one of the ten largest economies in the world by 2025 with an expected per capita income of USD 14,250-15,500 (Ministry of National Planning, 2011).

However, the figures of environmental damage have also amplified as a consequence of the fast growing economy in the last decades. Among emerging economies, this country is one of main contributors of world CO_2 emissions as well as one of the most accelerating contributors to global emissions (EDGAR, 2011)[25]. Along with deforestation, industrial based economic growth and rising middle-income class consumption are what lead to this rising CO_2 emissions profile. The growing trend of CO_2 emissions generates debatable issues, particularly for Indonesia. One of central questions is whether Indonesia can push growth without causing environmental degradation, or whether this country can implement emission reduction without impeding growth. To address these issues, this study will examine the econometric relationships between output, emissions and socio-economic development, including rising urbanization and investment.

Recent studies investigated the relationship between GHG emissions (mainly CO_2 emissions) and socio-economic development, ranging from cross or panel studies (e.g. Selden and Song, 1994; Dinda and Coondoo, 2006; Coondoo and Dinda, 2002; Baek et al., 2008; Bernard et al., 2011; Choi et al., 2010; Martinez-Zarzoso and Maroutti, 2011) to more specific national/regional analyses (e.g. Zaman, 2010; Zhang and Cheng, 2009; Tiwari, 2011; Akbostanci et al., 2009; Nasir and

[25] See **Appendix Table C.12.**

Rehman, 2011). As for the determinants of environmental degradation, Shafik (1994) differentiates them into structural and policy drivers; which are as follows: (1) endowment, such as location and climate; (2) income, reflecting the production structure, private consumption patterns, and urbanization; (3) other exogenous factors such as technology in particular; and (4) policies, reflecting public decisions related to environmental public goods.

One of the central issues in the literature on development and the environment (climate change) is a question regarding the relationship between CO_2 emissions, economic growth, and energy use. A quick glance at the literature shows that there are at least three nexuses for the relationships of the three variables, which are as follows. The first nexus basically focuses on income and energy use that proposes as the economy grows, energy consumption increases as one of the important elements in making growth possible. In this line of research, a number of studies (e.g. Kraft and Kraft, 1978; Masih and Masih, 1996, 1997; Narayan et al., 2008) generally measure the existence and direction of causality between economic growth and energy consumption. In the US case, Kraft and Kraft (1978), for instance, found the evidence of an income to energy use uni-directional Granger-causality. Moreover, Masih and Masih (1996) and Narayan et al. (2008) investigated this income-energy use causality using countries panel data, but they found that in some cases the causality is ambiguous.

The second nexus deals with the examination of the impact of economic growth on environmental degradation. One of most popular arguments is the hypothesis of the Environmental Kuznets Curve (EKC) that suggests an inverted U-shape relationship between economic performance and environmental degradation (e.g. Selden and Song, 1993; Grossman and Krueger, 1995; Stern, 2004; Dinda and Coondoo, 2006; Akbostanci et al., 2009; Martinez-Zarzoso and Maroutti, 2011; Nasir and Rehman, 2011). However, it is found that their results, whether employing cross-country or single country data, differ substantially and are to some extent inconclusive. For instance, Grossman and Krueger (1995), employing the reduced-form relationship between per capita income and a number of environmental indicators including emissions, indicated no evidence that steady environmental degradation correlates with economic performance, but for most environmental indicators, a growing economy reasonably causes an initial stage of environmental decline. Selden and Song (1993), which investigate the EKC for four air pollutants, found that per capita emission of all emission sources reveal an inverted-U relationships pattern with respect to per capita output, suggesting that the emissions will decrease in the long-run.

However, numerous studies suggest that the discussion on EKC is inadequate. For instance, Coondoo and Dinda (2002) and Dinda and Coondoo (2006) propose that there are at least two arguments on this matter. First, the EKC assumption of uni-directional causality from income to emissions could be over-simplistic as environment (less emission) might affect further consumers' wellbeing as well as future income[26]. Second, more importantly, it just assumes the immediacy in causality, i.e. change in one variable would instantly cause change in other variables. In other words, it does not distinctively highlight the dynamic process of change, which is essential in the EKC relationships.

To get a better understanding of the interplay between income and emissions, Coondoo and Dinda (2002) and Dinda and Coondoo (2006) utilize the 'inter-temporal choice model'. Suppose an economy has E(t), K(t), and C(t) that indicate environment, capital stock, and consumption at time t, and assume there is $\theta(t)$ ($0 < \theta(t) < 1$) portion of K is used for production and the remaining $1 - \theta(t)$ of its fraction is allocated for environmental upgrading. Assume there is γ ($\gamma > 0$) of pollution rate (in our case, emission per output), then the infinite time horizon 'inter-temporal choice' could be identified by the following:

$$\text{Max } W = \int_0^\infty e^{-\rho t} U\big(C(t), E(t)\big) dt \qquad (3.1)$$

which would be subject to the accumulation constraints related to the physical capital formation, $\dot{K} = f(\theta K(t), E(t)) - C(t)$, and accumulation constraints related to the net environmental change from production as well as upgrading the

[26] It is suggested that emission can affect consumers' wellbeing since it is considered as excludable public goods, and can affect income creations by being virtual input to generate further output (Dinda and Coondoo, 2006).

environment, $\dot{E} = g\big((1-\theta)K(t), E(t)\big) - \gamma f(\theta K(t), E(t))$. In this case, $\rho(>0)$ is the discount rate while $f(\cdot)$ and $g(\cdot)$ represent the production and environmental upgrading functions, respectively. Considering K(t) and E(t) as state variables while C(t) and θ as control variables, the above problem has optimal condition which can be expressed as follows:

$$\alpha(t)\frac{\dot{C}(t)}{C(t)} + \beta(t)\frac{\dot{E}(t)}{E(t)} - \phi(t) = 0 \qquad (3.2)$$

where $\alpha(t) = \frac{C(t)U_{CC}}{U_C}$, $\beta(t) = \frac{E(t)U_{CE}}{U_C}$, and $\phi(t) = \left(-\frac{f_K g_K}{g_K + \gamma f_K} + \rho\right)$

U_C, U_{CC}, U_{CE} are the 1^{st}- and 2^{nd}- order partial derivatives of $U(\cdot)$, while f_K and g_K represent the 1^{st}-order derivative of $f(\cdot)$ and $g(\cdot)$ with respect to K, respectively.

The above conditions propose that the time paths of income (C), and emission (E) should be interdependent, indicating that there would generally exist two-way causality between output and emission. Meanwhile, if we suppose a case where $U_{CC} = 0$ but $U_{CE} \neq 0$, then an autonomously selected path of income (C) suggests that the emission time path (E) will be driven by the optimality condition. Since E is driven by C (autonomous), we can say to have the case of the income to emission uni-directional causality. Last, for the case where $U_{CC} = 0$ but $U_{CE} = 0$, the time path of C is driven conditional upon the autonomously selected time path of E, indicating the emission to income uni-directional causality.

To determine the direction of causality, it is possible to employ a (time-series) econometric causality test to observe the direction of causality between income and emission. The Granger-causality test is one of the widely known applications to test the presence of such statistical feedback effects between (at least) the two series of variables in the system.

In the empirical analysis, Coondoo and Dinda (2002) analyze the income-emission causality for different groups of countries using the Granger causality test. They found that contrary to developed countries (North America and Western Europe in their study case), which have causality running from emission to income, developing countries in Latin America and Oceania show an income to emission uni-directional causality. For Asia and Africa, they found the causality to be bi-directional. Similarly, Dinda and Coondoo (2006), analyze the direction of the income-emission causality by applying a cointegration analysis, Granger causality, and an ECM. They found a bi-directional causal relationship between the two variables for several regions such as Africa, America, Europe, and the whole world.

The third strand of the literature combines the first two nexuses in a single framework, which examines the causality between emissions, energy use, and output. The main idea of this nexus is partly to avoid omitted variable bias problems by modelling income, energy use, and emissions in separate models. A quick glance of the literature showed these studies are mostly conducted for single countries. Zhang and Cheng (2009), Jalil and Mahmud (2009), Tiwari (2011) are among contributors to this group of literature.

In addition to just three variables, numerous studies also add other control variables into the system. For instance, Choi et al. (2010) investigate the relationships between CO_2 emissions, output and openness for three countries including China (representing emerging markets), South Korea (representing newly industrialized countries), and Japan (representing developed countries). Employing the VECM for the data from 1971 to 2006, the findings show that there is no uniform evidence of the environmental effects due to economic growth and openness for all countries. The estimated EKC shows different patterns due to differences in national characteristics[27].

From a policy perspective, this study will also replicate the above investigations by using the case of Indonesia, following the single-country analysis, such as the US case (Soytas et al., 2007), China (Zhang and Cheng, 2009), and India (Tiwari, 2011), which generally links emission, energy use, and economic growth. Soytas et al. (2007), employing the Granger-causality method and including labor and gross fixed capital formation in the model, generally found that although energy

[27] In terms of curve patterns, China has an N-shaped while Japan has a U-shaped. For the relationships between CO_2 emissions and openness, Korea and Japan show inverted U-shaped,while China has a U-shaped.

consumption Granger-causes emissions, income does not Granger cause emissions in the US in the long run. They later propose that economic growth by itself could not become a solution to environmental degradation. For the Chinese case, Zhang and Cheng (2009), also using the Granger causality method but including capital and urban population in the system, found a uni-directional causality running from income to energy consumption and an income to energy use uni-directional causality in the long run. As their findings indicate that neither emissions nor energy use leads to economic growth, they propose that the Chinese government could pursue long-run conservative emissions reduction and energy policies without impeding economic growth. For the Indian case, by applying VECM-Granger causality and the VAR Dolado-Lütkepohl's approach the authors found that emissions Granger-cause output, but energy use does not. In the opposite direction, GDP does not Granger-cause emission, while energy consumption does. Emissions Granger-cause energy use but GDP does not Granger-cause emissions. Their findings suggest that India may choose an energy conservation strategy in line with efficient energy utilization.

Specifically, the objectives of this study are as follows. First we will examine the existence and direction of long-run and short-run causality between economic growth, energy consumption and CO_2 emissions employing several recent time series analyses. We further ask whether urbanization, investment (gross-fixed capital formation), and other possible control variables matter. Second, what is the reaction of variables (particularly CO_2 emissions) overtime in response to some external shocks (economic growth, energy consumption, urbanization, and investment). Third, we measure the contributions of each variable overtime to other variables as well as how much of any variable can be explained by exogenous shocks to the other variables in the system.

Therefore, the novelties of this study are as follows. First, we will employ a multivariate analysis, which combines the two nexuses of growth-environment and growth-energy into a single model (e.g. Soytas et al., 2007; Zhang and Cheng, 2009; Tiwari, 2011). Second, in terms of the methodological aspect, this study employs various time series applications ranging from the single equation Engle-

Granger cointegration to Dynamic OLS, Vector Error Correction Estimation, and 'modified' VAR, to partly deal with data properties as well as to employ robustness checks, which will be explained in more detail in the methodology section. Third, this study could fill a gap in the previous literatures by using time series data for the single country of Indonesia (e.g. Saboori and Soleymani, 2011, and Shahbaz et al., 2012)) as we add other possible control variables including urbanization (e.g. Hossain, 2011; Martinez-Zarzoso and Maruotti, 2011), and capital formation (e.g. Soytas et al., 2007; Zhang and Cheng, 2009). Moreover, a single-country time series analysis (Indonesia for this case) may identify a relationship amongst variables and allow us to examine the impact of development conditions (urbanization, capital stock, environmental policies), and other exogenous factors through time. The study conducted for Indonesia using national time-series data would represent a country case study to the literature as well as provide helpful information for policy implications in the sense that it identifies the specific tendencies for that country.

The rest of this paper will be organized as follows. Section 3.2 will provide an overview of Indonesia as a case study. Data, model and estimation strategies will be explained in Section 3.3 followed by Section 3.4, which provides the empirical results and discussions. The final part provides conclusions and possible policy implications.

3.2 Indonesia: a case study

Among several interesting features on why Indonesia is an interesting country to analyze due to the economic, demographic, as well as the country's energy policies. First, regarding the overall macroeconomic stance, this country has experienced an economic crisis in 1997-1998 but since then per capita GDP has returned to growth, and has been rising despite the global financial crisis of 2008. Domestic consumption is the main driver of the economy; which roughly accounted for about 56.7% of GDP in 2010, followed by investment (32.2%), and government consumption (9.1%). In terms of international trade, Indonesian exports depend on natural resource products (mainly gas, crude coal, crude palm oil), which accounted for about 50% of overall exports (BPS, 2010).

Second, looking at the oil and gas sectors, as the total oil production cannot meet rising consumption, Indonesia has been a net importing country since 2004 and has left the Organization of Petroleum Exporting Countries (OPEC) in 2008. Moreover, this country has been struggling with a huge subsidy on energy (fuels and electricity), which accounted for about 22.9% of the 2012 overall budget (Ministry of Finance, 2012). In addition, it has caused high opportunity cost and was poorly targeted as 80% of the fuel subsidies only benefited the highest income quintile (Ministry of Energy and Mineral Resources, 2012).

Third, the challenges in GDP composition and energy subsidies are then strengthened by the demographic development. According to the official census (BPS, 2010), from 240 million population based on 2010 census, 58% of them are living in Java and Bali (which just account for around 6% of all Indonesian land area). Massive urbanization has been also another challenge. The urban population accounts for about 44% (2010) of the total population, double the figure in the 1980s. The expected growth rate of urbanization from 2010 to 2015 is around 1.7% annually, which is higher than the 1.03% population growth rate. In addition, the recent report of the median age of the total population is 28.5 years, meaning there is a demographic bonus since 17.1% and 42.2% of population is around 15-24 and 25-54 year old, respectively.

3.3 Data and estimation strategies

3.3.1 Data and theoretical model

We use annual data from 1971 to 2010 of CO_2 emissions (in kg per capita), real per capita GDP (in constant 2000 USD), energy consumption (in kg oil equivalent per capita), urban population, and capital formation. All data are taken from

World Development Indicators (WDI)[28]. Historical data are shown in **Appendix Figure C.1.**

We utilize several estimation techniques to analyze the long-run and short-run causality between emission, energy consumption and economic development. First we employ a log linear specification to measure long-run causality between emission, energy consumption and output using OLS estimates as benchmark. The long-run causality can be expressed as follows:

$$LNCO2CP_t = \alpha_0 + \alpha_1 LNECP_t + \alpha_2 LNYCP_t + \varepsilon_t, \quad (3.3)$$

where $LNCO2CP_t$, $LNECP_t$, and $LNYCP_t$ represent per capita CO_2 emission, per capita energy use, and per capita output (all in natural logarithm), respectively. ε_t is the error term assumed to be iid $(0, \sigma^2)$. We also implement adequately modified equations utilizing LNECP and LNYCP as the dependent variables.

3.3.2 Tests for univariate integration, multivariate cointegration, and short-run estimations

Before the examination of long-run causality, we follow common practice in time series econometric analysis since classical OLS regression properties only hold when the variables are integrated at level, I(0), or stationary. In most cases however economic variables are just integrated in the first difference, I(1), or higher, hence they do not satisfy classical assumptions. The first step is to determine the order of integration of each series of variables. We employ the standard technique Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979), and Phillip-Perron (PP) (Phillips and Perron, 1988) unit root tests on individual

[28] The WDI basically reports the per capita CO_2 emissions from Carbon Dioxide Information Analysis Center (CDIAC) that calculates CO_2 emissions from the burning of fossil fuels and the manufacture of cement. They also include CO_2 produced during consumption of solid, liquid, and gas fuels and gas flaring (http://cdiac.ornl.gov/). The data of energy of the WDI are taken from International Energy Agency (IEA) Statistics that accounts use of primary energy before transformation to other end-use fuels, which equals to indigenous production plus imports and stock changes, minus exports and fuels supplied for international transport (http://www.iea.org/stats/index.asp).

series in levels, first differences, second differences. The null hypothesis is that the series contains a unit root (non-stationary).

Variables do not satisfy the OLS assumption when they are integrated of order 1 or higher, but if an error correction mechanisms or a long-run relationship exists, we can interpret the OLS estimation as the long-run relationship. In this case, the variables are supposed to be cointegrated and OLS estimation of these cointegrated variables may be super-consistent.

Numerous methods are commonly applied to examine the presence of cointegration. We first apply the Engle-Granger cointegration method (Granger, 1986; Hendry, 1986; Engle and Granger, 1987). This test basically argues that two or more variables are cointegrated (they reveal long-run equilibrium relationship) if they share common trends (Masih and Masih, 1996). Granger (1986, 1988) argues that if two variables are cointegrated, one can rule out the non-causality. Given this, there should exist causality, in the Granger sense, being either uni-directional or bidirectional[29].

Technically, this approach suggests conducting a unit root analysis to the OLS residuals of the supposed long-run model to detect the presence of cointegration. If residuals are stationary or integrated at level, I(0), the model is considered to be cointegrated and there should be a valid long-run relationship between variables which rules out the possibility of the estimated relationship being spurious. In order to do so, we can utilize the ADF test to check the unit root properties of residuals. The null hypothesis is that residuals have unit roots (non stationary). The ADF test of Engle-Granger cointegration test follows the McKinnon critical value.

However the OLS approach in the Engle-Granger technique could have certain problems related to the parameter bias and endogeneity of regressors. In this regard, the estimated parameter could be biased particularly in the presence of dynamic effects and small samples. In addition, if we analyze more than two

---

[29] The Granger causality aims to determine whether one time series variable forecast another, the causality in the Granger sense is then considered as 'predictive causality' since it is just reflected by predicting the future values of a (time series) variable utilizing the historical values of another (time series) variable (Granger, 1969; Geweke, 1984).

regressors, it is possible that we have more than one cointegrating relationship due to the endogeneity of the regressors. These issues motivate us to employ an alternative procedure developed by Johansen and Juselius (1990, 1992), which could improve the single equation cointegration in several ways: (1) the presence of more than one cointegrating vector is not excluded a priori but it is even incorporated in the testing procedure; (2) the Johansen-Juselius approach assumes the regressors to be endogenous, thus it relaxes the assumption of one direction causality; (3) it provides a powerful set of tests, which allow us to identify the number of cointegrating vectors as well as the possibility of evaluating the effect of various restrictions. Technically, the Johansen approach tries to identify the rank of Π matrix in the following equation:

$$\Delta X_t = \partial + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi \Delta X_{t-k} + \mathcal{E}_i \quad (3.4)$$

where X_t represents a vector of m variables, Γ, Π represent coefficient matrices, Δ represents difference operator, k is the lag length and ∂ is constant.

To examine the number of cointegrating vectors (rank of Π, r), we should first estimate the parameters of the matrix Π to get the associated eigenvalues. Zero rank of Π means that no stationary linear combination can be identified. Meanwhile if rank of matrix is more than zero, there would be r possible stationary linear combination(s) so that Π could be decomposed into $\Pi = \alpha\beta'$, α and β have $m \times r$ dimensions. α contains the coefficient of adjustment, and β comprises the coefficient of the r distinct cointegrating vectors that make $\beta' X_t$ stationary albeit X_t is non-stationary.

Given that variables are cointegrated, Engle and Granger (1987) claim the presence of a corresponding error correction terms, ECT, which captures that apart from changes in the other explanatory variables, the dependent variables change as a function of the level of disequilibrium in the cointegrating relationship. We first follow the Johansen-Juselius method (Johansen and Juselius, 1990, 1992) to estimate the vector error correction specification. For the emission (lnCO2P), the VECM is expressed as follows:

$$\Delta \text{LNCO2CP}_t = \sum_j^J \varphi_j \Delta \text{LNCO2CP}_{t\text{-}j} + \sum_{j=1}^J \phi_j \Delta \text{LNECP}_{t\text{-}j} + \sum_{j=1}^J \phi_j \Delta \text{LNYCP}_{t\text{-}j} + \alpha(\text{LNCO2P}_{t\text{-}1} + \beta_1 \text{LNECP}_{t\text{-}1} + \beta_2 \text{LNYCP}_{t\text{-}1}) + \text{E}_t \quad (3.5)$$

We implement the same procedure with energy use (LNECP) and output (LNYCP) as dependent variables. Intuitively, we can interpret when variables are cointegrated, and then the short-run deviations from the long-run equilibrium will feed back on the changes in dependent variables so as to force the movement towards the long-run equilibrium.

