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IAEE 2017 Awards Evening Event (ESI Photos).

In this issue ...


IAEE 2017 Awards Evening Event (ESI Photos).

INTRODUCTION

This issue of the Bulletin contains the second tranche of presentations delivered by ESI staff at the 40th International Conference of the International Association for Energy Economics (IAEE) which was held at the Marina Bay Sands Convention Centre from 18 to 21 June this year.

ESI staff made a total of ten presentations at the conference, and shortened versions of three of them appeared in the previous (August 2017) issue of the Bulletin. A further three appear in this issue. The remaining presentations have been accepted for publication in various international refereed journals and, for copyright reasons, cannot be reproduced in the Bulletin.

The summaries of the three presentations in this issue reflect on-going research priorities within the ESI, although there is no single theme linking them.

National greenhouse gas inventories prepared according to the guidelines of the United Nations Framework Convention on Climate Change take only domestic, i.e., territory-based, emissions into account. However, in order to obtain a more realistic picture of a nation's contribution to global greenhouse gas emissions, inventories should be based upon emissions embodied in domestic consumption of goods and services, not production. To accomplish this, embodied emissions due to imports and exports of goods and services must be quantified, and the national inventory adjusted accordingly. Dr. Brantley Liddle's presentation compared and analysed both consumption- and territory-based carbon emissions data to establish some stylised facts and to estimate relationships between emissions, trade flows, income and energy structure. He concluded that for territory-based emissions, fossil fuel consumption (but not so much trade) matters and for consumption-based emissions, trade patterns (exports, imports) matter and trading partners' consumption of fossil fuels matter. Since we cannot live in a world in which every country exports more than they import, the main policy lesson is that countries should have both an interest and a responsibility to help lower the carbon intensity of energy in countries that are particularly important for global carbon transfers, *viz*: China and India.

Green bonds are fixed-income financial instruments that are issued by governments, multinational banks, or corporations to raise finance for climate change projects or programmes. The issuing entity guarantees repayment of the bond over a certain period of time, plus either a fixed or variable rate of return. They are a relatively new asset class, but they are growing rapidly. The presentation by Melissa Low and Jacqueline Tao focused on the rise of issuance of green bonds in China and India. For both countries, they observed that the green bond market has continued to mature, judging from the increase in the quantity and quality of issuances. However, they asserted that the market needs to grow at speed if it is to close the financing gap for green investments. Further, greater harmonisation and international alignment of the market is needed to build investor confidence and to secure scalability. Both countries have policy developments that are underway and have identified best-practices in leading jurisdictions from which they can learn. These include preferential risk weighting, exemption from loan-deposit ratio, fast-track approval and tax incentives for the issuance of green bonds, but more studies need to be done to assess if these will indeed increase the issuances and liquidity in the market. They conclude that in order to ensure that the environmental concerns of financed projects are addressed, and also to improve the conditions for the green bond market to take off, more attention should be paid to enhancing investors' confidence and trust that each project's environmental goals will actually be met.

Simply stated, the rebound effect conjectures an improvement in energy efficiency and compares the achieved reduction in energy use to the forecasted reduction in energy use that ignores consumer and market responses. Such consumer and market-wide responses are likely to occur because the energy efficiency improvement changes relative prices (and real income). The rebound effect is expressed as a percentage of the forecasted reduction in energy use that is 'lost' due to the sum of consumer and market responses. The origin of the concept is generally attributed to Stanley Jevons, a British economist who was writing at the height of the industrial revolution in Britain. Jevon's proposition was that exogenous improvements in energy efficiency (i.e., not policy induced) for steam power generation and for steel production would effectively reduce the input price of coal, thus encouraging its greater use and, additionally, would raise its use through higher levels of economic growth. Ultimately this would lead to exhaustion of the UK coal resource. This became known as the Jevons Paradox. Allan Loi's presentation was based on an ESI research project that aimed to understand the possible rebound effect from a field experiment designed to evaluate the actual energy savings from Singapore households who have recently replaced their air-conditioners with a more efficient model. He concluded that the rebound effect is present, and it is likely that it varies across household segments due to the heterogenous nature of energy lifestyles. Despite this limiting factor to energy savings, the rebound does not eliminate theoretical electricity savings from an energy efficient purchase. In addition, given that there are positive externalities for the household from increased energy use, the rebound should not be taken solely as being detrimental to welfare.

