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## On the Environmental Challenges of Economic Development in Indonesia

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# SUMMARY

This thesis aims to contribute to the study of interactions between global environmental change, economic development and the spatial structure of the economic system in developing countries. The research presented in this thesis focuses on Asian countries, with a specific focus on Indonesia.

Countries in the global South play a key role when it comes to the need of reconciling expansion of the world economy with global environmental sustainability. Economic development is accompanied by urbanization and both processes are fueled by access to modern energy sources. If these sources mainly consist of fossil fuels, energy consumption will continue to be a main driver of local air pollution and global greenhouse gas emissions. Consequently, these countries therefore face a major dual 'energy challenge': the simultaneous expansion and greening of their energy supply. Against this background, this thesis presents a set of different studies into the relationship between energy use and the spatial structure of economic development.

In Chapter 2 we developed a meta-analysis of previously published empirical studies on the so-called Environmental Kuznets Curve (EKC) – an inverted U-shaped relationship between income and emissions – to shed new light on the long-lasting debate on the income-emission relationship (IER). In Chapter 3 we tried to identify the role of cultural values in a society in determining the income-emission relationship across a sample of Asian economies. Since CO<sub>2</sub> emissions result from human activities, cultural values can be thought of as (implicit) drivers of CO<sub>2</sub> emissions.

In Chapters 4, 5 and 6 we focused on the role of cities in defining the interaction between global environmental change and economic development. In Chapter 4 we developed a spatial energy model to analyze the potential trade-off between greening and brown expansion of the electricity supply in developing countries under the influence of increasing population density. The model builds on the concept of an energy source's power density in watts per square metre (W/m<sup>2</sup>) as measure of a resource's 'spatial productivity'. Power density differs between renewable energy and fossil fuels. A non-renewable resource (like coal) is more power dense and hence spatially more productive than a renewable resource (like solar), which, all things

being equal, implies that it is cheaper to transport fossil fuels. We calibrated the model to the case of Indonesia. In Chapter 5 we analyzed urban energy-use patterns across Indonesia. Based on a dataset for 71 Indonesian cities that was constructed from existing household surveys and census data, we investigated whether urbanization influences the per capita energy consumption, controlling for the impact of urbanization on per capita incomes. In addition, we analyze the spatial patterns of energy consumption across districts within the metropolitan area of Yogyakarta, one of Indonesia's largest cities. The latter was done on the basis of a survey on energy consumption and travel behavior that we conducted among 748 households in Yogyakarta Province. Finally, in Chapter 6 we used the results from this field study to analyze the way in which urban form influences preferences for the use and ownership of motorcycles in the metropolitan area of Yogyakarta.

The main findings of this dissertation are as follows:

1. *There is evidence supporting the hypothesis of an inverted U-shaped relationship between income and emissions, the so-called Environmental Kuznets Curve (EKC).* By collecting 919 estimates from 136 published studies on the Income-Emission Relationship (IER), this dissertation found that the percentage of observations with positive slopes of the IER curves in our database is increasing at lower levels of GDP per capita, but decreasing for higher GDP per capita. The meta-analysis study shows that the likelihood of finding evidence for an EKC is larger when a study uses data for developed countries and employs variables controlling for trade and environment. The likelihood of finding evidence for an EKC is lower in studies published in prominent journals or in journals that have an SJR ranking (but the higher the SJR ranking of a journal, the larger the probability of finding evidence for an EKC). In line with the meta-analysis results, based on an own primary study this dissertation found that per capita income has a statistically significant positive effect on the CO<sub>2</sub> emission intensity, but the EKC theory cannot be proven based on a mixed-effect regression model with random effects at the country level using data for nine emerging Asian countries during the period 1972–2014.