3.3.3 Long-run estimation and long-run Granger-causality: DOLS

Thomas (1993) discussed that theory typically has nothing to say about short-term relationships. Hence it is important to estimate long-run coefficients in the system. Apart from the Johansen-Juselius procedure that is a maximum likelihood approach, we also employ an alternative approach, namely dynamic OLS (DOLS) as proposed by Stock and Watson (1993), which has certain advantages over OLS procedures since it remedies sources of OLS bias from small samples and dynamic sources. It also has an advantage over maximum likelihood given the possibility in the Johansen-Juselius approach (full information technique) that estimation in one equation could be affected by other estimation's misspecification in the VAR system. In contrast, the DOLS approach is fairly robust since it removes the endogeneity of the regressors by the inclusion of lead(s) and lag(s) of the first difference of all regressors. Moreover, it can be free from serial correlation of errors by using the generalized least square (GLS) procedure. The standard error of DOLS estimation follows Newey and West (1987). It has also another benefit since it has the same asymptotic optimality properties as the distribution of Johansen technique. Technically, modifying Masih and Masih (1996) and Saikkonen (1991), the DOLS model can be expressed as follow:

$$\text{lnCO2CP}_t = c_0 + c_1 \text{lnECP}_t + c_2 \text{lnYCP}_t + \sum_{i=-p}^{i=+p} \Phi_i \vartriangle \text{lnECP}_{t-i} + \sum_{i=-p}^{i=+p} \Psi_i \vartriangle \text{lnYCP}_{t-i} + \mathcal{E}_t \quad (3.6)$$

where p represents lead(s) and lag(s) of all regressors, accounting for possible endogeneity of regressors and serial correlation. We implement the same procedure with LNECP and output LNYCP as dependent variables. Suppose that LNCO2CP is I(1) and LNECP and LNYCP are I(1) and cointegrated, then the DOLS estimates can be obtained.

When variables are cointegrated, we could then estimate the direction of causality between all variables by conducting Granger-causality through estimating the following ECM:

$$\Delta LNCO2CP_t = \sum_j^J \theta_j \Delta LNCO2CP_{t-j} + \sum_j^J \phi_j \Delta LNECP_{t-j} + \sum_j^J \varphi_j \Delta LNYCP_{t-j} + \lambda ECT_{t-1} + u_t \quad (3.7)$$

ECT that is derived from lagged residuals of DOLS estimation (3.6). A negative and significant λ reveals the presence of long-run Granger causality from the regressors to the dependent variables.

3.3.4 Extended short-run analysis: Augmented-VAR estimation

Finally, when adding other variables into the VAR system, namely urbanization and capital formation, we employ a modified (lag-augmented) VAR as proposed by Toda and Yamamoto (1995). Some of the central reasons for applying this method are related to flexibility regarding the possibility to implement this technique for variables with different orders of integration (Toda and Yamamoto, 1995). There are several steps included in conducting this estimation technique. First, measuring the order of integration of all variables (called d). Second, determining the optimum lag length criteria of the original VAR model (called p) employing Akaike information criterion (AIC), Schwarz information criterion (SBC), and the sequential modified lag length statistic (LR), all test at the 5% critical value. Third, estimating the modified (lag-augmented) VAR model by augmenting original VAR(p) to VAR(p+d) through the following formula:

$$V_t = \delta_0 + \delta_1 V_{t-1} + \delta_2 V_{t-2} + \cdots + \delta_p V_{t-p} + \delta_{p+d} V_{t-p-d} + \varepsilon_t \quad (3.8)$$

where V is vector of variables, δ_0 is vector of constant, δ_p is coefficient matrix, and ε_t is white noise residuals (Toda and Yamamoto, 1995; Soytas et al., 2007; Zhang and Cheng, 2009; Tiwari, 2011). Fourth, having checked the robustness (via diagnostic tests) of the augmented VAR(p+d), a Wald test is employed on the first p parameters instead of on all parameters in the augmented VAR(p+d) model, and the statistics follows an asymptotic χ^2 distribution with p degrees of freedom (Toda and Yamamoto, 1995), where the null hypothesis is that the row i, column j element in δ_k equals zero for k=1,2 … , p. The rejection of the null hypothesis indicates that the j_{th} element of V_t does Granger-cause the i_{th} element of V_t, and vice versa.

In addition to the modified Granger Causality, we also estimate our model employing two well-known innovations, namely variance error decomposition (VED) and impulse response function (IRF). The VED investigates how change in a variable (shown as variance error) that is determined by other variables and to see the strength of each variable in explaining other variables in the longer period. The IRF examines how and for how long variables respond to innovations in other variables overtime. In other words, it traces out the responsiveness of the dependent variables to shocks to each of other explanatory variables overtime (Enders, 2009).

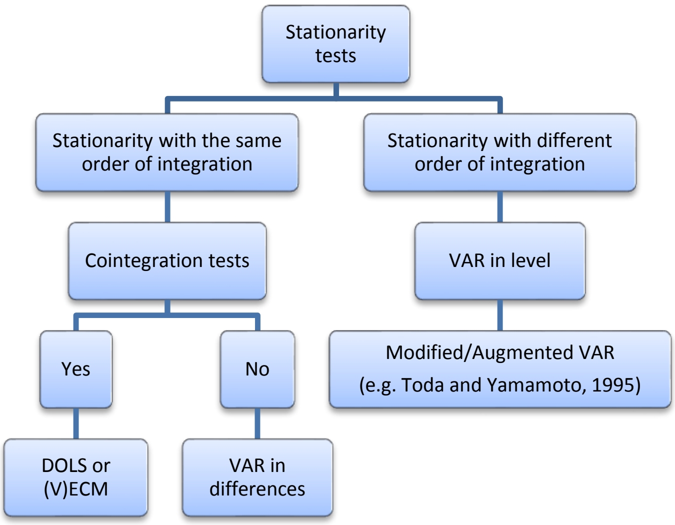

Figure 3.1 Analytical framework

Source: adapted from Engle and Granger (1987), Johansen and Juselius (1990, 1992), Stock and Watson (1993), Toda and Yamamoto (1995), Enders (2009).

Figure 3.1 summarizes our analytical framework that has been explained before. First we figure out the order of integration of each series of variables by means stationarity tests. If the variables have the same order of I(d), it is possible to employ tests of cointegration such as Engle-Granger's method or Johansen-Juselius procedure. The presence of cointegration allows us to estimate series variables using single-equation (or vector) ECM to estimate long-run and short-run coefficients. Once the variables cannot pass the cointegation test, a VAR system could be estimated in first difference although it only captures short-run analysis. Second, the case variables have different orders of integration I(d) leads us to conduct VAR in levels. One way of doing VAR in levels is, as proposed by Toda-Yamamoto's approach, by augmenting the original VAR(p) with a maximum order of integration of variables in the system.

3.4 Results and discussions

The preliminary stage in time series data is the test of the existence of unit roots, which assesses the order of integration of each variable. The ADF and PP tests are summarized in **Table 3.1.** In general, we found that LNCO2CP, LNYCP, and

LNECP are integrated at first difference, I(1), while urban population (LNU) and capital formation are integrated at I(2) and I(0), respectively. To sum up, the unit root analysis indicates that the integration orders of all variables do not appear to be exceeding I(2).

Table 3.1 Unit root analysis

	ADF test statistic		PP (adjusted) test statistic	
Variables	**Constant**	**Constant and trend**	**Constant**	**Constant and trend**
Level, I(0)				
LNCO2CP	-2.72*	-1.61	-2.87*	-1.87
LNECP	-1.49	-2.11	-1.49	-2.11
LNYCP	-1.42	-2.13	-1.33	-1.98
LNU	2.20	0.63	4.10	3.48
LNK	-2.92*	3.47**	-5.25***	-3.97**
First difference, I(1)				
D(LNCO2CP)	-5.11***	-5.73***	-5.11***	-5.72***
D(LNECP)	-7.40***	-7.37***	-7.25***	-7.24***
D(LNYCP)	-4.53***	-4.57***	-4.53***	-4.58***
D(LNU)	-0.19	1.98	-0.03	-1.89
2nd difference, I(2)				
D(LNU,2)	-6.35***	-6.50***	-6.37***	-7.11***

Source: Author's estimation. Note: * (**, ***) indicates significance at the ten (five, one) percent level. For the ADF test, the lag length is based on the AIC.

In the first step, we estimate the long-run causality by applying the Engle-Granger cointegration and single equation error correction model (ECM) for the three main variables including emission, energy use, and income. We first estimate emissions as the function of energy use and income as presented in **Table 3.2**. We then conduct the ADF unit root test for the residuals of this estimation to examine the presence of a long-run relationship between three variables (presented in **Appendix Table C.3)**. As the residual is integrated at I(0), it is clearly suggested there is a cointegration between emission, energy use, and income. Hence we can interpret the OLS parameter estimates as long-run coefficients.

Table 3.2 presents simple OLS estimations that regress emission on energy use and output. Estimating output as a function of both energy use and output, we found that the long-run elasticity of energy consumption and income on emission are about 0.68 and 0.71 respectively. However, estimating the emission function without energy use found a higher elasticity of income at about 1.43, while estimating emission as a function of energy use found that energy use elasticity to be about 1.34. All long-run elasticities have the predicted signs and are significant. Engle-Granger short-run estimates can be seen in **Table 3.3**. The model passes all diagnostic tests (normality, serial correlation, and heteroskedasticity). We found that the ECT coefficient is about -0.25, suggesting that the speed of adjustment of the disequilibrium (to long-run equilibrium) is about 25% annually. From the short-run estimates, although output does not have a significant short-run impact, it does have a significant impact in the long-run.

Table 3.2 Long run estimates: OLS

	Dep. Variable: LNCO2CP					
	A		B		C	
Variable	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
LNECP	0.6799***	0.1106	1.3397***	0.0278		
LNYCP	0.7123***	0.1174			1.4222***	0.0297
C	-1.9978***	0.1522	-1.4273***	0.1668	-2.4341***	0.1889
R^2	0.9919		0.9839		0.9837	
Adjusted R^2	0.9915		0.9835		0.9832	

Source: Author's estimation. Note: * (**, ***) indicates significance at the ten (five, one) percent level.

Table 3.3 Short-run estimates: ECM

	Dependent variable: D(LNCO2CP)	
Variable	Coefficient	Std. Error
ECT(-1)	-0.2536***	0.1049
D(LNECP)	0.3749***	0.0828
D(LNYCP)	0.2168	0.1664
C	0.0315***	0.0086
R^2	0.4523	
Adjusted R^2	0.4053	

Source: Author's estimation. Note: ECT(-1) indicates lagged of residual of Table 3.2 panel A. Note: * (**, ***) indicates significance at the ten (five, one) percent level.

We later compare these single-equation estimation results with other cointegration estimations including Johansen-Juselius procedure and DOLS estimation when variables are cointegrated. The Johansen-Juselius approach suggests the presence of one cointegrating equation since we can reject the null hypothesis of no cointegrating equation at the 5% critical value, both employing trace statistic and maximum eigenvalue (**Table 3.4**). Given this, we can then conduct the VECM-maximum likelihood estimation of the cointegrating vector. Estimating the complete model, the results show consistent signs of long-run elasticity of energy use and income of about 0.06 and 1.18, respectively (**Appendix C.5**). It is important to note that the estimation results are quite different from the single equation Engle-Granger (complete model, **Table 3.2 column A**), given that the

VECM approach treats all variables in a full system (not a partial system), which are dependent on each other. The higher value of income elasticities is however relatively similar to the single equation model without energy use. In short-run analysis, which is the focus of our analysis, it is found that the speed of adjustment of the disequilibrium to long-run equilibrium is about 21.2% annually, which is also close to the single equation estimation (**Table 3.3**).

Table 3.4 Johansen cointegration tests

No. of cointegrating equations			Trace			Maximum eigenvalue		
H0	**H1**	**Eigenvalue**	**Trace statistic**	**5% Critical Value**	**Prob.**	**Max Eigen Statistic**	**5% Critical Value**	**Prob.**
None *	At most 1	0.463304	43.17964	35.19275	0.0056	23.64826	22.29962	0.0322
At most 1	At most 2	0.317050	19.53138	20.26184	0.0628	14.49070	15.89210	0.0819
At most 2	At most 3	0.124228	5.040685	9.164546	0.2790	5.040685	9.164546	0.2790

Source: Author's estimation. Note: Note: ECT(-1) indicates lagged of residual of Table 2a panel A. * (**, ***) indicates significance at the ten (five, one) percent level.

Table 3.5 Short-run VECM Estimates

Short-run Estimates			
Error Correction:	D(LNCO2CP)	D(LNECP)	D(LNYCP)
ECT(-1)	-0.212939	-0.047260	-0.081293
	(0.04869)	(0.08498)	(0.04420)
	[-4.37378]	[-0.55614]	[-1.83929]
D(LNCO2CP(-1))	0.045064	0.397083	0.114930
	(0.18556)	(0.32388)	(0.16845)
	[0.24286]	[1.22601]	[0.68227]
D(LNECP(-1))	0.028818	-0.319227	-0.006377
	(0.11288)	(0.19703)	(0.10248)
	[0.25529]	[-1.62018]	[-0.06223]
D(LNYCP(-1))	-0.064884	0.280332	0.246254
	(0.21950)	(0.38313)	(0.19927)
	[-0.29560]	[0.73168]	[1.23579]

Source: Author's estimation. Note: Adjustment sample: 1973-2010.
Standard errors and t-statistics are in () and [].

The Stock-Watson's DOLS estimates are presented in **Table 3.6**. We include up to j =+/-2 lags and leads as we use an annual database. The standard errors are following Newey and West (1987). Consistent with the ECM estimates, we found that the expected and significant long-run elasticity of energy use and income are about 0.74 and 0.64 (using a complete model). Estimating the emission equation without energy use as an independent variable, we found that the elasticity of income is 1.42, which is similar to the previous estimation (**Appendix Table C.7**). This suggests that energy use is a key intervening variable linking income to emission. In terms of the serial correlation of the residual, heteroskedasticy, non-normality of residuals, and functional misspecifications, our DOLS estimates are robust to various departures from the OLS regression, and passed stability tests[30].

Table 3.6 Stock-Watson DOLS estimates

Variable	Dependent Variable: LNCO2CP			Dependent Variable: LNECP			Dependent Variable: LNYCP		
	Coef.	Std. Error	Prob.	Coef.	Std. Error	Prob.	Coef.	Std. Error	Prob.
C	-1.956***	0.245	0.000	2.406***	0.391	0.000	0.737	0.730	0.324
LNCO2CP				0.628***	0.153	0.001	0.340	0.308	0.281
LNECP	0.746**	0.263	0.010				0.543	0.448	0.239
LNYCP	0.647**	0.266	0.024	-0.053	0.203	0.797			
D(LNCO2CP)				-0.020	0.195	0.919	0.430	0.424	0.322
D(LNCO2CP(-1))				-0.014	0.169	0.934	0.687	0.447	0.139
D(LNCO2CP(-2))				-0.031	0.182	0.866	0.289	0.329	0.390
D(LNCO2CP(1))				0.102	0.242	0.678	0.876**	0.364	0.025
D(LNCO2CP(2))				0.073	0.261	0.782	0.925***	0.322	0.009
D(LNECP)	-0.013	0.187	0.945				-0.500	0.319	0.132
D(LNECP(-1))	-0.111	0.184	0.555				-0.471	0.298	0.129
D(LNECP(-2))	-0.051	0.118	0.670				-0.139	0.202	0.498
D(LNECP(1))	0.272	0.261	0.309				-0.187	0.194	0.346
D(LNECP(2))	0.199	0.141	0.173				-0.236	0.156	0.143
D(LNYCP)	-0.490**	0.205	0.026						
D(LNYCP(-1))	-0.400*	0.215	0.077						
D(LNYCP(-2))	-0.202	0.182	0.279						
D(LNYCP(1))	0.115	0.189	0.548						
D(LNYCP(2))	0.177	0.117	0.145						
D(LNYCP)				0.213	0.221	0.346			
D(LNYCP(-1))				0.224*	0.113	0.059			
D(LNYCP(-2))				-0.083	0.191	0.667			
D(LNYCP(1))				-0.010	0.110	0.927			
D(LNYCP(2))				-0.055	0.108	0.616			
R^2	0.995			0.987			0.988		
Adjusted R^2	0.993			0.980			0.981		

Source: Author's estimation. Note: * (**, ***) indicates significance at the ten (five, one) percent level.

Having the evidence of cointegration among variables, it is also important to investigate the presence and the direction of long-run Granger-causality using DOLS. Highlighted findings, which focus on ECT estimates, are presented in **Table 3.7**. First, from the emission equation, as we found a negative and significant ECT(-1), we could argue that both energy use and output have a long-run impact due to Granger-causality on emission. Second, from the energy use equation, as ECT(-1) is not significant, we cannot find any evidence that both emissions and output Granger-cause energy consumption in the long-run. Third, from the output equation, findings do not show any evidence of the long-run Granger-causality, neither from emission nor energy use to output. To sum up,

[30] CUSUM and CUSUMSQ stability test

there is in general only evidence of uni-directional causality running from output to emissions as well as from energy use to emissions. These findings could send the message that energy use and output tend to increase emission and in the opposite direction the effort to reduce emission could be achieved without impeding growth.

Table 3.7 Error correction term and long-run Granger causality

	Dependent Variable: D(LNCO2CP)			Dependent Variable: D(LNECP)			Dependent Variable: D(LNYCP)		
Variable	**Coef.**	**Std. Error**	**Prob.**	**Coef.**	**Std. Error**	**Prob.**	**Coef.**	**Std. Error**	**Prob.**
C	0.024**	*0.011*	0.047	0.013	*0.017*	0.453	0.028**	*0.011*	0.014
D(LNCO2CP(-1))	0.354*	*0.204*	0.094	0.577*	*0.284*	0.052	0.069	*0.093*	0.460
D(LNCO2CP(-2))	0.218**	*0.097*	0.034	0.167	*0.274*	0.547	-0.108	*0.088*	0.230
D(LNECP(-1))	-0.207	*0.126*	0.114	-0.449***	*0.158*	0.009	-0.033	*0.133*	0.804
D(LNECP(-2))	-0.097	*0.110*	0.384	-0.084	*0.269*	0.758	0.055	*0.034*	0.119
D(LNYCP(-1))	-0.028	*0.187*	0.883	0.375	*0.285*	0.199	0.336	*0.190*	0.089
D(LNYCP(-2))	0.251**	*0.098*	0.017	-0.138	*0.202*	0.500	-0.022	*0.081*	0.791
ECT(-1)	-0.420**	*0.196*	0.041	0.315	*0.526*	0.554	-0.131	*0.225*	0.565
R^2	0.162			0.113			0.107		
Adjusted R^2	-0.055			-0.117			-0.124		
F-statistic	0.747			0.489			0.464		
Prob(F-statistic)	0.635			0.834			0.852		

Source: Author's estimation. Note: * (**, ***) indicates significance at the ten (five, one) percent level.