We hope you find these presentation summaries of interest and welcome your views and comments.

Professor Anthony D. Owen, ESI Principal Fellow and Head of the Energy Economics Division
(On behalf of the ESI Bulletin Team)

The Importance of Consumption-Based Accounting in a Potential Trade-Carbon Emissions Nexus Literature

Brantley Liddle, ESI Senior Research Fellow

Kuo Chang at Hong Kong, China, 2009. Photo by pete (Permission under CC BY 2.0).

Overview

There has long been a concern that countries—particularly wealthy ones—might lower emissions via international trade in such a way that those emissions reductions are (at least) offset by increases elsewhere.[1] Recently, a consumption-based carbon emissions database has been developed where emissions calculations are based on the domestic use of fossil fuels plus the embodied emissions from imports, minus exports.[2] Hence, one can now test directly for the importance of trade in national emissions; yet, most economic-based inquiries into the trade-emissions relationship still employ conventionally-measured territory-based carbon data.[3] This paper compares and analyses both consumption- and territory-based carbon emissions data to establish some stylised facts and to estimate relationships among emissions, trade flows, income and energy structure.

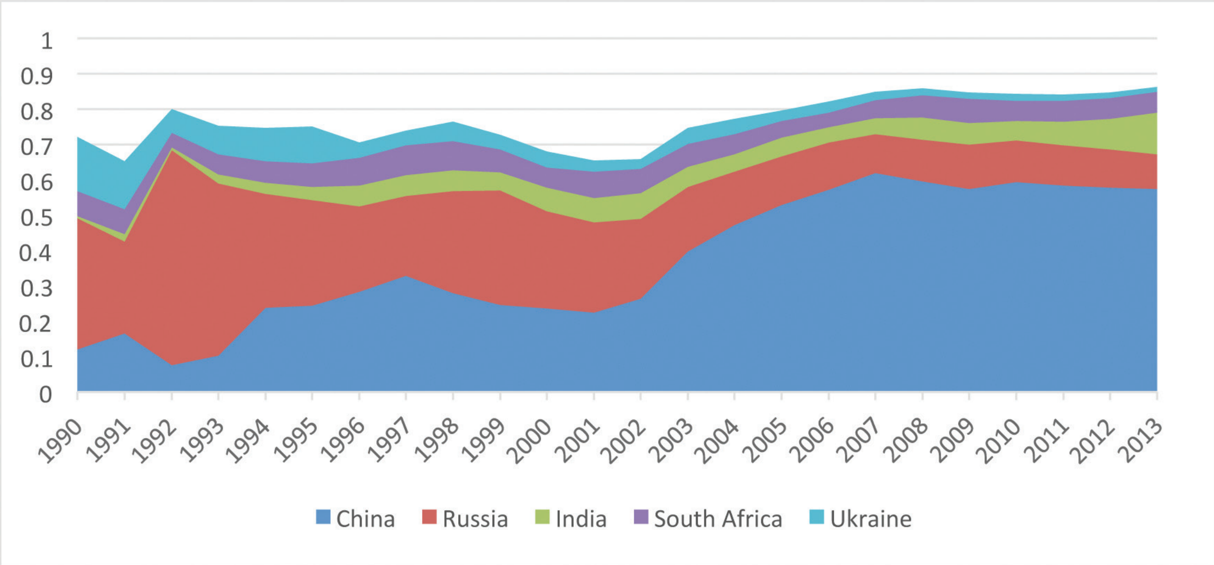
Data and Initial Investigation

Consumption-based carbon emissions in million tons of carbon per year covered 117 countries from 1990 to 2013 and were updated from Peters et al.[4] These emissions data can be compared to territory-based carbon emissions (also in million tons of carbon per year and for the same countries and time-frame) from the UNFCCC and CDIAC. Other variables sourced from the World Bank's *World Development Indicators* included real GDP per capita (adjusted for PPP and in 2011 international USD), population (to convert emissions to per capita), fossil fuel energy consumption as a share of total consumption, and industry value added, trade, exports of goods and services, and imports of goods and services, all as a percent of GDP.