2. *Technological progress, the usage of green energy and higher fuel prices foster the decrease of the CO<sub>2</sub> emission intensity, but this is partly counteracted by an increase of per capita CO<sub>2</sub> emission intensities caused by the growth of population size and urbanization.*

The mixed-effect regression model developed in this dissertation also shows that technological advances, higher share of green energy and higher fuel price significantly reduce the CO<sub>2</sub> emission intensity. However, per capita CO<sub>2</sub> emission intensities increase with population size and urbanization. Thus, whether technological advances, which can also be reflected in term of the utilization of green energy, could reduce the CO<sub>2</sub> emission intensity will also depend on how fast population and urbanization grows.

3. *Cultural factors can significantly affect the CO<sub>2</sub> emission intensity.*

Cultures influence people's behaviour and thus may affect the CO<sub>2</sub> emission intensity. Based on the model developed using data from nine emerging Asian countries during 1972–2014, this dissertation found that countries with a high degree of power inequality in terms of reputation, riches and authority, countries whose societies tend to avoid uncertainty, countries whose societies have lower desire to compete for the best, high achievement, etc. and have higher desire to cooperate and support each other, be humble, etc., and countries having high societal norms in limiting the needs for pleasure in life, tend to have a lower CO<sub>2</sub> emission intensity. When corrected for income, people with higher individualism characteristics and people with long-term orientation tend to have lower CO<sub>2</sub> emission intensity.

4. *High population growth may lead to a decreasing share of electricity produced with renewable energy sources.*

This dissertation developed a deterministic partial equilibrium model of the electricity supply chain, in which the demand for electricity in a large city can be satisfied by a non-renewable ('brown') energy fuel, a renewable ('green') energy source or both. We calibrated the model to the case of Indonesia, to simulate the influence of population growth on electricity production generated from brown and green resources. Indonesia's scattered geography, the associated high costs to

transport coal and its relatively 'clean infrastructure slate' may enable the country to exploit quickly a range of low-carbon alternatives. However, we found for Indonesia that the increasing population density over time causes a reduction in green electricity production and thus a falling share of green electricity production in the total electricity supply. Indeed, in Indonesia, coal-fired power plants are increasingly satisfying the rising demand for electricity. We showed that, until 2050, the expected population growth in Indonesia is predicted to lead to about a 35% reduction of the country's share of electricity produced with renewable energy sources. This reduction is accompanied by a decrease in the renewable exploitation area, suggesting competition between the need for renewable energy production and other needs, such as residential use.

5. *In Indonesia larger and denser cities have no direct effect on energy use other than through an income effect.*

Using data across cities in Indonesia, this dissertation found no evidence that larger and denser cities – the so-called compact city theory – have a direct effect on energy use other than through an income effect. The income effect is substantial: a 1% increase in the per capita income increases the per capita total energy expenditure by 0.38%, per capita energy expenditure on transport by 0.45% and per capita energy expenditure on dwellings by 0.35%. We also found a significant positive effect of city size on per capita energy expenditure but no effect of population density.

6. *Urban characteristics – especially distance to the city centre – play a role in explaining within-city variation in energy consumption.*

Within the metropolitan area of Yogyakarta, we found that urban characteristics play an important role in explaining energy use; household characteristics explain only about 40% of the per capita total energy consumption. We found that the distance to the city centre – which is correlated with the population density – plays a crucial role in explaining the within-city variation in energy consumption. People who live closer to the city centre (in a denser district) tend to consume less energy, because their relatively short commuting distance saves energy consumption for transport. We also found an indication that people who live far from the city centre

might consume less energy, that is, electricity, in their dwelling. In general, however, the effect sizes that we found show that the (positive) effect of income on energy consumption or expenditure dominates the potential decelerating effects of urban form.

7. *The urban form does affect preferences regarding the transport mode.*

We found that in the Yogyakarta metropolitan area the urban form explains about 20% of the observed variance in transport mode choice, while it explains less than 6% of the observed variance in the probability of household ownership of motorcycles and cars. The chance of people using a motorcycle is increasing with population density, travel distance and travel frequency. The chance of people using motorcycle also increases for people whose home is at an intermediate distance from the city centre; near the city centre the probability of travelling by car is higher, whereas far from the city centre people have a higher tendency to travel by bicycle. This distance effect is, however, relatively small.