Finally, we extend our analysis by incorporating other variables into the system, namely urban population and capital formation to investigate the causality in the short-run. By including these two variables, all series do not have the same order of integration; Toda and Yamamoto (1995) is among the appropriate procedures to estimate the model for both the Granger causality test as well as innovation accounting. Lag length of VAR suggested that based on LR, AIC, and HQ criteria, the maximum lag is about 3, while only SC suggests 1 lag (**Appendix Table C.9**). Then we have to decide how much maximum VAR(p+d) should be employed following the Toda-Yamamoto approach. Having the maximum order of integrations among variables being 2 (d = 2), and the majority of lags of original VAR proposed 3 as the optimum lag (p = 3), we can then augment our model to VAR(p+d) to VAR(5). In addition, choosing this VAR(5), with $V_t = (LNCO2CP_t, LNECP_t, LNYCP_t, LNK_t, LNU_t)'$, also passes the stability tests.

Table 3.8 Short-run Granger-causality

Dependent variable: LNCO2CP		
Excluded	χ^2	Prob.
LNYCP	9.843953*	0.0798
LNECP	13.15049**	0.0220
LNU	4.547104	0.4736
LNK	5.863166	0.3198
All	52.03977***	0.0001

Dependent variable: LNU		
Excluded	χ^2	Prob.
LNCO2CP	5.262322	0.3847
LNYCP	1.150363	0.9495
LNECP	4.411578	0.4918
LNK	2.878113	0.7188
All	43.37403***	0.0018

Dependent variable: LNYCP		
Excluded	χ^2	Prob.
LNCO2CP	7.099016	0.2134
LNECP	9.245992*	0.0996
LNU	4.463491	0.4848
LNK	9.148862	0.1033
All	18.58177	0.5491

Dependent variable: LNK		
Excluded	χ^2	Prob.
LNCO2CP	8.479434	0.1317
LNYCP	7.439830	0.1899
LNECP	9.397698*	0.0942
LNU	7.581426	0.1809
All	26.27474	0.1569

Dependent variable: LNECP		
Excluded	χ^2	Prob.
LNCO2CP	18.77003***	0.0021
LNYCP	1.350570	0.9296
LNU	13.05599**	0.0229
LNK	17.01388***	0.0045
All	73.43952***	0.0000

Source: Author's estimation. Note: Granger-causality is based on block exogeneity Wald test. * (**, ***) indicates significance at the ten (five, one) percent level.

The estimation of the (short-run) Granger causality test highlights some particular findings as summarized in **Table 3.8**. We focus on the direction of causality from output, energy use, urbanization and capital stock to emissions. First, there is a short-run output to emission uni-directional Granger causality[31], but not from the opposite direction. This indicates that while economic growth will increase emissions but the effort to reduce emission could be fulfilled without impeding economic growth.

Second, we indicate the evidence of energy use–emission bi-directional short-run causality[32]. Likewise, this finding suggests that energy can cause rising emission, but effort to reduce emission will impede energy use. For policy perspective, this could send a message to develop low-carbon energy systems such as by intensifying renewable energy uses so as to reduce emissions without harming energy use, which is needed for a growing economy.

Finally, urbanization and capital stock have the same direction of causality to emissions. There is uni-directional causality running from urbanization and

[31] At the 10% significance level

[32] From energy use to emissions at the 5% significance level, and from emissions to energy use at 1% significance level.

capital formation to energy use[33], and more importantly no causality from the urbanization and capital formation to emissions. These findings indicate that both concentrations in urban areas (as a consequence of urbanization) as well as rising investment tend to increase energy use but does not directly trigger rising emissions. Both urbanization and investment could be carbon 'neutral' such as by promoting low-carbon urban development strategies and sustainable investment and energy policies for economic activities.

In addition to the causality analysis among the series, it is also noteworthy to conduct innovation simulations in the VAR system. In this regard, we employ VED to examine what the contributions of other variables overtime are, and the IRF to measure how and for how long variables respond to innovations in other variables overtime. The results, which are presented in **Figure 3.2**[34], can be highlighted as follows. First, variation of emission (LNCO2CP) is initially explained by itself, but the contribution of energy consumption (LNECP), output (LNYCP) and urban population (LNU) significantly increases in the longer period, which was started by the higher contribution of energy consumption from the second period, and urban population from the third period. In the last period of simulation, LNYCP, and LNECP are the two largest contributors to LNCO2CP.

Second, the major variation of LNECP was initially explained by LNCO2CP (64%), but the contribution of LNECP, LNYCP and LNU then increased overtime. This finding confirmed the fact that energy production consists mostly from non-renewable (mainly fossil fuel) resources that have higher carbon intensity (**Appendix Figure C.2**). In the end of the simulation, LNCO2CP still dominantly contributes to the variation of LNECP, followed by LNYCP. Third, more interestingly, the variation of LNYCP is initially contributed by LNECP (63%) but its contribution is decreasing. The contribution of LNCO2CP to LNYCP increases in the longer period and is then relatively constant in the longer period.

[33] At the 5% significance level.
[34] Numerical presentation of the VED is presented in **Appendix Table C.10.**

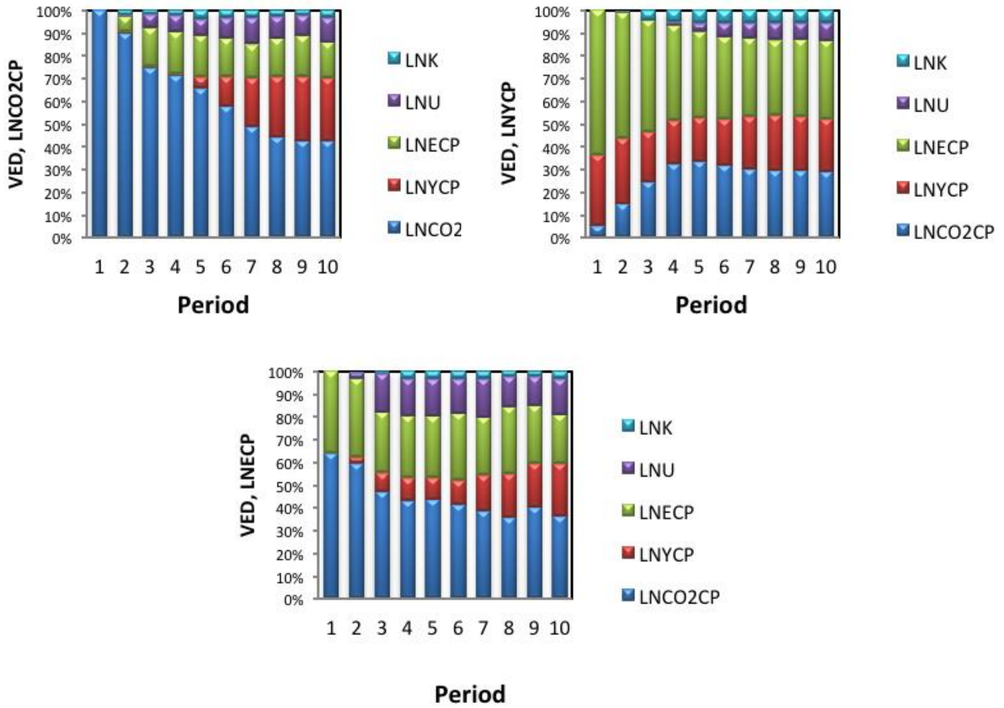

Figure 3.2 Variance error decomposition

Source: Author's estimation

Finally, we conduct a simulation to analyze the response of any variable to any exogenous shock in the system. In order to do so, we utilize IRF which investigates how a shock to one variable affects other variables, as well as how long the effect lasts in the short-run. In other words, IRF allows us to investigate how variables react to a shock in another variable, whether the shock initially occurs and whether it persists in the longer time period, and whether it evaporates quickly or slowly.

Our main findings are summarized in **Figure 3.3**[35]. First, the response of LNCO2CP to the innovations of other variables as follows: (i) the response of LNCO2CP to LNECP is minor in the initial period, then has a negative sign in the second and 6^{th} period but has generally has positive impact in simulation period; (ii) the initial impact of LNYCP to LNCO2CP is initially low and persists with

[35] Numerical presentation can be seen in **Appendix Table C.11.**

positive signs from the third period on; (iii) LNU has a low initial impact on LNCO2CP, and although it has negative impact until the 4th period it has a minor positive effect in the longer period; (iv) consistent with the previous VED analysis, the response of LNCO2CP to capital formation (LNK) is minor over the simulation period.

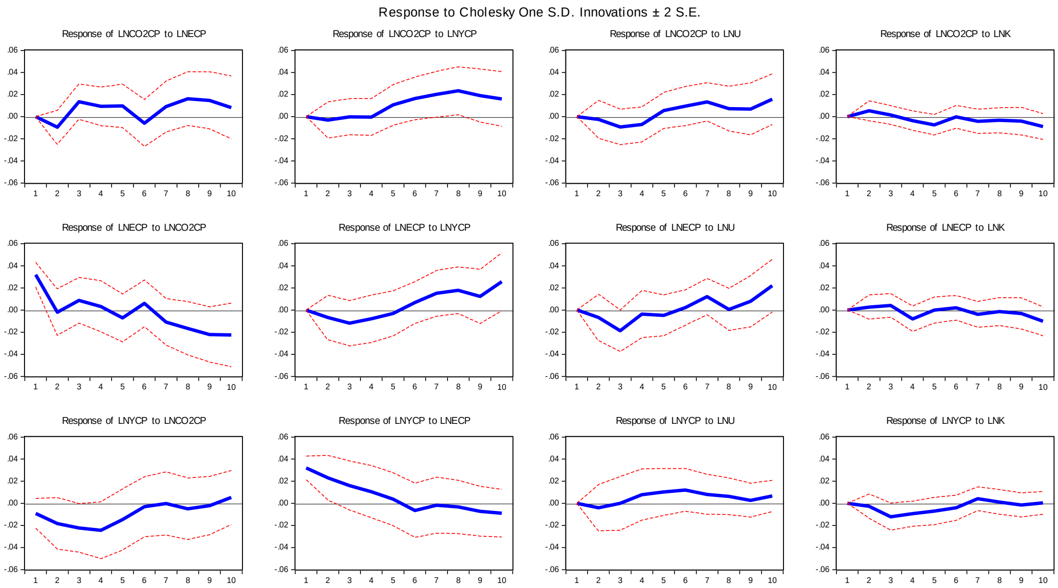

Figure 3.3 Impulse response function

Source: Author's estimation

Second, the responses of LNECP to the innovations in other variables can be highlighted as follows: (i) there is a minor initial impact of LNYCP to LNECP, and although there was a decreasing impact but generally has positive impact the longer period; (ii) The response of LNECP to the innovation of LNCO2CP is positive in the initial period, and it gradually decreases in the longer period; (iii) LNU has a minor initial impact to LNECP, decreased until the 3rd period, and then increased with small positive impact after that period; (iv) although there were some fluctuations, the response of LNCO2CP to LNK is generally minor over the simulations period.

Third, responses of LNYCP to the innovations of other variables are as follows. (i) The impact of LNCO2CP to LNYCP is initially negative and vanished in the longer period of simulation; (ii) The initial impact of LNECP to LNYCP is positive and lessening in the longer period, (iii) similar to the previous evidence on LNCO2CP; LNU and LNK steadily have a low impact on LNYCP.

To sum up, the IRF analysis shows although there are fluctuations of reactions of any variable to a shock in another variables, it seems that only shocks of output to energy use and emissions that could persist in the longer period of simulations.

3.5 Conclusion

This study analyses the three causality nexuses between emissions, energy use and economic performance along with urbanization and investment (capital formation), for the case of Indonesia. Employing the Engle-Granger cointegration procedure, we found evidence of long-run causality amongst variables. Employing the complete model, the long-run elasticities of energy use and income to emissions are about 0.68 and 0.71 (1.34 and 1.43 if using separate model) respectively. The speed of adjustment is about 25%, which is also confirmed by the Johansen-Juselius procedure of about 21%. The Stock-Watson DOLS long-run estimates are quite consistent at about 0.74 for energy use and 0.64 for output. Similarly, estimating the emission equation without energy use, we found long-run causality of output to emissions to be about 1.42, suggesting that energy use could be a key intervening variable linking income to emission. More importantly, we do find evidence that energy use and output Granger-cause emissions, but not in the opposite direction, suggesting that while by nature output (and energy use) will foster emissions, there is the possibility to implement emission reduction strategies without impeding growth.

When adding urbanization and capital formation, we employ augmented-VAR procedures to measure the short-run Granger-causality. Similarly, in the short-run, we found a uni-directional Granger causality running from output to emission, which suggests the possibility of implementing green growth development in Indonesia. Bi-directional causality between energy use and CO_2 emission indicates that rising energy consumption (which is mainly derived from fossil and non-renewable energy sources), will increase emissions indicating that any effort that aims to reduce emissions will impede energy use. This suggests that, among other strategies, the energy policy should pursue an alternative strategy toward intensifying renewable energy sources.

With respect to urbanization and capital formation we found an uni-directional causality of both variables to energy consumption, implying that the population concentration in urban area as well as investment will surge energy use and importantly there is no evidence of causality existing running from urbanization investment to rising CO_2 emissions. These findings suggest that urbanization and investment would be reasonably 'carbon neutral' if sustainable low-carbon urban development and investment strategies are promoted.

The VED analysis reveals that the contribution of energy use, output and urbanization to the variation in CO_2 emissions considerably increased in the longer periods. The IRF analysis also supports these findings, which suggests that the response of emission to output increases and could persist in the longer period. Furthermore, most of the variation in energy use is initially explained by CO_2 emissions, however the contribution of output and urbanization increase over the remaining periods of the simulation. Regarding the variation of output, the contribution of energy use and emission explaining the variation in output is relatively constant. Finally, urbanization could have significant contribution on energy use (and then on emissions), but in the longer period, appropriate low-carbon urban development strategies could moderate it.

For the policy standpoint, those findings motivate the promotion of sustainable energy system as a way out to decouple economic development with emission trade-offs. Specifically, for the Indonesian case, the policies that could be applied such as improving energy efficiency (consuming less energy to provide the same service), developing renewable energy (replacing current high dependency on fossil fuels), the provision of green infrastructures, supporting investment in environmentally friendly technologies, promoting sustainable urban development and transport systems, and gradual reduction (and well-targeted) energy subsidies.

For further research, the above findings can contribute empirical evidence of inter-temporal links in CO_2 emissions, energy use, and the economic growth nexus, including urbanization and investment. Although only utilizing Indonesia as an example, this could also be relevant to other emerging economies, which could have similar characteristics. For future study, it would be fruitful to incorporate more relevant variables into the analysis if econometrically feasible. Potential variables could be education, renewable energy production and consumption, domestic oil price (ratio to international price), trade openness, financial development, among other potential candidates. Due to data availability and methodological issues, such additional variables are beyond this study and left for further investigations.

Appendix A (Chapter 1)

Table A.1. CO_2 Emission Intensity (gram CO_2/Rp), domestic technology, domestic emission

IO code	Sectors	CO_2 intensity
1	Paddy	0.006820
2	Corn	0.004500
3	Cassava	0.002800
4	Sweet potato	0.001020
5	Other tubers	0.024600
6	Bean	0.002180
7	Soybean	0.002860
8	Other nuts	0.003790
9	Vegetables	0.002660
10	Fruits	0.001850
11	Grains and other foodstuffs	0.000780
12	Rubber	0.007480
13	Cane	0.021460
14	Coconut	0.019640
15	Palm	0.025310
16	Fiber crops	0.000310
17	Tobacco	0.038470
18	Coffee	0.029880
19	Tea	0.029950
20	Clove	0.028100
21	Cocoa	0.025890
22	Cashew nuts	0.026000
23	Other plantation crops	0.033320
24	Other agricultural products	0.029300
25	Livestock and their products except fresh milk	0.005670
26	Fresh milk	0.023430
27	Poultry and their products	0.009140
28	Other animal products	0.003740
29	Timber	0.028400
30	Other forest products	0.028310
31	Marine fish and other marine products	0.046800
32	The inland fish and products	0.045190
33	Shrimp	0.046910
34	Agricultural services	0.032950
35	Coal	0.008320
36	Petroleum	0.008160
37	Natural gas and geothermal	0.081440
38	Tin ore	0.028600
39	Nickel ore	0.025250
40	Seeds of bauxite	0.043390
41	Copper seed	0.030620
42	Gold ore	0.031790
43	Silver ore	0.039280
44	Iron	0.027290
45	Other metallic minerals	0.024600
46	Nonmetallic mineral mining products	0.034900
47	Coarse salt	0.030480
48	Excavation of all types of goods	0.033690
49	Meat, offal and the like	0.006420
50	Processed and preserved meat	0.026770
51	Food and beverages made from milk	0.013140
52	Fruits and vegetables are processed and preserved	0.093870
53	Dried fish and salted fish	0.023870
54	Processed and preserved fish	0.025020
55	Copra	0.019600
56	Animal and vegetable oils	0.009260
57	Rice	0.004670
58	Wheat flour	0.010970
59	Other flours	0.012080
60	Bread, biscuits and the like	0.015100
61	Noodles, macaroni and the like	0.014640
62	Sugar	0.010110
63	Peeling grains	0.019800
64	Chocolate and sugar confectionery	0.012800
65	Ground and peeling coffee	0.015140
66	Processed tea	0.029010
67	Soybean processing results	0.013100
68	Other food	0.014480
69	Animal feed	0.018200
70	Alcoholic beverages	0.025000
71	Non alcoholic beverages	0.023500
72	Processed Tobacco	0.034640
73	Cigarette	0.020450
74	Cotton	0.076400
75	Thread	0.082420

76	Textiles	0.072660
77	Textiles products unless clothes	0.054530
78	Knitted goods	0.033800
79	Apparel	0.026400
80	Rugs, rope and other textiles	0.037070
81	Equate skin and processed	0.019420
82	Leather products	0.020030
83	Footwear	0.021260
84	Sawn and preserved timber	0.036540
85	Plywood etc	0.030980
86	Building materials of wood	0.030480
87	Furniture made of wood, bamboo and rattan	0.019920
88	Products of wood, cork, bamboo and rattan	0.022480
89	Webbing products unless plastic	0.013320
90	Pulp	0.053740
91	Paper and paperboard	0.066100
92	Processed goods from paper and paperboard	0.060060
93	Printed goods	0.071730
94	Basic chemicals except fertilizers	0.012060
95	Fertilizer	0.023240
96	Pesticide	0.031640
97	Synthetic resins, plastic materials and synthetic fibers	0.023960
98	Paints, varnishes and lacquers	0.037870
99	Drugs (medicals)	0.021070
100	Traditional herb	0.023610
101	Soap and cleaning agents	0.023290
102	Cosmetic goods	0.020070
103	Other chemical goods	0.019500
104	The products of oil refinery	0.110930
105	Liquefied natural gas (LNG)	0.128280
106	Crumb rubber and rubber fumes	0.011870
107	Tire	0.037650
108	Other items of rubber	0.027660
109	Plastic products	0.031330
110	Ceramics and items made of clay	0.368250
111	Glass and glass products	0.385420
112	Ceramics and building materials from clay	0.373310
113	Cement	0.446190
114	Other items of non-metallic materials	0.395520
115	Iron and steel basic	0.138910
116	Items of basic iron and steel	0.133080
117	Base metal (non-iron)	0.024030
118	Products of metal rather than iron	0.051320
119	Kitchen tools, woodworking and agriculture of the metal	0.052470
120	Household-office furniture from metal	0.054190
121	Construction materials from metal	0.068670
122	Other metal products	0.069270
123	First driving machine	0.020000
124	Machinery and equipment nec	0.006760
125	Generator and electric motors	0.015840
126	Electrical machinery and equipment	0.020130
127	Electronic goods, communications and equipment	0.020680
128	Electrical appliances for household	0.020910
129	Other electrical equipment	0.026940
130	Batteries and accumulators	0.020140
131	Shipbuilding and repair services	0.013680
132	Train and repair services	0.041400
133	Motor vehicles except motorcycles	0.013010
134	Motorcycle	0.016270
135	Other conveyance	0.028900
136	Aircraft repairs and services	0.008260
137	Measuring devices, photographic, optical and clocks	0.050580
138	Jewelry	0.097850
139	Musical instruments	0.108740
140	Sports tools	0.091770
141	Other industry products	0.100440
142	Electricity and gas	1.049620
143	Clean water	0.152200
144	Residential and non residential buildings	0.039490
145	Agricultural infrastructure	0.045890
146	Roads, bridges and ports	0.041360
147	Building and installations, electricity, gas and water supply and communication	0.030220
148	Other buildings	0.033460
149	Trade in services	0.028160
150	Restaurant services	0.015450
151	Hospitality services	0.013600
152	Railway services	0.171560
153	Road transport services	0.111490
154	Marine transportation services	0.163380
155	River and lake transport services	0.161530
156	Air transport services	0.204210

157	Transport support services	0.107950
158	Communication services	0.015180
159	Bank	0.014460
160	Other financial institutions	0.014820
161	Insurance and pension funds	0.012100
162	Building and land rent	0.005080
163	Corporate services	0.020050
164	General government services	0.025900
165	Government educational services	0.023290
166	Government health services	0.016340
167	Other government services (entertainment, recreation and culture)	0.018760
168	Private education services	0.019120
169	Private health services	0.015720
170	Other community services	0.016430
171	Film and distribution services of private	0.006330
172	Entertainment services, recreation and culture of private	0.020130
173	Overhaul services	0.023410
174	Personal and household services	0.018980
175	Goods and services not included elsewhere	0.039860

Source: Author’s computation based on GTAP-E and IO 2005.