By comparing these two datasets we created two additional series: (i) the ratio of consumption -based to territory -based emissions; and (ii) the difference between territory-based and consumption-based emissions, or the net emissions flows. If the consumption-to-territory emissions ratio is greater than one, then a country effectively imports carbon emissions. Only 28 countries had a mean ratio (from 1990 to 2013) of less than one. The average country mean ratio was 1.26, and the mean ratio for each year ranged from 1.2 to 1.4. The annual ratio was stable for most countries: most countries' maximum and minimum yearly ratio was within 20 to 30 per cent of their mean ratio. So the vast majority of countries consume more carbon emissions than they produce/emit at home, and the "average" country consumes about one-quarter more carbon emissions. Five countries—China, Russia, India, South Africa and Ukraine—have been responsible for 65 per cent to 86 per cent of yearly net carbon transfers from 1990 to 2013, and since 2005, China alone has been responsible for over half of those emissions transfers as displayed in Figure 1.

South African Cargo Boeing 737-200, 2005. Photo by Konstantin von Wedelstaedt (Permission under GFDL 1.2).

Figure 1: Yearly Net Carbon Transfers from 1990 to 2013



Source: Authors' Analysis.

Estimation Method

Because we know/suspect that the data exhibit both cross-sectional correlation and nonstationarity, we employed a heterogeneous panel estimator, the Pesaran (2006) common correlated effects mean group estimator (CMG).[5] The CMG estimator accounts for the presence of unobserved common factors by including in the regression cross-section averages of the dependent and independent variables, and is robust to nonstationarity, cointegration, breaks and serial correlation, and at least mitigates, if not fully addresses, cross-sectional correlation. We considered two dependent variables: consumption-based and territory-based CO_2 emissions per capita. For independent variables we included GDP per capita, the carbon intensity of energy and several trade-based and economic structure indicators. The sample was divided into OECD and non-OECD countries, and all variables were in natural logs.

Results and Discussion

Industry's share of GDP was insignificant as was trade's share (results not shown). As Table 1 indicates, exports and imports were insignificant for territory-based emissions, but both import and export share did matter (they worked in opposite directions) for consumption-based emissions—a result that was true for both the OECD and non-OECD. The share of fossil fuels mattered more for territory-based than consumption-based emissions.

So for territory-based emissions, fossil fuel consumption (but not so much trade) matters and for consumption-based emissions, trade patterns (exports, imports) matter and trading partners' fossil fuel consumption matter (which is not in the database). Since we cannot live in a world in which every country exports more than they import, the main policy lesson is that countries should have both an interest and a responsibility to help lower the carbon intensity of energy in countries that are particularly important for global carbon transfers—China and India.

1 D. Rothman, "Environmental Kuznets Curves: Real Progress or Passing the Buck? A Case for Consumption-based Approaches" *Ecological Economics* 25 (1998): 177-94.

2 G. Peters, J. Mix, C. Weber and O. Endenhofer, "Growth in Emissions Transfers via International Trade from 1990 to 2008" *Proceedings of the National Academy of Science* 108 (2011): 8903-08.

3 M. Shahbaz, S. Nasreen, K. Ahmed and S. Hammoudeh, "Trade Openness-carbon Emissions Nexus: The Importance of Turning Points of Trade Openness for Country Panels" *Energy Economics* 61 (2016): 221-32.

4 G. Peters, et al (op cit).

5 M. Pesaran, "Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure" *Econometrica* 74, 4 (2006): 967-1012.

Table 1: Carbon Emissions and Trade Flows

	OECD		Non-OECD	
Dependent variable	Territory-based CO_2 p.c.	Consumption-based CO_2 p.c.	Territory-based CO_2 p.c.	Consumption-based CO_2 p.c.
GDP p.c.	0.42***	0.57***	0.57***	0.64***
	[0.25 0.59]	[0.35 0.79]	[0.39 0.74]	[0.38 0.89]
Exports share	0.01	-0.24***	0.02	-0.33***
	[-0.07 0.10]	[-0.32 -0.16]	[-0.04 0.08]	[-0.42 -0.24]
Imports share	-0.02	0.14*	-0.04	0.22***
	[-0.12 0.08]	[0.01 0.27]	[-0.13 0.05]	[0.11 0.33]
Fossil fuels share	1.28***	0.52**	1.21***	0.70***
	[0.73 1.62]	[0.16 0.88]	[0.90 1.52]	[0.37 1.02]
Obs	781	781	1616	1613
x-sects	33	33	69	69

Notes: Statistical significance is indicated by: *** p <0.001, ** p <0.01, and * p <0.05. 95%. The confidence intervals are in brackets.