A.2a. GTAP sectors

No.	Code	Description
1	pdr	Paddy rice
2	wht	Wheat
3	gro	Cereal grains nec
4	v_f	Vegetables, fruits, nuts
5	osd	Oilseeds
6	c_b	Sugar cane, sugar beet
7	pfb	Plant-based fibers
8	ocr	Crops nec
9	ctl	Bovine cattle, sheep and goats, horses
10	oap	Animal products nec
11	rmk	Raw milk
12	wol	Wool, silk-worm cocoons
19	cmt	Bovine cattle, sheep and goat, horse meat products
20	omt	Meat products nec
21	vol	Vegetable oils and fats
22	mil	Dairy products
23	pcr	Processed rice
24	sgr	Sugar
25	ofd	Food products nec
26	b_t	Beverages and tobacco products
15	col	Coal
16	oil	Oil
17	gas	Gas
32	p_c	Petroleum, coal products
43	ely	Electricity
44	gdt	Gas manufacture, distribution
13	for	Forestry
14	fsh	Fishing
18	omn	Minerals nec
27	tex	Textiles
28	wap	Wearing apparel
29	lea	Leather products
30	lum	Wood products
31	ppp	Paper products, publishing
33	crp	Chemical, rubber, plastic products
34	nmm	Mineral products nec
35	i_s	Ferrous metals
36	nfm	Metals nec
37	fmp	Metal products
38	mvh	Motor vehicles and parts
39	otn	Transport equipment nec
40	ele	Electronic equipment
41	ome	Machinery and equipment nec
42	omf	Manufactures nec
45	wtr	Water
46	cns	Construction
47	trd	Trade
48	otp	Transport nec
49	wtp	Water transport
50	atp	Air transport
51	cmn	Communication
52	ofi	Financial services nec
53	isr	Insurance
54	obs	Business services nec
55	ros	Recreational and other services
56	osg	Public administration and defense, education, health
57	dwe	Dwellings

Source: Huff, McDougall, Walmsley (2000). Contributing Input-Output Tables to the GTAP Data Base. *GTAP Technical Paper* No. 1 Release 4.2 January 2000.

A.2b. GTAP sectors: detailed description

No.	Code	Code	Description
1	pdr	113	Rice, not husked
		114	Husked rice
2	wht	111	Wheat and meslin
3	gro	112	Maize (corn)
		115	Barley
		116	Rye, oats
		119	Other cereals
4	v_f	12	Vegetables
		13	Fruit and nuts
5	osd	14	Oil seeds and oleaginous fruit
6	c_b	18	Plants used for sugar manufacturing
7	pfb	192	Raw vegetable materials used in textiles
8	ocr	15	Live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds
		16	Beverage and spice crops
		17	Unmanufactured tobacco
		191	Cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets
		193	Plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes
		194	Sugar beet seed and seeds of forage plants
		199	Other raw vegetable materials
9	ctl	211	Bovine cattle, sheep and goats, horses, asses, mules, and hinnies, live
		299	Bovine semen
10	oap	212	Swine, poultry and other animals, live
		292	Eggs, in shell, fresh, preserved or cooked
		293	Natural honey
		294	Snails, live, fresh, chilled, frozen, dried, salted or in brine, except sea snails; frogs' legs, fresh, chilled or frozen
		295	Edible products of animal origin n.e.c.
		297	Hides, skins and furskins, raw
		298	Insect waxes and spermaceti, whether or not refined or coloured
11	rmk	291	Raw milk
12	wol	296	Raw animal materials used in textile
13	for	3	Forestry, logging and related service activities
19	cmt	21111	Meat of bovine animals, fresh or chilled
		21112	Meat of bovine animals, frozen
		21115	Meat of sheep, fresh or chilled
		21116	Meat of sheep, frozen
		21117	Meat of goats, fresh, chilled or frozen
		21118	Meat of horses, asses, mules or hinnies, fresh, chilled or frozen
		21119	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen
		2161	Fats of bovine animals, sheep, goats, pigs and poultry, raw or rendered; wool grease
20	omt	21113	Meat of swine, fresh or chilled
		21114	Meat of swine, frozen
		2112	Meat and edible offal, fresh, chilled or frozen, n.e.c.
		2113	Preserves and preparations of meat, meat offal or blood
		2114	Flours, meals and pellets of meat or meat offal, inedible; greaves
		2162	Animal oils and fats, crude and refined, except fats of bovine animals, sheep, goats, pigs and poultry
21	vol	2163	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed rape, colza and mustard oil, crude
		2164	Palm, coconut, palm kernel, babassu and linseed oil, crude
		2165	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and mustard oil and their fractions, refined but not chemically modified; other oils obtained solely from olives and sesame oil, and their fractions, whether or not refined, but not chemically modified
		2166	Maize (corn) oil and its fractions, not chemically modified
		2167	Palm, coconut, palm kernel, babassu and linseed oil and their fractions, refined but not chemically modified; castor, tung and jojoba oil and fixed vegetable fats and oils (except maize oil) and their fractions n.e.c., whether or not refined, but not chemically modified
		2168	Margarine and similar preparations
		2169	Animal or vegetable fats and oils and their fractions, partly or wholly hydrogenated, inter-esterified, re-esterified or elaidinised, whether or not refined, but not further prepared
		217	Cotton linters

		218	Oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes
22	mil	22	Dairy products
23	pcr	2316	Rice, semi- or wholly milled
24	sgr	235	Sugar
25	ofd	212	Prepared and preserved fish
		213	Prepared and preserved vegetables
		214	Fruit juices and vegetable juices
		215	Prepared and preserved fruit and nuts
		2311	Wheat or meslin flour
		2312	Cereal flours other than of wheat or meslin
		2313	Groats, meal and pellets of wheat
		2314	Cereal groats, meal and pellets n.e.c.
		2315	Other cereal grain products (including corn flakes)
		2317	Other vegetable flours and meals
19		2318	Mixes and doughs for the preparation of bakers' wares
		232	Starches and starch products; sugars and syrups n.e.c.
		233	Preparations used in animal feeding
		234	Bakery products
		236	Cocoa, chocolate and sugar confectionery
		237	Macaroni, noodles, couscous and similar farinaceous products
		239	Food products n.e.c.
26	b_t	24	Beverages
		25	Tobacco products
14	fsh	15	Hunting, trapping and game propagation including related service activities
		5	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
15	col	101	Mining and agglomeration of hard coal
		102	Mining and agglomeration of lignite
		103	Mining and agglomeration of peat
16	oil	111	Extraction of crude petroleum and natural gas
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	111	Extraction of crude petroleum and natural gas
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	12	Mining of uranium and thorium ores
		13	Mining of metal ores
		14	Other mining and quarrying
27	tex	17	Manufacture of textiles
		243	Manufacture of man-made fibres
28	wap	18	Manufacture of wearing apparel; dressing and dyeing of fur
29	lea	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
30	lum	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
31	ppp	21	Manufacture of paper and paper products
		22	Publishing, printing and reproduction of record media
32	p_c	231	Manufacture of coke oven products
		232	Manufacture of refined petroleum products
		233	Processing of nuclear fuel
33	crp	241	Manufacture of basic chemicals
		242	Manufacture of other chemical products
		25	Manufacture of rubber and plastics products
34	nmm	26	Manufacture of other non-metallic mineral products
35	i_s	271	Manufacture of basic iron and steel
		2731	Casting of iron and steel
36	nfm	272	Manufacture of basic precious and non-ferrous metals
		2732	Casting of non-ferrous metals
37	fmp	28	Manufacture of fabricated metal products, except machinery and equipment
38	mvh	34	Manufacture of motor vehicles, trailers and semi- trailers
39	otn	35	Manufacture of other transport equipment
40	ele	30	Manufacture of office, accounting and computing machinery
		32	Manufacture of radio, television and communication equipment and apparatus
41	ome	29	Manufacture of machinery and equipment n.e.c.
		31	Manufacture of electrical machinery and apparatus n.e.c.
		33	Manufacture of medical, precision and optical instruments, watches and clocks
42	omf	36	Manufacturing n.e.c.
		37	Recycling
43	ely	401	Production, collection and distribution of electricity
44	gdt	402	Manufacture of gas; distribution of gaseous fuels through mains
		403	Steam and hot water supply

45	wtr	41	Collection, purification and distribution of water
46	cns	45	Construction
47	trd	50	Sales, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
		51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
		521	Non-specialized retail trade in stores
		522	Retail sale of food, beverages and tobacco in specialized stores
		523	Other retail trade of new goods in specialized stores
		524	Retail sale of second-hand goods in stores
		525	Retail trade not in stores
		526	Repair of personal and household goods
		55	Hotels and restaurants
48	otp	60	Land transport; transport via pipelines
		63	Suupporting and auxiliary transport activities;
49	wtp	61	Water transport
50	atp	62	Air transport
51	cmn	64	Post and telecommunications
52	ofi	65	Financial intermediation, except insurance and pension funding
		67	Activities auxiliary to financial intermediation
53	isr	66	Insurance and pension funding, except compulsory social security
54	obs		Real estate, renting and business activities
55	ros	92	Recreational, cultural and sporting activities
		93	Other service activities
		95	Private households with employed persons
56	osg	75	Public administration and defense; compulsory social security
		80	Education
		85	Health and social work
		90	Sewage and refuse disposal, sanitation and similar activities
		91	Activities of membership organizations n.e.c.
		99	Extra-territorial organizations and bodies
57	dwe	n.a.	n.a.

Source: Huff, McDougall, Walmsley (2000). Contributing Input-Output Tables to the GTAP Data Base. *GTAP Technical Paper* No. 1 Release 4.2 January 2000.
Note: GTAP A5GSC2 sectors defined by reference to the ISIC.

Table A.3. Expenditure category: description

	Description
Cereal	Rice, grains, and cereals
Vegetable and fruit	Vegetable and fruit
Oil and fat	Oil and fat ingredients
Beverage	Drink material, season, noodles, chips, alcohol drink
Egg, fish, meat, and dairy	Egg, fish, meat, dairy products
Tobacco	Tobacco
Fuel and light	Electricity bill, fuel
Telecommunication	Telephone bill, other telecommunication
Transportation	Transportation cost
Health	Health costs, health insurance
Education	Education costs
Toiletry	Soap, cosmetic, etc
Clothes	Clothes
House and durable goods	House and durable goods
Services and rent	Services
Taxes	Taxes, retribution, other taxes
Recreation, entertainment, ceremony	Recreation, entertainment, ceremony

Source: Author's computation, based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.

Table A.4. Descriptive analysis by income quintiles: 2005 and 2009

2005	Q1	Q2	Q3	Q4	Q5	Overall
Total household expenditure (Rp 000)	4,264	6,804	9,131	12,600	26,600	11,900
Per capita expenditure (Rp 000)	846	1,564	2,283	3,396	8,036	2,917
CO_2 emissions (kg)	1,280	1,782	2,271	3,042	5,861	2,847
Per capita CO_2 emission (kg)	254	410	568	820	1,771	698
Household size (persons)	5.04	4.35	4.00	3.71	3.31	4.08
No. of observations	51,582	51,581	51,581	51,581	51,581	257,906

2009	Q1	Q2	Q3	Q4	Q5	Overall
Total household expenditure (Rp 000), deflated	6,775	10,145	12,899	16,594	27,899	14,855
Per capita expenditure (Rp 000), deflated	1,293	2,275	3,265	4,782	10,410	3,751
CO_2 emissions (kg)	1,663	2,425	3,084	3,973	6,637	3,556
Per capita CO_2 emission (kg)	317	544	781	1,145	2,476	898
Household size (persons)	5.24	4.46	3.95	3.47	2.68	3.96
No. of observations	58,351	58,351	58,351	51,850	51,850	291,753

Source: Author's computation, based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.
Note: Quintile classification is based on household per-capita expenditure distribution. Quintile 1 refers to the poorest quintile. Expenditure in 2009 is deflated (2005=100)

Table A.5. Consumption category

Group of expenditure	Nominal (Rp)			CPI deflated (Rp) (2005=100)			Expenditure share (%)	
	2005	2009	Growth (%)	2005	2009	Growth (%)	2005	2009
Cereal	1,932,727	3,178,787	64.47	1,932,727	2,303,469	19.18	16.24	15.51
Vegetable and fruit	1,095,324	1,822,202	66.36	1,095,324	1,320,436	20.55	9.20	8.89
Oil and fat	366,246	576,454	57.40	366,246	417,720	14.05	3.08	2.81
Beverage	1,784,393	2,980,696	67.04	1,784,393	2,159,925	21.05	14.99	14.54
Egg, fish, meat, dairy	1,572,178	2,538,249	61.45	1,572,178	1,839,311	16.99	13.21	12.38
Tobacco	987,676	1,582,001	60.17	987,676	1,146,378	16.07	8.30	7.72
Fuel and light	788,083	1,255,051	59.25	788,084	909,457	15.40	6.62	6.12
Telecommunication	178,571	433,491	142.75	178,571	314,124	75.91	1.50	2.11
Transportation	415,262	922,775	122.21	415,262	668,677	61.03	3.49	4.50
Health	204,061	421,968	106.78	204,061	305,774	49.84	1.71	2.06
Education	306,425	581,749	89.85	306,425	421,557	37.57	2.58	2.84
Toiletry	349,539	510,649	46.09	349,539	370,035	5.86	2.94	2.49
Clothes	401,673	650,842	62.03	401,673	471,625	17.42	3.38	3.17
House and durable goods	255,414	413,278	61.81	255,415	299,477	17.25	2.15	2.02
Services and rent	1,339,935	2,268,360	69.29	1,339,935	1,643,739	22.67	11.26	11.07
Taxes	80,531	172,592	114.32	80,531	125,066	55.30	0.68	0.84
Recreation, entertainment, ceremony	148,476	190,859	28.55	148,476	138,304	-6.85	1.25	0.93

Source: Author's computation, based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.

Table A.6. Expenditure: share to total expenditure (%)

Group of expenditure	2005			2009		
	National	Rural	Urban	National	Rural	Urban
Cereal	16.24	19.68	10.49	15.51	18.67	9.72
Vegetable and fruit	9.20	9.72	8.34	8.89	9.37	8.01
Oil and fat	3.08	3.51	2.35	2.81	3.21	2.09
Beverage	14.99	14.32	16.12	14.54	13.62	16.23
Egg, fish, meat, dairy	13.21	13.44	12.83	12.38	12.60	11.98
Tobacco	8.30	9.08	6.99	7.72	8.42	6.42
Fuel and light	6.62	6.08	7.54	6.12	5.87	6.58
Telecommunication	1.50	0.55	3.09	2.11	1.53	3.18
Transportation	3.49	2.64	4.91	4.50	3.86	5.68
Health	1.71	1.61	1.89	2.06	1.89	2.36
Education	2.58	1.93	3.65	2.84	2.41	3.62
Toiletry	2.94	2.84	3.11	2.49	2.46	2.54
Clothes	3.38	3.42	3.31	3.17	3.21	3.10
House and durable goods	2.15	2.13	2.17	2.02	2.02	2.02
Services and rent	11.26	9.11	14.86	11.07	9.17	14.53
Taxes	0.68	0.53	0.93	0.84	0.67	1.16
Recreation, entertainment, ceremony	1.25	1.34	1.09	0.93	1.01	0.78

Source: Author's computation, based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.

Table A.7. CO_2 emissions (kg) per expenditure category

	2005	2009	Growth (nominal, %)	Growth (real, %)
Cereal	41.84	75.91	81.45	31.49
Vegetable and fruit	107.54	194.38	80.75	30.98
Oil and fat	20.55	35.51	72.84	25.24
Beverage	163.86	308.16	88.06	36.28
Egg, fish, meat, dairy	181.92	332.71	82.89	32.53
Tobacco	67.59	120.25	77.91	28.92
Fuel and light	1,688.51	2,768.80	63.98	18.82
Telecommunication	29.84	57.70	93.38	40.13
Transportation	183.07	400.84	118.95	58.66
Health	13.08	28.84	120.45	59.75
Education	22.97	47.47	106.63	49.74
Toiletry	18.64	29.02	55.66	12.8
Clothes	46.45	81.68	75.84	27.42
House and durable goods	126.65	202.95	60.25	16.12
Services and rent	84.79	151.85	79.09	29.77
Taxes	3.68	7.85	113.01	54.35
Recreation, entertainment, ceremony	46.47	63.88	37.44	-0.4

Source: Author’s computation, based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.