Development Pathways for Green Bonds: A Comparative Case Study of China and India

Melissa Low, ESI Research Fellow and Jacqueline Tao, ESI Research Associate

People's Bank of China Headquarters, Beijing, China, 2007. Photo by Yongxinge (Permission under GNU Free Documentation License).

Introduction

In December 2015, 195 countries adopted the Paris Agreement under the United Nations Framework Convention on Climate Change. The Agreement set aspirations to limit global temperature increase to 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the warming to 1.5 degrees Celsius. Indeed, climate change presents the world with an unprecedented opportunity for low-carbon investments for mitigation and adaptation projects. According to the International Energy Agency, USD53 trillion is required by 2035 in the energy sector alone, while the New Climate Economy estimates that USD93 trillion is required across the whole economy by 2030. These investments will require financial flows from both public (government) and private (commercial) actors. Institutional investors such as pension and sovereign wealth funds and insurance companies can help fill the financial gap.

Green Bonds

Green bonds are ordinary bonds with proceeds earmarked or ring-fenced for green assets or projects. Their tenure typically ranges from 18 months to 30 years. Currently, 49 per cent of issued green bonds have tenures between one to five years, 30 per cent for five to ten years and 21 per cent of all issuances have tenure of more than 10 years. Issuers may be governments, intergovernmental organisations, regional development banks, financial institutions, or corporations, among others. Green bond issuances are dominated by the public sector (44 per cent of all issuances). As for investors, green bonds attract a pool of diverse investors from both the public and private sectors. Within the green bonds market, second party assurances, audits and third-party certifications have helped to ensure and verify proper use of proceeds, not only in terms of financial assurance but also in the environmental sense, in the absence of market-wide standardisation.

Green bonds are considered one of various financial instruments that could enhance the involvement of institutional investors and give greater access to the large capital pools. A particular characteristic of this instrument is its ability to provide comparable returns to their non-green counterparts, thereby offering a green investment opportunity without compromising the investor's quest for yield. In 2016, the total volume of green bonds issued was USD81 billion, equivalent to approximately USD9.2 million raised every hour. Green infrastructure typically involves higher upfront investments as compared to traditional infrastructure, but also comes with a broader set of returns and benefits.[1] Investment capital needs to be reallocated from high-carbon projects to those that promote a low-carbon future. Bonds could play a role in the low-carbon transition. The decisive factor for an increased uptake of green investments will be the risk-adjusted financial returns of the investment. The green aspect can be considered as a supplement to the underlying financial returns of the investment opportunity that green bonds provide.[2]

Since the first green bond was issued in 2012, the green bond market has seen impressive growth rates. To date, green bonds do not have a significant price difference from traditional bonds, but this might change as the market matures and if there is strong demand from environmental-focused funds or investors, i.e., if investors place a premium on climate and environmental impacts. Currently, any entity that is able to issue standard bonds can also issue green bonds. These include commercial banks, municipalities, national governments, private corporations and international financial institutions such as the World Bank. The World Bank, in cooperation with Skandinaviska Enskilda Banken (SEB) was the first to develop green bonds back in 2007, and later continued to dominate the market as issuers until other players such as companies and municipalities began issuing green bonds.[3]

While growth in this market was pushed forward by supranational and developed economies in its formative years, emerging country issuances, led by China and India, have been a rising influence in recent years. Presently, most issuers and purchasers of green bonds are from Europe or North America.[4] However, a growing share of green bond financed projects are found in developing countries.[5] In 2015 alone, Chinese and Indian green bond issuances accounted for a collective USD2.1 billion, or five per cent of the global USD41.8 billion market. Indeed, the speed with which the primary market for green bonds is expanding is largely underpinned by rising volumes from China and India. With the rising need for green projects in these emerging economies, a continued growth spurt in demand is expected in the coming years. This comparative study on China and India's different development pathways reveals push and pull factors driving the green bond market in Asia.