Table A.8. Emission share to total emission vs. expenditure share to total expenditure, by quintile

	Overall household				**I**				**II**			
	s CO2		**s EXP**		**s CO2**		**s EXP**		**s CO2**		**s EXP**	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Cereal	0.025	0.023	0.162	0.155	0.044	0.032	0.261	0.210	0.030	0.027	0.198	0.181
Vegetable and fruit	0.050	0.049	0.092	0.089	0.059	0.054	0.101	0.102	0.054	0.052	0.100	0.095
Oil and fat	0.011	0.010	0.031	0.028	0.016	0.013	0.040	0.037	0.013	0.011	0.036	0.031
Beverage	0.065	0.068	0.150	0.145	0.058	0.062	0.134	0.144	0.062	0.065	0.147	0.144
Egg, fish, meat, dairy	0.076	0.073	0.132	0.124	0.076	0.065	0.116	0.112	0.077	0.072	0.130	0.122
Tobacco	0.032	0.031	0.083	0.077	0.034	0.027	0.078	0.069	0.036	0.033	0.090	0.083
Fuel and light	0.573	0.559	0.066	0.061	0.586	0.613	0.063	0.070	0.591	0.576	0.067	0.063
Telecommunication	0.006	0.009	0.015	0.021	0.001	0.004	0.001	0.009	0.002	0.007	0.004	0.015
Transportation	0.050	0.070	0.035	0.045	0.028	0.043	0.017	0.028	0.038	0.061	0.026	0.039
Health	0.005	0.006	0.017	0.021	0.004	0.005	0.013	0.018	0.004	0.005	0.015	0.018
Education	0.007	0.009	0.026	0.028	0.008	0.006	0.026	0.018	0.007	0.008	0.023	0.025
Toiletry	0.008	0.007	0.029	0.025	0.009	0.007	0.030	0.028	0.008	0.007	0.030	0.026
Clothes	0.019	0.018	0.034	0.032	0.021	0.017	0.034	0.030	0.020	0.019	0.035	0.032
House and durable	0.028	0.027	0.021	0.020	0.017	0.016	0.011	0.011	0.020	0.019	0.014	0.014
Services and rent	0.028	0.029	0.113	0.111	0.024	0.025	0.087	0.102	0.024	0.026	0.093	0.099
Taxes	0.001	0.001	0.007	0.008	0.001	0.001	0.004	0.005	0.001	0.001	0.005	0.007
Recreation, entert.	0.016	0.012	0.012	0.009	0.016	0.011	0.011	0.008	0.015	0.011	0.011	0.008

	III				**IV**				**V**			
	s CO2		**s EXP**		**s CO2**		**s EXP**		**s CO2**		**s EXP**	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Cereal	0.023	0.023	0.159	0.155	0.017	0.019	0.122	0.131	0.010	0.015	0.072	0.098
Vegetable and fruit	0.051	0.049	0.097	0.090	0.046	0.046	0.090	0.084	0.037	0.040	0.072	0.074
Oil and fat	0.011	0.010	0.032	0.028	0.009	0.009	0.028	0.025	0.006	0.007	0.019	0.019
Beverage	0.064	0.068	0.152	0.146	0.066	0.070	0.154	0.146	0.077	0.075	0.162	0.148
Egg, fish, meat, dairy	0.079	0.075	0.140	0.127	0.079	0.077	0.145	0.131	0.069	0.076	0.129	0.127
Tobacco	0.035	0.033	0.092	0.084	0.033	0.032	0.088	0.081	0.025	0.027	0.068	0.070
Fuel and light	0.584	0.558	0.068	0.060	0.573	0.539	0.068	0.058	0.532	0.511	0.065	0.055
Telecommunication	0.003	0.009	0.009	0.020	0.007	0.011	0.018	0.026	0.016	0.015	0.043	0.035
Transportation	0.048	0.072	0.033	0.047	0.059	0.082	0.042	0.053	0.078	0.093	0.056	0.060
Health	0.004	0.005	0.016	0.020	0.005	0.006	0.018	0.022	0.006	0.008	0.023	0.026
Education	0.006	0.009	0.024	0.028	0.006	0.010	0.025	0.032	0.008	0.012	0.031	0.039
Toiletry	0.007	0.007	0.030	0.024	0.007	0.006	0.029	0.024	0.007	0.006	0.028	0.023
Clothes	0.019	0.019	0.035	0.032	0.018	0.019	0.034	0.033	0.017	0.018	0.032	0.032
House and durable	0.024	0.024	0.017	0.018	0.030	0.030	0.023	0.023	0.052	0.045	0.043	0.035
Services and rent	0.025	0.027	0.103	0.104	0.029	0.029	0.120	0.113	0.040	0.037	0.161	0.135
Taxes	0.001	0.001	0.006	0.008	0.001	0.001	0.008	0.009	0.002	0.002	0.012	0.013
Recreation, entert.	0.015	0.011	0.012	0.009	0.016	0.013	0.013	0.010	0.018	0.015	0.016	0.012

Source: Author's computation, based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.

Table A.9. Province dummy

Code	Province	I	II	III	IV	V	VI
12	Sumatera Utara	0.164	0.165	0.208	-0.080	-0.077	-0.077
13	Sumatera Barat	0.174	0.175	0.216	-0.038	-0.036	-0.035
14	Riau	0.175	0.175	0.297	-0.046	-0.047	-0.048
15	Jambi	0.193	0.193	0.180	0.016	0.013	0.012
16	Sumatera Selatan	0.179	0.179	0.171	-0.028	-0.029	-0.030
17	Bengkulu	0.178	0.178	0.134	0.010	0.009	0.009
18	Lampung	0.287	0.286	0.221	-0.011	-0.014	-0.015
19	Bangka-Belitung	0.186	0.185	0.296	-0.018	-0.020	-0.020
21	Kepulauan Riau	0.229	0.229	0.381	-0.066	-0.067	-0.068
31	DKI Jakarta	0.258	0.257	0.648	-0.191	-0.193	-0.194
32	Jawa Barat	0.311	0.310	0.270	-0.011	-0.013	-0.013
33	Jawa Tengah	0.403	0.402	0.274	0.023	0.020	0.022
34	DI Yogyakarta	0.305	0.306	0.157	0.056	0.059	0.064
35	Jawa Timur	0.383	0.382	0.229	0.041	0.038	0.039
36	Banten	0.253	0.253	0.376	-0.090	-0.091	-0.090
51	Bali	0.354	0.354	0.405	-0.024	-0.024	-0.023
52	Nusa Tenggara Barat	0.152	0.152	0.044	0.023	0.022	0.019
53	Nusa Tenggara Timur	0.000	0.001	-0.104	-0.036	-0.035	-0.033
61	Kalimantan Barat	0.066	0.066	0.090	-0.022	-0.022	-0.023
62	Kalimantan Tengah	0.062	0.062	0.028	0.035	0.034	0.032
63	Kalimantan Selatan	0.176	0.175	0.109	0.063	0.061	0.060
64	Kalimantan Timur	0.199	0.198	0.348	-0.069	-0.070	-0.070
71	Sulawesi Utara	0.131	0.131	0.066	0.019	0.016	0.018
72	Sulawesi Tengah	0.124	0.124	0.077	0.002	0.001	0.001
73	Sulawesi Selatan	0.193	0.193	0.164	-0.017	-0.018	-0.017
74	Sulawesi Tenggara	0.222	0.222	0.223	-0.049	-0.047	-0.047
75	Gorontalo	0.077	0.076	0.046	0.007	0.003	0.002
76	Sulawesi Barat	0.215	0.216	0.194	-0.019	-0.017	-0.018
81	Maluku	0.021	0.021	0.092	-0.103	-0.103	-0.100
82	Maluku Utara	-0.013	-0.013	0.081	-0.083	-0.083	-0.082
91	Papua	-0.006	-0.005	-0.000	-0.000	0.002	-0.001
94	Papua Barat	0.030	0.030	0.002	0.052	0.051	0.047

Source: Author's estimation, based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009. Note: Nanggroe Aceh Darussalam (province code 11) as benchmark.

Table A.10a. Quantile regression (excluding expenditure square)

	OLS		Q(0.1)		Q(0.25)	
	coef	**se**	**coef**	**se**	**coef**	**se**
lnexp	0.957***	0.001	1.035***	0.002	0.999***	0.001
hhsize	0.046***	0.002	0.070***	0.004	0.065***	0.003
hhsizesq	-0.011***	0.000	-0.014***	0.001	-0.014***	0.001
hhsizecub	0.001***	0.000	0.001***	0.000	0.001***	0.000
age	0.020***	0.001	0.022***	0.001	0.022***	0.001
agesq	-2.91E-04	0.000	-0.000***	0.000	-3.39E-04	0.000
agecub	1.50E-06	0.000	1.74E-06	0.000	1.80E-06	0.000
Urbanity	0.173***	0.001	0.209***	0.002	0.206***	0.001
Married HH-head	0.051***	0.002	0.047***	0.004	0.052***	0.003
Female HH-head	0.051***	0.002	0.052***	0.004	0.053***	0.003
Elementary school	0.023***	0.002	0.048***	0.003	0.032***	0.002
Secondary school	0.024***	0.002	0.056***	0.004	0.035***	0.003
High school	0.051***	0.002	0.085***	0.004	0.065***	0.003
At least college	0.064***	0.003	0.084***	0.005	0.074***	0.004
Survey year 2009	0.065***	0.001	0.053***	0.002	0.050***	0.001
_cons	-8.323***	0.018	-10.154***	0.033	-9.318***	0.025
#Obs	549,659		549,659		549,659	
(pseudo)R^2	0.806		0.553		0.557	

	Q(0.50)		Q(0.75)		Q(0.90)	
	coef	**se**	**coef**	**se**	**coef**	**se**
lnexp	0.954***	0.001	0.914***	0.001	0.886***	0.001
hhsize	0.050***	0.003	0.031***	0.003	0.016***	0.003
hhsizesq	-0.012***	0.001	-0.008***	0.001	-0.006***	0.001
hhsizecub	0.001***	0.000	4.46E-04	0.000	3.51E-04	0.000
age	0.021***	0.001	0.017***	0.001	0.013***	0.001
agesq	-3.22E-04	0.000	-2.49E-04	0.000	-1.83E-04	0.000
agecub	1.70E-06	0.000	1.26E-06	0.000	8.60E-07	0.000
Urbanity	0.177***	0.001	0.143***	0.001	0.121***	0.002
Married HH-head	0.052***	0.003	0.045***	0.003	0.034***	0.003
Female HH-head	0.050***	0.003	0.046***	0.003	0.035***	0.003
Elementary school	0.018***	0.002	0.011***	0.002	0.001	0.003
Secondary school	0.019***	0.003	0.010***	0.003	-0.002	0.003
High school	0.047***	0.003	0.036***	0.003	0.023***	0.003
At least college	0.065***	0.003	0.057***	0.003	0.041***	0.004
Survey year 2009	0.048***	0.001	0.058***	0.001	0.075***	0.002
_cons	-8.281***	0.022	-7.286***	0.022	-6.532***	0.028
#Obs	549,659		549,659		549,659	
(pseudo)R^2	0.564		0.573		0.576	

Source: Author's estimation based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009. * (**, ***) indicates significance at the ten (five, one) percent level

Table A.10b. Quantile regression (excluding expenditure square)

	OLS		Q(0.1)		Q(0.25)	
	coef	**se**	**coef**	**se**	**coef**	**se**
lnexp	0.959***	0.001	1.039***	0.002	1.001***	0.001
hhsize	-0.014***	0.000	-0.011***	0.001	-0.013***	0.000
Age	0.003***	0.000	0.003***	0.000	0.003***	0.000
Urbanity	0.172***	0.001	0.206***	0.002	0.205***	0.002
Married HH-head	0.075***	0.002	0.082***	0.004	0.084***	0.003
Female HH-head	0.059***	0.002	0.063***	0.004	0.062***	0.003
Elementary school	0.029***	0.002	0.054***	0.003	0.039***	0.002
Secondary school	0.029***	0.002	0.062***	0.004	0.042***	0.003
High school	0.057***	0.002	0.092***	0.004	0.072***	0.003
At least college	0.068***	0.003	0.085***	0.005	0.077***	0.004
Survey year 2009	0.065***	0.001	0.054***	0.002	0.050***	0.001
_cons	-7.996***	0.014	-9.796***	0.024	-8.929***	0.019
#Obs	549,659		549,659		549,659	
(pseudo) R2	0.805		0.552		0.556	

	Q(0.50)		Q(0.75)		Q(0.90)	
	coef	**se**	**coef**	**se**	**coef**	**se**
lnexp	0.955***	0.001	0.915***	0.001	0.886***	0.001
hhsize	-0.013***	0.000	-0.013***	0.000	-0.012***	0.000
Age	0.003***	0.000	0.002***	0.000	0.002***	0.000
Urbanity	0.177***	0.001	0.142***	0.001	0.120***	0.002
Married HH-head	0.078***	0.002	0.063***	0.003	0.046***	0.003
Female HH-head	0.058***	0.003	0.052***	0.003	0.040***	0.003
Elementary school	0.025***	0.002	0.017***	0.002	0.005*	0.003
Secondary school	0.026***	0.003	0.016***	0.003	0.002	0.003
High school	0.055***	0.003	0.043***	0.003	0.027***	0.003
At least college	0.071***	0.003	0.063***	0.003	0.046***	0.004
Survey year 2009	0.047***	0.001	0.056***	0.001	0.074***	0.002
_cons	-7.913***	0.016	-6.996***	0.016	-6.305***	0.021
#Obs	549,659		549,659		549,659	
(pseudo) R^2	0.563		0.572		0.575	

Source: Author’s estimation based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009. Note: * (**, ***) indicates significance at the ten (five, one) percent level.

Table A.11. Kaya Identity (expenditure deflated)

a. Data

	CO_2 (kg)		HH size (person)		Expenditure (Rp)	
	2005	2009	2005	2009	2005	2009
Q1	1280	1,663	5.04	5.24	4,263,872	6,774,874
Q2	1782	2,425	4.35	4.46	6,803,753	10,144,928
Q3	2271	3,084	4.00	3.95	9,130,943	12,898,551
Q4	3042	3,973	3.71	3.47	12,600,000	16,594,203
Q5	5861	6,637	3.31	2.68	26,600,000	27,898,551
All Obs	2847	3,556	4.08	3.96	11,900,000	14,855,072

b. Factors of Kaya equation

	CO_2 (kg)		HH size (person)		Per capita expenditure		CO2 intensity (g/Rp)	
	2005	2009	2005	2009	2005	2009	2005	2009
Q1	1,280	1,663	5.04	5.24	846,681	1,292,854	0.3	0.25
Q2	1,782	2,425	4.35	4.46	1,563,965	2,272,167	0.26	0.24
Q3	2,271	3,084	4.00	3.95	2,283,311	3,265,409	0.25	0.24
Q4	3,042	3,973	3.71	3.47	3,400,690	4,781,893	0.24	0.24
Q5	5,861	6,637	3.31	2.68	8,039,117	10,416,367	0.22	0.24
All HH	2,847	3,556	4.08	3.96	2,916,770	3,750,554	0.24	0.24

c. Decomposition - change in kg CO_2 emissions attributable to each factor, 2005 to 2009

	CO_2 change (kg)	Population effect	Expenditure (income) effect	Carbon intensity effect	Check (sum should equal CO_2 change)
Q1	383	58	619	-294	383
Q2	643	54	780	-191	643
Q3	813	-33	951	-104	813
Q4	930	-228	1189	-30	930
Q5	775	-1319	1617	478	775
All HH	709	-94	802	2	709

d. Decomposition - change in CO_2 emissions attributable to each factor, 2005 to 2009

	CO_2 change	Population effect	Expenditure (income) effect	Carbon intensity effect	Check (sum should equal CO_2 change)
Q1	29.90	4.50	48.40	-23.00	29.90
Q2	36.10	3.00	43.70	-10.70	36.10
Q3	35.80	-1.40	41.90	-4.60	35.80
Q4	30.60	-7.50	39.10	-1.00	30.60
Q5	13.20	-22.50	27.60	8.10	13.20
All HH	24.90	-3.30	28.20	0.10	24.90

Source: Author’s computation based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.

Source: Author’s estimation based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009.
Note: expenditure in 2009 is deflated (2005=1)

Table A.12. Expenditure elasticites to CO_2 emission shares, pooled estimation

Share of CO_2 emission	I	II	III	IV	V	Overall
Cereal	-0.010	-0.011	-0.010	-0.008	-0.005	-0.009
Vegetable and fruit	-0.004	-0.006	-0.007	-0.009	-0.009	-0.007
Oil and fat	-0.003	-0.004	-0.004	-0.004	-0.003	-0.003
Beverage	0.003	0.004	0.001	0.003	-0.009	0.001
Egg, fish, meat, dairy	0.016	0.025	0.020	0.013	-0.006	0.011
Tobacco	0.016	0.010	0.006	-0.001	-0.006	0.004
Fuel and light	-0.061	-0.083	-0.084	-0.090	-0.076	-0.082
Telecommunication	0.004	0.005	0.007	0.009	0.006	0.007
Transportation	0.029	0.034	0.032	0.033	0.017	0.031
Health	0.000	0.001	0.002	0.003	0.005	0.002
Education	0.003	0.002	0.002	0.002	0.001	0.003
Toiletry	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Clothes	0.004	0.002	0.001	0.001	-0.001	0.002
House and durable goods	0.008	0.015	0.022	0.034	0.051	0.029
Services and rent	-0.004	0.002	0.005	0.008	0.021	0.007
Taxes	0.000	0.001	0.001	0.001	0.001	0.001
Recreation, ceremony	0.001	0.004	0.007	0.006	0.010	0.006
No. of observations						549,659

$sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij}$

Source: Author's estimation. Note: all estimated coefficients are significant at one percent level

Table A.13. Expenditure elasticites to CO_2 emission shares, 2005 and 2009 estimation

Share of CO_2 emission	I		II		III	
	2005	2009	2005	2009	2005	2009
Cereal	-0.0298	-0.0036	-0.0113	-0.0114	-0.0089	-0.0138
Vegetable and fruit	-0.0086	-0.0030	-0.0073	-0.0049	-0.0079	-0.0072
Oil and fat	-0.0065	-0.0017	-0.0043	-0.0030	-0.0047	-0.0038
Beverage	0.0099	-0.0007	-0.0014	0.0057	-0.0075	0.0056
Egg, fish, meat, dairy	0.0087	0.0184	0.0096	0.0221	0.0128	0.0146
Tobacco	0.0088	0.0202	0.0138	0.0144	0.0116	0.0080
Fuel and light	-0.0026	-0.0911	-0.0459	-0.1007	-0.0548	-0.0956
Telecommunication	0.0006	0.0050	0.0010	0.0070	0.0024	0.0076
Transportation	0.0198	0.0349	0.0270	0.0445	0.0301	0.0467
Health	0.0001	-0.0002	-0.0006	0.0002	0.0000	0.0008
Education	-0.0011	0.0061	0.0039	0.0056	0.0034	0.0061
Toiletry	-0.0018	-0.0006	-0.0008	-0.0011	-0.0006	-0.0012
Clothes	0.0021	0.0057	0.0036	0.0054	0.0027	0.0024
House and durable goods	0.0076	0.0078	0.0140	0.0104	0.0156	0.0184
Services and rent	-0.0083	-0.0019	-0.0046	-0.0005	-0.0040	0.0019
Taxes	-0.0002	0.0003	0.0004	0.0005	0.0003	0.0007
Recreation, ceremony	-0.0009	0.0028	0.0011	0.0029	0.0074	0.0057

Share of CO_2 emission	IV		V	
	2005	2009	2005	2009
Cereal	-0.0090	-0.0135	-0.0046	-0.0084
Vegetable and fruit	-0.0064	-0.0088	-0.0079	-0.0094
Oil and fat	-0.0041	-0.0041	-0.0025	-0.0028
Beverage	-0.0130	0.0001	-0.0102	-0.0079
Egg, fish, meat, dairy	0.0075	0.0073	-0.0145	-0.0017
Tobacco	0.0068	0.0005	-0.0052	-0.0072
Fuel and light	-0.0565	-0.0857	-0.0690	-0.0776
Telecommunication	0.0051	0.0083	0.0062	0.0059
Transportation	0.0314	0.0375	0.0144	0.0195
Health	0.0010	0.0021	0.0043	0.0047
Education	0.0011	0.0055	-0.0024	0.0037
Toiletry	-0.0009	-0.0012	-0.0010	-0.0006
Clothes	0.0016	0.0022	-0.0010	-0.0008
House and durable goods	0.0285	0.0320	0.0565	0.0487
Services and rent	-0.0009	0.0064	0.0215	0.0216
Taxes	0.0004	0.0010	0.0014	0.0016
Recreation, ceremony	0.0055	0.0072	0.0129	0.0083

$sCO2_{ij} = \beta_0 + \beta_{1_{ij}} \ln EXP_i + \beta_{2_{ij}} X_i + \varepsilon_{ij}$

Source: Author's estimation based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009. Note: all estimated coefficients are significant at one percent level

Table A.14. Expenditure elasticities to expenditure shares

Share of expenditure	Overall		Rural		Urban	
	2005	2009	2005	2009	2005	2009
Cereal	-0.0856	-0.0539	-0.1016	-0.0600	-0.0665	-0.0456
Vegetable and fruit	-0.0173	-0.0205	-0.0126	-0.0198	-0.0231	-0.0215
Oil and fat	-0.0118	-0.0101	-0.0126	-0.0110	-0.0109	-0.0088
Beverage	0.0016	-0.0145	0.0089	-0.0104	-0.006	-0.0203
Egg, fish, meat, dairy	0.0102	0.0154	0.0239	0.0194	-0.0056	0.0102
Tobacco	0.0075	0.0083	0.0163	0.0184	-0.0024	-0.0048
Fuel and light	-0.0094	-0.0165	-0.0085	-0.0176	-0.0111	-0.0151
Telecommunication	0.0172	0.0152	0.0102	0.0138	0.0243	0.0170
Transportation	0.0193	0.0197	0.0207	0.0221	0.0177	0.0163
Health	0.0065	0.0049	0.0068	0.0037	0.0064	0.0064
Education	-0.0026	0.0143	0.0001	0.0130	-0.0064	0.0160
Toiletry	-0.0043	-0.0044	-0.0041	-0.0049	-0.0046	-0.0038
Clothes	0.0004	0.0025	0.0019	0.0035	-0.0014	0.0013
House and durable goods	0.0298	0.0204	0.0328	0.0216	0.0267	0.0189
Services and rent	0.0248	0.0097	0.0070	-0.0010	0.0448	0.0236
Taxes	0.0043	0.0049	0.0031	0.0038	0.0056	0.0062
Recreation, entertainment,	0.0069	0.0046	0.0077	0.0052	0.0059	0.0038

Source: Author's estimation based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009. Note: all estimated coefficients are significant at one percent level

Table A.15. Expenditure elasticities to expenditure shares: by quintiles

Share of expenditure	I		II		III	
	2005	2009	2005	2009	2005	2009
Cereal	-0.0827	-0.0108	-0.1188	-0.0523	-0.1097	-0.0778
Vegetable and fruit	-0.0082	-0.0243	-0.0142	-0.0236	-0.0179	-0.0274
Oil and fat	-0.0110	-0.0101	-0.0140	-0.0100	-0.0134	-0.0129
Beverage	0.0180	-0.0215	0.0199	0.0060	0.0051	-0.0169
Egg, fish, meat, dairy	0.0310	0.0157	0.0403	0.0084	0.0430	0.0244
Tobacco	0.0311	0.0515	0.0350	0.0287	0.0236	0.0176
Fuel and light	-0.0056	-0.0261	-0.0096	-0.0234	-0.0097	-0.0118
Telecommunication	0.0023	0.0116	0.0094	0.0166	0.0170	0.0187
Transportation	0.0127	0.0200	0.0248	0.0344	0.0240	0.0298
Health	0.0028	-0.0025	0.0055	0.0025	0.0057	0.0065
Education	0.0007	0.0183	-0.0042	0.0197	-0.0088	0.0278
Toiletry	-0.0032	-0.0059	-0.0052	-0.0067	-0.0046	-0.0043
Clothes	0.0067	0.0073	0.0042	0.0048	-0.0013	0.0115
House and durable goods	0.0083	0.0040	0.0125	0.0049	0.0177	0.0093
Services and rent	-0.0058	-0.0312	0.0048	-0.0155	0.0105	-0.0006
Taxes	0.0002	0.0020	0.0024	0.0046	0.0051	-0.0007
Recreation, ceremony	0.0034	0.0020	0.0028	0.0008	0.0049	0.0066

Share of expenditure	IV		V	
	2005	2009	2005	2009
Cereal	-0.1007	-0.0666	-0.0478	-0.0439
Vegetable and fruit	-0.0126	-0.0100	-0.0220	-0.0223
Oil and fat	-0.0116	-0.0087	-0.0085	-0.0089
Beverage	0.0008	-0.0270	-0.0171	-0.0214
Egg, fish, meat, dairy	0.0048	0.0189	-0.0365	-0.0219
Tobacco	-0.0076	-0.0029	-0.0244	-0.0313
Fuel and light	-0.0065	-0.0077	-0.0112	-0.0109
Telecommunication	0.0294	0.0183	0.0140	0.0101
Transportation	0.0246	0.0150	0.0087	0.0078
Health	0.0114	0.0081	0.0093	0.0142
Education	-0.0041	0.0161	-0.0003	0.0102
Toiletry	-0.0029	-0.0030	-0.0033	-0.0028
Clothes	0.0040	0.0065	-0.0037	-0.0046
House and durable goods	0.0317	0.0348	0.0538	0.0458
Services and rent	0.0233	-0.0056	0.0678	0.0615
Taxes	0.0046	0.0042	0.0084	0.0098
Recreation, ceremony	0.0072	0.0098	0.0124	0.0087

Source: Author’s estimation based on GTAP-E, Indonesian Input Output and Susenas 2005 and 2009. Note: all estimated coefficients are significant at one percent level.

Appendix B (Chapter 2)

Table B.1. Descriptive analysis: 2005 and 2009

2005	Q1	Q2	Q3	Q4	Q5	Overall
Total household expenditure (Rp 000)	6,433	8,519	10,500	13,600	26,700	13,100
Per capita expenditure (Rp 000)	1,130	1,677	2,215	3,058	6,495	2,915
CO_2 emission (kg)	1,323	1,875	2,413	3,283	6,669	3,113
Per capita CO_2 emission (kg)	237	375	516	741	1,621	698
Household size (persons)	5.76	5.09	4.73	4.45	4.16	4.84
No of observation	210,420	210,419	210,416	210,420	210,416	1,052,091

2009	Q1	Q2	Q3	Q4	Q5	Overall
Total HH expenditure (Rp 000), deflated	6,685	10,072	12,826	16,739	29,348	15,145
Per capita expenditure (Rp 000), deflated	1,123	1,935	2,750	3,995	8,986	3,751
CO_2 emission (kg)	1,614	2,370	3,037	3,989	7,011	3,604
Per capita CO_2 emission (kg)	277	462	655	957	2,139	898
Household size (persons)	6.06	5.22	4.68	4.20	3.48	4.73
No of observation	231,119	231,116	231,105	231,113	231,113	1,155,566

Source: Author's estimation based on GTAP-E, IO 2005 and Susenas 2005 and 2009. Note: the computations are based on per capita level analysis. The CO_2 emissions are scaled up to national account expenditure. Quintile classification is based on the household per capita expenditure distribution. Quintile 1 refers to the poorest quintile. Expenditure in 2009 is deflated (2005=100).

Table B.2. Inequality measures of per capita emission and per capita expenditure, by subgroup (household characteristics) indices

	Per capita emission				**Per capita expenditure**			
	(unconditional) Gini Coefficient		**Theil Index**		**(unconditional) Gini Coefficient**		**Theil Index**	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Affluence								
Q1	0.262	0.260	0.117	0.115	0.109	0.155	0.023	0.047
Q2	0.214	0.206	0.075	0.069	0.048	0.063	0.003	0.006
Q3	0.203	0.194	0.068	0.061	0.047	0.057	0.003	0.005
Q4	0.196	0.188	0.064	0.058	0.063	0.070	0.006	0.007
Q5	0.317	0.313	0.169	0.161	0.259	0.267	0.118	0.119
Within group (%)			*0.098 (31%)*	*0.093 (28%)*			*0.031(14%)*	0.037(13%)
Between group (%)			*0.220(69%)*	*0.245 (72%)*			*0.185(86%)*	0.249(87%)
Location								
Rural	0.372	0.406	0.236	0.283	0.294	0.372	0.142	0.233
Urban	0.397	0.425	0.267	0.309	0.370	0.417	0.226	0.294
Within group (%)			*0.248(78%)*	*0.292(86%)*			*0.174(81%)*	0.254(88%)
Between group (%)			*0.071(22%)*	*0.046(14%)*			*0.042(19%)*	*0.032(12%)*
Education								
did not grad	0.405	0.435	0.281	0.327	0.329	0.400	0.177	0.269
elementary	0.398	0.427	0.271	0.314	0.320	0.393	0.169	0.261
secondary	0.405	0.427	0.280	0.315	0.336	0.396	0.186	0.265
high school	0.405	0.439	0.285	0.335	0.357	0.416	0.210	0.294
at least college	0.426	0.472	0.318	0.390	0.409	0.456	0.281	0.356
Within group (%)			*0.279(90%)*	*0.325(71%)*			*0.185(86%)*	*0.275(96%)*
Between group (%)			*0.040(10%)*	*0.013(29%)*			*0.031(14%)*	*0.011(4%)*
Household members								
1	0.427	0.394	0.319	0.264	0.404	0.369	0.272	0.231
2	0.417	0.381	0.297	0.245	0.365	0.351	0.219	0.206
3	0.392	0.378	0.260	0.241	0.331	0.347	0.179	0.202
4	0.405	0.381	0.278	0.245	0.338	0.348	0.187	0.203
5	0.420	0.387	0.302	0.255	0.350	0.350	0.203	0.206
6	0.424	0.394	0.306	0.264	0.348	0.354	0.199	0.211
7+	0.442	0.404	0.334	0.278	0.355	0.357	0.208	0.215
Within group (%)			*0.279(90%)*	*0.254(75%)*			*0.197(91%)*	*0.207(72%)*
Between group (%)			*0.040(10%)*	*0.083(25%)*			*0.019(19%)*	*0.079(28%)*
Gender of household-head								
Male	0.428	0.438	0.315	0.332	0.360	0.281	0.213	0.408
Female	0.432	0.445	0.322	0.342	0.364	0.291	0.218	0.415
Within group (%)			0.318(99%)	0.337(99%)			0.216(99%)	*0.286(99%)*
Between group (%)			7.0E-05(1%)	2.2E-04(1%)			1.0E-05(1%)	*1.8E-04(1%)*
Age								
<30	0.425	0.432	0.311	0.323	0.356	0.398	0.208	0.269
30-44	0.428	0.433	0.316	0.323	0.366	0.403	0.220	0.275
45-64	0.443	0.448	0.339	0.348	0.375	0.422	0.233	0.303
65+	0.415	0.471	0.296	0.390	0.351	0.455	0.203	0.356
Within group (%)			0.316(99%)	0.331(98%)			0.214(91%)	*0.280(98%)*
Between group (%)			0.003(1%)	0.007(2%)			0.002(9%)	*0.006(2%)*
Overall	0.430	0.442	0.318	0.338	0.362	0.411	0.216	0.286

Source: Author's estimation based on GTAP-E, IO 2005, and Susenas 2005 and 2009.

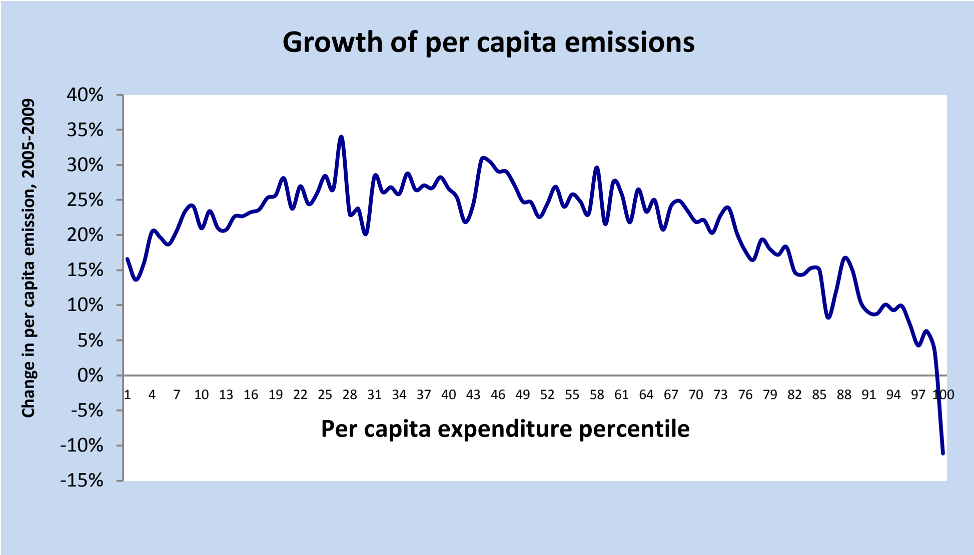

Figure B.1. Emission growth incidence curve

Source: Author's computation

Appendix C (Chapter 3)

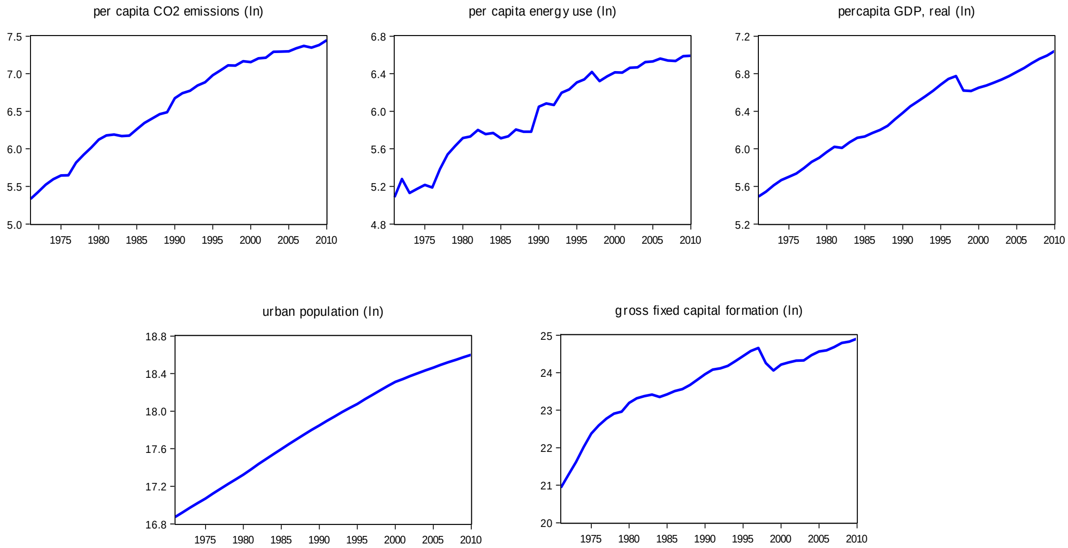

Figure C.1. Data

Source: WDI (2013), BPS (2013)

Table C.1. Data description

Variable	Measure
LNCO2CP	Per capita CO_2 emission, in kg CO_2 per capita (ln)
LNYCP	Per capita real GDP, in constant 2000 US$ (ln)
LNECP	Per capita energy use, kg of oil equivalent per capita (ln)
LNU	Urban population (ln)
LNK	Gross fixed capital formation, local currency (ln)

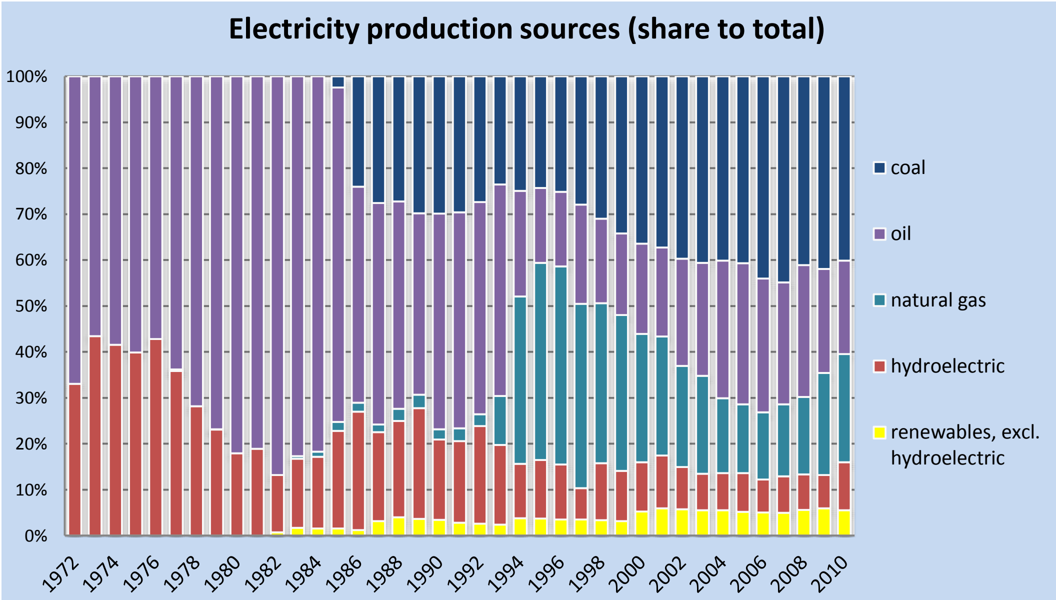

Figure C.2. Electricity production sources

Table C.2. Engel-Granger estimates

Dependent Variable: LNCO2CP				
	Coefficient	**Std. Error**	**t-Statistic**	**Prob.**
LNECP	0.679850	0.110600	6.146941	0.0000
LNYCP	0.712252	0.117429	6.065386	0.0000
C	-1.997799	0.152235	-13.12308	0.0000
R^2	0.991925		Mean dependent var	6.584764
Adjusted R^2	0.991488		S.D. dependent var	0.649683

Source: Author's estimation.

Table C.3. ADF test of residuals

		t-Statistic	**Prob.**
Augmented Dickey-Fuller test statistic		**-3.064830**	**0.0377**
Test critical values:	1% level	-3.610453	
	5% level	-2.938987	
	10% level	-2.607932	

Source: Author's estimation. Note: Residuals from **Table C.2.** Exogenous: Constant. Null hypothesis is that the residual has a unit root. Lag Length: 0 (based on SIC, maximum lag = 9)

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(Residuals **Table C.2**)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Residuals Table C.2(-1)	-0.409951	0.133760	-3.064830	0.0041
C	0.000204	0.007725	0.026444	0.9790
R-squared	0.202469			
Adjusted R-squared	0.180914			
S.E. of regression	0.048231			
Prob(F-statistic)	0.004052			

Table C.4. Engel-Granger short-run estimates[36]

Dependent Variable: D(LNCO2CP)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
ECT(-1)	-0.253578	0.104878	-2.417827	0.021
D(LNECP)	0.374931	0.082779	4.529315	0.0001
D(LNYCP)	0.216801	0.166448	1.302519	0.2012
C	0.031450	0.008620	3.648487	0.0009
R^2	0.452251		Sum squared resid	0.04517
Adjusted R^2	0.405302		F-statistic	9.632646
S.E. of regression	0.035925		Prob(F-statistic)	0.000089

Source: Author's estimation. Note: ECT(-1) is lagged of residuals from **Table C.2**.

[36] The model passes all diagnostic tests (normality, serial correlation, and heteroskedasticity

Table C.5. VECM Estimates

Short-run Estimates			
Error Correction:	D(LNCO2CP)	D(LNECP)	D(LNYCP)
CointEq1	-0.212939	-0.047260	-0.081293
	(0.04869)	(0.08498)	(0.04420)
	[-4.37378]	[-0.55614]	[-1.83929]
D(LNCO2CP(-1))	0.045064	0.397083	0.114930
	(0.18556)	(0.32388)	(0.16845)
	[0.24286]	[1.22601]	[0.68227]
D(LNECP(-1))	0.028818	-0.319227	-0.006377
	(0.11288)	(0.19703)	(0.10248)
	[0.25529]	[-1.62018]	[-0.06223]
D(LNYCP(-1))	-0.064884	0.280332	0.246254
	(0.21950)	(0.38313)	(0.19927)
	[-0.29560]	[0.73168]	[1.23579]

Long run coefficient (Cointegrating equation (CointEq1)			
LNCO2CP(-1)	LNECP(-1)	LNYCP(-1)	C
1.000000	-0.064256	-1.179065	1.028018
	(0.35680)	(0.37789)	(0.49308)
	[-0.18009]	[-3.12014]	[2.08489]

Source: Author’s estimation Note: sample (adjusted): 1973 2010. Standard errors in ( ) and t-statistics in [ ]

Table C.6a. DOLS: Dependent Variable: LNECP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.405715	0.390858	6.154956	0.000000
LNCO2CP	0.628015	0.153234	4.098397	0.000500
LNYCP	-0.052977	0.203446	-0.260401	0.797000
D(LNCO2CP)	-0.020073	0.195019	-0.102927	0.919000
D(LNCO2CP(-1))	-0.014191	0.168668	-0.084135	0.933700
D(LNCO2CP(-2))	-0.031098	0.182472	-0.170425	0.866200
D(LNCO2CP(1))	0.101980	0.242244	0.420980	0.677900
D(LNCO2CP(2))	0.073143	0.260620	0.280651	0.781600
D(LNYCP)	0.213008	0.221363	0.962256	0.346400
D(LNYCP(-1))	0.224483	0.112815	1.989821	0.059200
D(LNYCP(-2))	-0.083195	0.190633	-0.436415	0.666800
D(LNYCP(1))	-0.010232	0.110346	-0.092728	0.927000
D(LNYCP(2))	-0.054710	0.107635	-0.508295	0.616300
R^2	0.986905		F-statistic	138.1715
Adjusted R^2	0.979763		Prob(F-stat)	0.000000

Source: Author's estimation

Table C.6b. DOLS: Dependent Variable: LNYCP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.736960	0.729926	1.009637	0.323600
LNCO2CP	0.339954	0.307771	1.104570	0.281300
LNECP	0.543182	0.448280	1.211701	0.238500
D(LNCO2CP)	0.430340	0.424374	1.014058	0.321600
D(LNCO2CP(-1))	0.686992	0.446857	1.537387	0.138500
D(LNCO2CP(-2))	0.288925	0.329378	0.877182	0.389900
D(LNCO2CP(1))	0.875615	0.364071	2.405064	0.025000
D(LNCO2CP(2))	0.924711	0.321747	2.874030	0.008800
D(LNECP)	-0.499881	0.319438	-1.564875	0.131900
D(LNECP(-1))	-0.470964	0.298399	-1.578301	0.128800
D(LNECP(-2))	-0.139007	0.201865	-0.688616	0.498300
D(LNECP(1))	-0.186648	0.193648	-0.963852	0.345600
D(LNECP(2))	-0.236333	0.155522	-1.519609	0.142900
R^2	0.987592		F-statistic	145.9220
Adjusted R^2	0.980824		Prob(F-stat)	0.000000

Source: Author's estimation

Table C.7. DOLS estimation (without energy use)

	Dependent Variable: LNCO2CP		Dependent Variable: LNYCP	
Variable	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
LNCO2CP			0.702921	0.026794
LNYCP	1.419081	0.044247		
D(LNCO2CP)			-0.120042	0.178584
D(LNCO2CP(-1))			0.083999	0.198087
D(LNCO2CP(-2))			0.033320	0.165857
D(LNCO2CP(1))			0.368303	0.129736
D(LNCO2CP(2))			0.351898	0.155573
D(LNYCP)	-0.825987	0.146722		
D(LNYCP(-1))	-0.725341	0.132864		
D(LNYCP(-2))	-0.565653	0.170011		
D(LNYCP(1))	0.273623	0.133415		
D(LNYCP(2))	0.199060	0.202879		
C	-2.339396	0.287559	1.668240	0.1852
R^2	0.989079		0.983007	
Adjusted R^2	0.986739		0.979366	

Error correction term and long-run Granger causality

	Dependent Variable: D(LNCO2CP)		Dependent Variable: D(LNYCP)	
Variable	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
C	0.022777	0.011553	0.022953	0.008619
D(LNCO2CP(-1))	0.243703	0.164494	-0.004338	0.086125
D(LNCO2CP(-2))	0.120785	0.087678	-0.107175	0.092144
D(LNYCP(-1))	0.039806	0.133660	0.413820	0.150556
D(LNYCP(-2))	0.187066	0.096042	0.133591	0.118531
ECT(-1)	-0.368924	0.131873	-0.324250	0.257653
R^2	0.250666		0.197433	
Adjusted R^2	0.121471		0.059059	

Source: Author's estimation

Table C.8. DOLS estimation (without output)

	Dependent Variable: LNCO2CP		Dependent Variable: LNECP	
Variable	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
LNCO2CP			0.721377	0.034013
LNECP	1.112404	0.009131		
D(LNCO2CP)				
D(LNCO2CP(-1))			0.003441	0.287423
D(LNCO2CP(-2))			-0.065865	0.178829
D(LNCO2CP(1))			-0.370554	0.236548
D(LNCO2CP(2))			-0.382223	0.207391
D(LNECP)	1.351536	0.279200		
D(LNECP(-1))	-0.33126	0.298066		
D(LNECP(-2))	-0.358924	0.239348		
D(LNECP(1))	0.124845	0.309333		
D(LNECP(2))	-0.10153	0.346472		
R^2	0.965645		0.983007	
Adjusted R^2	0.959722		0.979366	

Source: Author's estimation

Error correction term and long-run Granger causality

	Dependent Variable: D(LNCO2CP)		Dependent Variable: D(LNECP)	
Variable	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
D(LNCO2CP(-1))	0.479643	0.170685	0.028467	0.017938
D(LNCO2CP(-2))	0.395428	0.188688	0.221372	0.198225
D(LNECP(-1))	-0.127246	0.111857	-0.021545	0.221538
D(LNECP(-2))	-0.052123	0.147050	-0.028810	0.169856
ECT(-1)	-0.071605	0.075035	-0.417095	0.198052
R^2	0.250666		0.197433	
Adjusted R^2	0.121471		0.059059	

Source: Author's estimation

Table C.9. Lag length of Toda-Yamamoto augmented-VAR

Lag	LR	AIC	SC	HQ
0	NA	-8.524277	-8.306586	-8.447531
1	446.6905	-21.58230	-20.27615*	-21.12182
2	46.84083	-22.03252	-19.63791	-21.18831
3	40.70280*	-22.61939*	-19.13633	-21.39145*

Source: Author's estimation. Note: Endogenous variables: LNCO2CP, LNYCP, LNECP, LNU, LNK. Exogenous variables: C. * indicates lag order selected by the criterion.

Table C.10. Analysis of variance decomposition (numerical presentation)

Variance Decomposition of LNCO2CP:						
Period	**S.E.**	**LNCO2CP**	**LNYCP**	**LNECP**	**LNU**	**LNK**
1	0.032725	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.036624	89.89743	0.689134	6.881835	0.442338	2.089265
3	0.040156	74.77979	0.573820	17.03446	5.745618	1.866313
4	0.044152	71.47139	0.478967	18.50352	7.355042	2.191075
5	0.049658	65.53069	4.947136	18.50419	7.067301	3.950678
6	0.054211	57.58714	13.36376	16.68023	9.051847	3.317016
7	0.061528	48.89557	21.10415	15.20023	11.74922	3.050824
8	0.070919	44.15391	26.74514	16.70995	9.877544	2.513464
9	0.077581	42.60191	28.37937	17.59227	9.046848	2.379594
10	0.084605	42.58124	27.42638	15.75068	11.12938	3.112319
Variance Decomposition of LNECP:						
Period	**S.E.**	**LNCO2CP**	**LNYCP**	**LNECP**	**LNU**	**LNK**
1	0.040066	64.08946	0.000000	35.91054	0.000000	0.000000
2	0.053076	59.42729	2.697644	34.79542	2.674279	0.405365
3	0.061032	47.27685	8.144295	26.33455	17.21666	1.027651
4	0.068044	43.26789	9.852112	27.29378	16.14980	3.436422
5	0.071621	43.56302	9.838986	26.88570	16.40728	3.305011
6	0.073884	41.31406	10.61616	29.63355	15.26857	3.167661
7	0.075873	38.57875	15.66925	25.33132	17.26757	3.153113
8	0.077140	35.65724	19.04559	29.62800	13.20826	2.460910
9	0.077576	40.21366	19.31490	25.55639	12.60389	2.311150
10	0.078548	36.22091	23.06676	21.71330	15.86087	3.138168
Variance Decomposition of LNYCP:						
Period	**S.E.**	**LNCO2CP**	**LNYCP**	**LNECP**	**LNU**	**LNK**
1	0.039950	5.130975	31.00192	63.86711	0.000000	0.000000
2	0.041562	14.70885	29.17508	55.30094	0.573309	0.241823
3	0.048297	24.56817	22.08082	48.75188	0.433652	4.165477
4	0.050717	32.57878	18.87698	41.57754	1.694753	5.271944
5	0.051716	33.61206	19.31362	37.80370	3.565372	5.705259
6	0.053914	31.76306	20.25942	36.27781	6.038689	5.661023
7	0.058490	30.12023	22.89932	34.45063	6.858771	5.671051
8	0.066888	29.56179	24.11283	33.50684	7.308080	5.510457
9	0.072046	29.30033	23.84351	34.01596	7.352171	5.488028
10	0.084696	29.03051	23.25775	34.46849	7.887009	5.356240

Source: Author's estimation Note: Cholesky Ordering: LNCO2CP LNECP LNYCP LNU LNK

Table. C.11. Impulse response function (numerical presentation)

Response of LNCO2CP:

Period	LNCO2CP	LNYCP	LNECP	LNU	LNK
1	0.032725	0.000000	0.000000	0.000000	0.000000
	(0.00391)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
2	0.011614	-0.00962	-0.003	-0.00244	0.005294
	(0.00881)	(0.00854)	(0.00729)	(0.00858)	(0.00452)
3	0.000121	0.011025	0.007799	-0.00931	0.001439
	(0.00773)	(0.00906)	(0.00713)	(0.00804)	(0.00424)
4	-0.01369	0.007444	0.005540	-0.00712	-0.00355
	(0.00943)	(0.00961)	(0.00743)	(0.00791)	(0.00439)
5	-0.01492	0.014089	-0.00312	0.005558	-0.0074
	(0.01016)	(0.01070)	(0.00798)	(0.00814)	(0.00463)
6	-0.00874	0.004628	-0.01683	0.009578	-0.00025
	(0.01115)	(0.01160)	(0.00853)	(0.00885)	(0.00515)
7	-0.0126	0.019096	-0.01126	0.013371	-0.00424
	(0.01170)	(0.01235)	(0.00897)	(0.00867)	(0.00550)
8	-0.01923	0.026717	-0.00987	0.007212	-0.00331
	(0.01276)	(0.01263)	(0.00959)	(0.01012)	(0.00565)
9	-0.01853	0.023017	-0.00718	0.006908	-0.0041
	(0.01344)	(0.01384)	(0.01051)	(0.01180)	(0.00622)
10	-0.022	0.015926	-0.00837	0.015879	-0.00892
	(0.01464)	(0.01523)	(0.01090)	(0.01144)	(0.00582)

Response of LNECP:

Period	LNCO2CP	LNYCP	LNECP	LNU	LNK
1	0.031982	0.019643	0.013685	0.000000	0.000000
	(0.00557)	(0.00330)	(0.00164)	(0.00000)	(0.00000)
2	-0.00192	-0.00824	0.002580	-0.0068	0.002646
	(0.01053)	(0.01037)	(0.00890)	(0.01046)	(0.00548)
3	0.008732	-0.00983	0.007745	-0.01885	0.004119
	(0.01035)	(0.01118)	(0.00902)	(0.00940)	(0.00532)
4	0.003183	0.003133	0.011890	-0.00372	-0.00803
	(0.01158)	(0.01195)	(0.00974)	(0.01065)	(0.00578)
5	-0.00723	0.001602	0.004919	-0.00484	-6.24E-05
	(0.01080)	(0.01202)	(0.00864)	(0.00925)	(0.00589)
6	0.005979	-0.00593	-0.01235	0.002233	0.001918
	(0.01058)	(0.01185)	(0.00797)	(0.00798)	(0.00555)
7	-0.01091	0.006745	-0.01368	0.012121	-0.00397
	(0.01053)	(0.01269)	(0.00850)	(0.00819)	(0.00587)
8	-0.0166	0.027741	-0.00234	0.000464	-0.00149
	(0.01207)	(0.01308)	(0.00850)	(0.00951)	(0.00630)
9	-0.02218	0.007811	-0.00951	0.007954	-0.00314
	(0.01251)	(0.01447)	(0.01030)	(0.01160)	(0.00705)
10	-0.0226	0.027070	-0.01226	0.021990	-0.01025
	(0.01440)	(0.01600)	(0.01106)	(0.01187)	(0.00655)

Response of LNYCP:

Period	LNCO2CP	LNYCP	LNECP	LNU	LNK
1	-0.00908	0.039025	0.000000	0.000000	0.000000
	(0.00668)	(0.00466)	(0.00000)	(0.00000)	(0.00000)
2	-0.01822	0.029229	-0.00158	-0.00402	-0.00261
	(0.01173)	(0.01088)	(0.00888)	(0.01047)	(0.00549)
3	-0.02238	0.013627	0.008545	-5.09E-05	-0.01218
	(0.01096)	(0.01267)	(0.01017)	(0.01214)	(0.00615)
4	-0.02436	0.012671	8.14E-05	0.007894	-0.00943
	(0.01288)	(0.01294)	(0.01014)	(0.01159)	(0.00565)
5	-0.01469	0.009261	-0.00671	0.010219	-0.00697
	(0.01384)	(0.01347)	(0.00989)	(0.01061)	(0.00620)
6	-0.00312	0.000871	-0.01248	0.012114	-0.00405
	(0.01361)	(0.01362)	(0.00984)	(0.00965)	(0.00567)
7	-0.00021	0.006937	-0.01293	0.008075	0.004176
	(0.01427)	(0.01409)	(0.00928)	(0.00904)	(0.00539)
8	-0.00502	0.003498	-0.01072	0.006327	0.001199
	(0.01393)	(0.01357)	(0.00870)	(0.00833)	(0.00557)
9	-0.00205	-0.00586	-0.00435	0.002753	-0.00154
	(0.01316)	(0.01302)	(0.00812)	(0.00769)	(0.00540)
10	0.005275	-0.00745	-0.00492	0.006645	0.000446
	(0.01228)	(0.01264)	(0.00776)	(0.00708)	(0.00515)

Source: Author's estimation. Note: Cholesky Ordering: LNCO2CP LNYCP LNECP LNU LNK. Standard Errors: Analytic

Table C.12. CO_2 emissions (in kilotons CO_2)

Rank	1990		1995		2000		2005	
1	USA	4,990,000	USA	5,260,000	USA	5,870,000	USA	5,940,000
2	China	2,510,000	China	3,520,000	China	3,560,000	China	5,850,000
3	Russian Fed.	2,440,000	Russian Fed.	1,750,000	Russian Fed.	1,660,000	Russian Fed.	1,720,000
4	Japan	1,160,000	Japan	1,250,000	Japan	1,280,000	Japan	1,320,000
5	Germany	1,020,000	Germany	920,000	India	1,060,000	India	1,290,000
6	Ukraine	770,000	India	870,000	Germany	870,000	Germany	850,000
7	India	660,000	UK	560,000	UK	550,000	Canada	570,000
8	UK	590,000	Canada	480,000	Canada	550,000	UK	550,000
9	Canada	450,000	Ukraine	450,000	Italy	460,000	South Korea	500,000
10	Italy	430,000	Italy	440,000	South Korea	450,000	Italy	480,000
11	France	390,000	South Korea	400,000	France	410,000	Iran	450,000
12	Poland	310,000	France	390,000	Mexico	380,000	Mexico	420,000
13	Mexico	310,000	Mexico	330,000	Australia	360,000	France	410,000
14	Australia	270,000	Poland	320,000	Ukraine	350,000	Australia	410,000
15	South Africa	270,000	Australia	300,000	Brazil	350,000	Brazil	370,000
16	Kazakhstan	255,684	South Africa	290,000	Iran	340,000	South Africa	360,000
17	South Korea	250,000	Iran	280,000	South Africa	310,000	Spain	360,000
18	Spain	230,000	Brazil	270,000	Spain	310,000	***Indonesia***	***360,000***
19	Brazil	220,000	Spain	250,000	Poland	290,000	Ukraine	340,000
20	Iran	210,000	Saudi Arabia	210,000	***Indonesia***	***290,000***	Saudi Arabia	320,000
21	Romania	184,706	***Indonesia***	***210,000***	Saudi Arabia	260,000	Poland	310,000
22	Saudi Arabia	170,000	Kazakhstan	181,119	Taiwan	230,000	Taiwan	270,000
23	Czech Republic	167,460	Turkey	177,111	Turkey	225,794	Turkey	246,134
24	Netherlands	160,000	Netherlands	170,000	Netherlands	170,000	Kazakhstan	191,703
25	***Indonesia***	***160,000***	Taiwan	170,000	Argentina	148,882	Netherlands	180,000
	World Total	22,060,863		22,957,340		24,586,832		28,438,699

Rank	2009		2010		2011	
1	China	8,270,000	China	8,900,000	China	9,700,000
2	USA	5,330,000	USA	5,530,000	USA	5,420,000
3	India	1,750,000	India	1,860,000	India	1,970,000
4	Russian Fed.	1,740,000	Russian Fed.	1,780,000	Russian Fed.	1,830,000
5	Japan	1,180,000	Japan	1,260,000	Japan	1,240,000
6	Germany	800,000	Germany	840,000	Germany	810,000
7	South Korea	540,000	South Korea	590,000	South Korea	610,000
8	Canada	530,000	Canada	540,000	Canada	560,000
9	UK	490,000	UK	500,000	***Indonesia***	***490,000***
10	Mexico	440,000	***Indonesia***	***490,000***	UK	470,000
11	Australia	440,000	Mexico	440,000	Saudi Arabia	460,000
12	***Indonesia***	***440,000***	Brazil	440,000	Mexico	450,000
13	Italy	410,000	Saudi Arabia	430,000	Brazil	450,000
14	Saudi Arabia	400,000	Italy	420,000	Australia	430,000
15	Brazil	390,000	Australia	400,000	Italy	410,000
16	France	380,000	Iran	400,000	Iran	410,000
17	Iran	380,000	France	380,000	France	360,000
18	South Africa	350,000	South Africa	360,000	South Africa	360,000
19	Poland	310,000	Poland	340,000	Poland	350,000
20	Spain	300,000	Ukraine	300,000	Ukraine	320,000
21	Ukraine	280,000	Spain	290,000	Spain	300,000
22	Taiwan	260,000	Taiwan	270,000	Turkey	278,866
23	Turkey	255,869	Turkey	264,492	Taiwan	270,000
24	Kazakhstan	204,601	Kazakhstan	211,496	Kazakhstan	222,991
25	Egypt	190,836	Egypt	204,467	Egypt	208,865
	World Total	30,728,861		32,377,875		33,376,327

Source: European Commission, Emission Database for Global Atmospheric Research (EDGAR), release version 4.2. Accessible at: http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2011&sort=des2. Note: CO_2 emissions are based on fossil fuel consumption and cement production. Emissions from land use, land use change, and forestry are not included.

Bibliography

Akbostanci, E., S. Turut-Asik, and G.I. Tunc (2009). The relationship between income and environment in Turkey: Is there an environmental Kuznets curve? *Energy Policy*, 37 (3) (2009), pp. 861–867.

Albert, J.R., and A.P. Ramos (2010). Examining recent trends in poverty, inequality, and vulnerability. *PIDS Policy Notes*, 2010 (03).

Alcantara, V., and J. A. Duro (2004). Inequality of energy intensities across OECD countries: a Note. *Energy Policy* 32 (11) (July): 1257–1260.

Ang, B.W. (2005). The LMDI approach to decomposition analysis: a practical guide, *Energy Policy* 32:1131-1139.

Badan Pusat Statistik (BPS) (2010). Census 2010. Indonesian Central Bureau of Statistics, 2010.

Baek, J.Y., S. Cho, and W.W. Koo (2008). The environmental consequences of globalization: a country-specific time series analysis. *Agribusiness and Applied Economics Report* No. 631, June 2008.

Baiocchi, G., J. Minx, and K. Hubacek (2010). The impact of social factors and consumer behavior on carbon dioxide emissions in the United Kingdom. *Journal of Industrial Ecology*, 14 (1): 50–72.

Banerjee, A.V., and E. Duflo (2008). What is middle class about the middle classes around the world? *The Journal of Economic Perspectives: a Journal of the American Economic Association*, 22(2): 3.

Bernard, J-T., M. Gavin, L. Khalaf, and M. Voia (2011). The Environmental Kuznets Curve: tipping points, uncertainty and weak identification. *CREATE Working paper*, December 2011.

Bin, S., and H. Dowlatabadi (2005). Consumer lifestyle approach to US energy use and the related CO_2 emissions. *Energy Policy*, 33(2): 197–208.

Blinder, A.S. (2009). Wage discrimination: Reduced form and structural estimates. *Journal of Human Resource*, VIII 4.

Boyce, J.K. (1994). Inequality as a cause of environmental degradation. *Ecological Economics*, 11 (1994): 169-178

Cameron, A.C., and P.K. Trivedi (2010). *Microeconometrics using Stata, Revised Edition.* Stata Press.

Cantore, N., and E. Padilla (2010). Equality and CO_2 emissions distribution in climate change integrated assessment modelling. *Energy*, 35 (1) (January): 298-313.

Carbon Dioxide Information Analysis Center (CDIAC) (2012). Ranking of the world's countries by 2009 per capita fossil fuel CO_2 emission rates. Available at http://cdiac.ornl.gov/trends/emis/top2009.cap.

Carbon Dioxide Information Analysis Center (CDIAC) (2013). Global carbon project, full global carbon budget (1959-2011). Available at http://cdiac.ornl.gov/trends/emis/meth_reg.html

Choi, E., A. Heshmati, Y. Cho (2010). An empirical study of the relationships between CO_2 emissions, economic growth and openness. *IZA Discussion Paper*, No. 5304, November 2010.

Clarke-Sather, A., J. Qu, Q. Wang, J. Zeng, and Y. Li (2011). Carbon Inequality at the Sub-national Scale: A Case Study of Provincial-level Inequality in CO2 Emissions in China 1997–2007. *Energy Policy*, 39 (9) (September): 5420–5428.

Coondoo, D., and S. Dinda (2002). Causality between income and emission: a country group-specific econometric analysis. *Ecological Economics*, 40 (2002) 351 367.

Deaton, A. (1997). The analysis of household surveys: a microeconometric approach to development policy, *World Bank Publications*.

Deaton, A. and J. Muellbauer (1980). *Economics and Consumer Behavior*, Cambridge University Press.

Dickey, D.A., and W.A. Fuller (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74 (366a) (1979): 427-431.

Dinda, S., and D. Coondoo (2006). Income and emission: A panel data-based cointegration analysis. *Ecological Economics*, 57 (2006): 167– 181.

Druckman, A., and T. Jackson (2009). The carbon footprint of UK households 1990–2004: a socio-economically disaggregated, quasi-multi-regional input–output model. *Ecological Economics*, 68 (7) (May 15): 2066–2077.

Duro, J.A. (2012). On the automatic application of inequality indexes in the analysis of the international distribution of environmental indicators. *Ecological Economics*, 76 (April): 1–7.

Duro, J.A., and E. Padilla (2006). International inequalities in per capita CO_2 emissions: a decomposition methodology by Kaya Factors." *Energy Economics,* 28 (2) (March): 170–187.

Duro, J.A., and J. Teixidó-Figueras (2013). Ecological footprint inequality across countries: the role of environment intensity, income and interaction effects. *Ecological Economics,* 93 (September): 34–41.

EDGAR (2011). Emission Database for Global Atmospheric Research (EDGAR), release version 4.2. http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2011&sort=des2

Enders, W. (2009). *Applied econometric time series,* 3rd edition. United Kingdom, Wiley.

Engle, R.F., and C.W.J. Granger (1987). Cointegration and error correction: representation, estimation, and testing, *Econometrica,* 55: 251 276.

Estudillo, J. P. (1997). Income inequality in the Philippines, 1961–91. *The Developing Economies,* 35 (1): 68–95.

Galeotti, M., M. Manera, and A. Lanza. (2009). On the robustness of robustness checks of the Environmental Kuznets Curve hypothesis. *Environmental and Resource Economics* 42 (4) (April 1): 551–574.

Geweke, J. (1984). Inference and causality in economic time series models. In: Z. Griliches and M. D. Intriligator (eds.) *Handbook of Econometrics*. Elsevier Science Publishers, Amsterdam, 1101-1144.

Girod, B., and P. de Haan (2009). GHG reduction potential of changes in consumption patterns and higher quality levels: Evidence from Swiss household consumption survey. *Energy Policy,* 37 (12), 5650-5661.

Golley, J., and X. Meng (2012). Income inequality and carbon dioxide emissions: The Case of Chinese Urban Households. *Energy Economics,* 34 (6) (November): 1864–1872.

Granger, C.W.J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica,* 37: 424-438.

Granger, C.W.J. (1986). Developments in the study of cointegrated economic variables, *Oxford Bulletin of Economics and Statistics*, 48: 213-228.

Granger, C.W.J. (1988). Some recent developments in a concept of causality. *Journal of Econometrics,* 39 (1-2): 199-211.

Groot, L. (2010). Carbon Lorenz Curves. *Resource and Energy Economics,* 32 (1) (January): 45–64.

Grossman, G.M., and A.B. Krueger (1995). Economic growth and the environment. *The Quarterly Journal of Economics,* 110 (2) (May, 1995): 353-377.

Grunewald, N. (2013). Growth, carbon dioxide emissions, climate and wellbeing. Dissertation at Wirtschaftswissenschaftlichen Fakultät, University of Göttingen.

Hedenus, F., and C. Azar (2005). Estimates of trends in global income and resource inequalities. *Ecological Economics,* 55 (3) (November 15): 351–364.

Heerink, N., A. Mulato, and E. Bulte (2001). Income inequality and the environment: aggregation bias in environmental Kuznets curves, *Ecological Economics,* 38: 359-367.

Heil, M.T., and Q.T. Wodon (1997). Inequality in CO_2 emissions between poor and rich countries. *The Journal of Environment and Development,* 6 (4) (December 1): 426–452.

Heil, M. T., and Q.T. Wodon (1999). Future inequality in carbon dioxide emissions and the projected impact of abatement proposals. *World Bank Publications,* 1999: 2084.

Hendry, D.F. (1986). Econometric modeling with cointegrated variables: an overview. *Oxford Bulletin of Economics and Statistics,* 48: 201-212.

Hertwich, E.G., and G.P. Peters (2009). Carbon footprint of nations: a global, trade-linked analysis. *Environmental Science and Technology,* 43(16): 6414–6420.

Hossain, S.M. (2011). Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanisation of newly industrialized countries. *Energy Policy,* 39 (2011): 6991-6999.

Huff, K., R. McDougall, and T. Walmsley (2000). Contributing input-output tables to the GTAP data base. *GTAP Technical Paper,* 1 (4.2), January 2000.

Jalil, A. and M. Feridun (2010). The impact of growth, energy and financial development on the environment in China: A cointegration analysis. *Energy Economics,* 33 (2010): 284-291.

International Energy Agency (IEA) (2013). *CO_2 Emissions from Fuel Combustion*. http://www.iea.org/publications/freepublications/publication/co2emissionsfromfuelcombustionhighlights2013.pdf

Jalil, A. and S. F. Mahmud (2009). Environment Kuznets Curve for CO_2 emissions: A cointegration analysis for China. *Energy Policy,* 37 (2009) 5167–5172.

Jann, B. (2008). The Blinder-Oaxaca decomposition for linear regression models. *The Stata Journal,* 8(4): 453-479

Johansen, S. and K. Juselius (1990). Maximum likelihood estimation and inference on cointegration – with applications to the demand for money. *Oxford Bulletin of Economics and Statistics,* 52(2) (May 1990): 169–210.

Johansen, S., and K. Juselius (1992). Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK. *Journal of Econometrics,* 53(1–3) (July-September 1992): 211–244.

Kakwani, N.C., A. Wagstaff, and E. van Doorslaer (1997). Socioeconomic inequalities in health: measurement, computation and statistical inference. *Journal of Econometrics,* 77(1): 87–104.

Kaya, Y. (1990). Impact of carbon dioxide emission control on GNP growth: Interpretation of proposed scenarios. *IPCC Energy and Industry Subgroup-Response Strategies Working Group*, 1990.

Kenny, T., and N.F. Gray (2009). A preliminary survey of household and personal carbon dioxide emissions in Ireland. *Environment InterTotal expenditure*, 35: 259-272.

Kerkhof, N.S., and H. Moll (2009). Relating the environmental impact of consumption to household expenditures: An input–output analysis. *Ecological Economics,* 68(4): 1160–1170.

Kok, R., R.M.J. Benders, and H.C. Moll (2006). Measuring the environmental load of household consumption using some methods based on input–output energy analysis: A comparison of methods and a discussion of results. *Energy Policy*, 34(17): 2744–2761.

Kraft, J., and A. Kraft (1978). Note and comments: on the relationship between energy and GNP. *The Journal of Energy and Development,* 3: 401-403.

Lee, H-L. (2008). An emissions database for integrated assessment of climate change policy using GTAP. *Center for Global Trade Analysis,* 2008.

Lenzen, M. (1998a). Energy and greenhouse gas cost of living for Australia during 1993/94. *Energy,* 23(6) (June): 497–516.

Lenzen, M. (1998b). Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. *Energy Policy,* 26(6): 495–506.

Lenzen, M., L.-L. Pade, and J. Munksgaard (2004). CO_2 multipliers in multi-region Input-Output models. *Economic Systems Research*, 16: 391–412.

Lenzen, M., M. Wier, C. Cohen, H. Hayami, S. Pachauri, and R. Schaeffer (2006). A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan. *Energy,* 31 (2–3) (February): 181–207.

Leontief, W. (1970). Environmental repercussions and the economic structure: An Input-Output approach. *The Review of Economics and Statistics*, 52(3): 262–271.

Lerman, R. I., and S. Yitzhaki (1985). Income inequality effects by income source: A new approach and applications to the United States. *The Review of Economics and Statistics*, 67 (1) (February 1): 151–156.

Levy, A., K. Chowdhury, and J. Livermore (2009). International emission inequality: abatement on a per capita basis with rewards. *Department of Economics, University of Wollongong Working Paper*, (2009): 09-15, 20p.

Li, J., and Y. Wang (2010). Income, lifestyle and household carbon footprints (carbon-income relationship), a micro-level analysis on China's urban and rural household surveys, *Environmental Economics,* 1 (2010): Issue 2.

Lopez-Feldman, A. (2006). Decomposing inequality and obtaining marginal effects. *The Stata Journal*, 6 (1): 106–111.

Martinez-Zarzoso, I., and A. Bengochea-Morancho (2004). Pooled mean group estimation of an environmental Kuznets curve for CO_2. *Economics Letters,* 82(1) (January): 121-126.

Martinez-Zarzoso, I., and A. Maruotti (2011). The impact of urbanization on CO_2 emissions: Evidence from developing countries. *Ecological Economics*, 70(7) (May): 1344-1353.

Masih, R., and A.M.M. Masih (1996). Stock-Watson dynamic OLS (DOLS) and error-correction modeling approaches to estimating long- and short-run elasticities in a demand function: new evidence and methodological implications from an application to the demand for coal in Mainland China. *Energy Economics,* 18 (1996): 315-334.

Ministry of Energy and Mineral Resources (2012). Media Komunikasi Kementrian Energi and Sumber Daya Mineral (Indonesian Ministry of Energy and Mineral Resources). ESDMMag, 2012(1).

Ministry of Finance (2013). *Data Pokok APBN 2007-2013*, Kementerian Keuangan Republik Indonesia, 2013.

Ministry of National Planning (Bappenas) (2011). Master plan for acceleration and expansion of Indonesia's economic development (MP3EI).

Minx, J.C., T. Wiedmann, R. Wood, G.P. Peters, M. Lenzen, A. Owen, K. Scott, J. Barrett, K. Hubacek, G. Baiocchi, A. Paul, E. Dawkins, J. Briggs, D. Guan, S. Suh, and F. Ackerman. (2009). Input-output analysis and carbon footprinting: an overview of applications. *Economic Systems Research*, 21(3) (September): 187-216.

Mishra, S.C. (2009). Economic inequality in Indonesia: trend causes and policy responses. *Strategic Asia*, March 2009.

Murthy, N., M. Panda, and J. Parikh (1997). Economic development, poverty reduction and carbon emissions in India. *Energy Economics*, 19(3): 327–354.

Myers, N., and J. Kent, J. (2003). New consumers: The influence of affluence on the environment. *Proc. Natl. Acad. Sciences USA* ,100 (8): 4963-4968.

Narayan, P. K., I. Nielsen, and R. Smyth (2008). Panel data, cointegration, causality and Wagner's law: Empirical evidence from Chinese provinces. *China Economic Review*, 19(2): 297-307.

Nasir, M., and F.U. Rehman (2011). Environmental Kuznets Curve for carbon emissions in Pakistan: An empirical investigation. *Energy Policy,* 39 (2011): 1857–1864.

Newey, W.K. and K.D. West (1987). A simple, positive semi-definite hcteroscedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55: 703-708.

Oaxaca, R. (1973). Male-female wage differentials in urban labor markets. *International Economic Review,* 14(3) (October 1973): 693-709.

Pachauri, S. (2004). An analysis of cross-sectional variations in total household energy requirements in India using micro survey data. *Energy Policy,* 32 (2004): 1723–1735.

Pachauri, S., and D. Spreng (2002). Direct and indirect energy requirements of households in India. *Energy policy*, 30(6): 511–523.

Pachauri, S., and L. Jiang (2008). The household energy transition in India and China. *Energy Policy,* 36 (2008): 4022-4035.

Padilla, E., and A. Serrano (2006). Inequality in CO_2 emissions across countries and its relationship with income inequality: A distributive approach. *Energy Policy,* 34(14) (September): 1762–1772.

Padilla, E., and J.A. Duro. (2013). Explanatory factors of CO_2 per capita emission inequality in the European Union. *Energy Policy,* 62 (November 2013): 1320–1328

Pao H-T., and C-M. Tsai (2010). CO_2 emissions, energy consumption and economic growth in BRIC countries. *Energy Policy,* 38: 7850-7860.

Parikh, J., M. Panda, and N. S. Murthy. (1997). Consumption patterns by income groups and carbon dioxide implications for India: 1990-2010. *International Journal of Global Energy,* 9 (4-6): 237–255.

PEACE (2007). Indonesia and Climate Charge: Current Status and Policies. http://siteresources.worldbank.org/INTINDONESIA/Resources/Environment/ClimateChange_Full_EN.pdf

Peters, G.P., J.C. Minx, C.L. Weber, and O. Edenhofer (2011). Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences, 108: 8903-8908.

Phillips, P.C.B., and P. Perron, 1988, Testing for a unit root in time series regression. *Biometrika*, 75 (2): 335–346.

Ravallion, M., and S. Chen (2003). Measuring pro-poor growth. *Economics Letters*, 78(1) (January): 93-99.

Ray, D. (1998). *Development Economics*. Princeton, NJ: Princeton University Press.

Rees, W. E. (1992). Ecological footprints and appropriated carrying capacity: What urban economics leaves out. *Environment and Urbanization,* 4(2) (October 1): 121-130.

Saboori, B. and A. Soleymani (2011). Environmental Kuznets curve in Indonesia, the role of energy consumption and foreign trade. *MPRA Paper,* (June 2011): 31534.

Saboori, B., J.B. Sulaiman, and M. Saidatulakmal (2012). An empirical analysis of the Environmental Kuznets Curve for CO_2 emissions in Indonesia: the role of energy consumption and foreign trade. *International Journal of Economics and Finance,* 4(2), February 2012.

Saikkonen, P. (1991). Asymptotically efficient estimation of cointegrating regressions, *Econometrica Theory,* 7: 1-21.

Schäfer, A. (2005). Structural change in energy use. *Energy Policy,* 33 (2005): 429–437.

Selden, T. M., and D. Song (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and Management,* 27 (1994): 147-162.

Shafik, N. (1994). Economic development and environmental quality: an econometric analysis. *Oxford Economic Papers*, 46 (October 1994): 757-773.

Shahbaz, M., Q.M.A. Hye, and A.K. Tiwari (2013). Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. *MPRA Paper*, 43272.

Soytas, U., R. Sari, and B.T. Ewing (2007). Energy consumption, income, and carbon emissions in the United States. *Ecological Economics,* 62 (2007): 482-489.

Stark, O., J. E. Taylor, and S. Yitzhaki (1986). Remittances and inequality. *Economic Journal*, 96: 722-740.

Stern, D. I. (2004). The rise and fall of the Environmental Kuznets Curve. *World Development,* 32 (8) (August): 1419–1439.

Stock, J. H., and M. Watson (1988). Testing for common trends. *Journal of the American Statistical Association*, 83: 1097-1107.

Stock, J. H., and M. Watson (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica,* 61: 783-820.

Suh, S. 2009. *Handbook of Input-Output economics in industrial Ecology*. Springer. USA.

Thomas, R.L. (1993). *Introductory Econometrics: Theory and Applications*, Longman, London.

Tiwari, A.K. (2011). Energy consumption, CO_2 emission, and economic growth: evidence from India. *Journal of International Business and Economy*, 12(1) (2011): 85-122.

Toda, H.Y., and T. Yamamoto (1995). Statistical inference in vector autoregressions with possibly integrated processes). *Journal of Econometrics* 66 (1995): 225-250.

Torras, M., and J.K. Boyce (1998). Income, inequality, and pollution: a reassessment of the environmental Kuznets Curve. *Ecological Economics,* 25 (1998): 147–160.

Tukker, A., and B. Jansen (2006). Environment impacts of products - a detailed review of studies. *Journal of Industrial Ecology*, 10: 159–182

U.S. Energy Information Administration (EIA) (2012). *International Energy Outlook*, 2011.

UNFCCC (2010). United Nations Framework Convention on Climate Change, available at http://unfccc.int/2860.php.

Wackernagel, M., and W.E. Rees (1996). *Our Ecological Footprint. Reducing Human Impact on Earth*. New Society Press.

Weber, C. L. and H.S. Matthews (2008). Quantifying the global and distributional aspects of American household carbon footprint. *Ecological Economics*, 66(2-3): 379–391.

Weidema, B. P., M. Thrane, P. Christensen, J. Schmidt, and S. Løkke (2008). Carbon Footprint. *Journal of Industrial Ecology,* 12 (1): 3–6.

Wiedmann, T., and J. Minx (2007). A definition of carbon footprint. *Ecological Economics Research Trends,* 1: 1–11.

Wier, M., M. Lenzen, J. Munksgaard, and S. Smed (2001). Effects of household consumption patterns on CO_2 requirements. *Economic Systems Research*, 13: 259–274.

World Bank (2013). CO_2 Emissions (metric Tons Per Capita). Available at http://data.worldbank.org/indicator/EN.ATM.CO2E.PC

Yusuf, A.A. (2006). On the re-assessment of inequality in Indonesia: household survey or national account? *MPRA Paper,* No 1728, February 2007.

Zaman, K. (2010). Trade liberalisation, financial development and economic growth: evidence from Pakistan (1980-2009). *Journal of International Academic Research*, 10 (2010): No.2.

Zhang, X-P., and X-M. Cheng (2009). Energy consumption, carbon emissions, and economic growth in China. *Ecological Economics*, 68 (2009): 2706–2712.