China's Green Bond Market

In 2016, green bond investments in China raised CNY255 billion (USD36.9 billion). Table 1 outlines the main actors in China's green bond markets. Key sectors in the Chinese market include large infrastructure projects, e.g., transport and rail projects and renewable energy projects. In China, standards and guidelines follow a definition of "green" that is localised to the national context, with a focus on pollution prevention and ecological protection. The Chinese green bond market faces challenges ahead, not least related to harmonising domestic guidelines with international standards and enhancing credit ratings of potential issuers. There might also be a need to overcome the difficulties that foreign investors encounter when trying to buy into China's green bond market.

Table 1: Main Actors in China's Green Bond Markets

Main Actors	Examples
State Institutions	China's State Council, Ministry of Finance, People's Bank of China (Central Bank), National Development and Reform Commission (NDRC), China Banking Regulatory Commission (CBRC), China Securities Regulatory Commission (CSRC)
Rating Agencies	China Chenxin International Credit Rating, China Lianhe Credit Rating, Dagong International Credit Rating (all supervised by the Chinese central bank, The People's Bank of China), forthcoming: Noah Holdings Ltd
Investors	Commercial banks (64 per cent), mutual funds (11 per cent), insurance companies (9 per cent)[a]
Domestic Banks	Shanghai Pudong Development Bank Co., China Industrial Bank, Agricultural Bank of China, Bank of Qingdao
Utilities	China Datang Renewable Power Co., CLP Holdings, Yalong River Hydropower Development Co., Guodian Technology and Environment Group Corporation, Chaowei Power

Sources: COWI, European Commission, Climate Bonds Initiative (CBI) and Carbon Pulse.
Note (a) Climate Bonds Initiative, "Growing a Green Bond Market in China", 2015.

India's Green Bond Market

India's green bond investments raised R79 billion (USD1.2 billion) in 2015, showing growing momentum in its debut year. Table 2 outlines the main actors in India's Green Bond Markets. Key sectors include renewable energy projects (>60 per cent) and low carbon transport assets such as rail. The standards and guidelines in the Indian market come in the form of Green Bond Requirements published by the Securities and Exchange Board of India in January 2016, which serve as rules that govern the issuance of green bonds locally. The environmental integrity of Indian issuances are aligned with international standards such as the Climate Bond Standard with verification done through both international and local partners.[6] Due to its focus on foreign investors, India's green bond market faces challenges such as the need to diversify funding sources and improving capital market access, credit enhancement, reducing forex-hedging costs and enhancing certification and standardisation.

Table 2: Main Actors in India's Green Bond Markets

Main Actors	Examples
State Institutions	Reserve Bank of India (RBI), Ministry of Finance, Securities Exchange Board of India (SEBI), Insurance Regulatory and Development Authority (IREDA), and Pension Fund Regulatory, Development Authority (PFRDA), Indian Railway Finance, National Clean Environment Fund, and Ministry of New and Renewable Energy
Rating Agencies	Securities and Exchange Board of India (SEBI)
Investors	International Finance Corporation (IFC)
Banks	Axis Bank, Yes Bank, ICICI Bank, Export-Import (Exim) Bank, IDBI Bank
Utilities	NTPC, ReNew Power Ventures, Hero Future Energies, CLP India (Wind Farms)
Commercial sector	Greenko Group

Sources: COWI, European Commission and CBI.

Reserve Bank of India Headquarters, Delhi, India, 2007. Photo by Soham Banerjee (Permission under CC BY 2.0).

The Indian development model is a policy-driven market growth model. In India, policy directives pertaining to greening the whole financial system kick-started the growth in the green bond market. This is supported by ambitious renewable energy targets, which ensured the need for capital in green areas and ensured a stable pool of viable projects in the pipelines. In 2013, the Indian Renewable Energy Development Agency (IREDA) highlighted their commitment for renewable energy projects, and in February 2014, issued their first green bond, officially opening up the market. Following IREDA's lead, leading financial institutions joined the market, under the insurance of the nation's ambitious renewable energy target. Beyond creating the market, policy makers in India were also active in deepening the demand for these green financial products, through both direct fiscal incentives and indirect policy support.

Comparison of China's and India's Green Bond Markets

There are some similarities and differences between the two markets, as well as some features that are unique to each. In both China's and India's green bond markets, state financial institutions, commercial banks and utilities lead in issuances. For China however, the focus is currently still on transportation and rail networks, while India's renewable power sector is increasingly being financed through the issuance of green bonds. The main difference in both markets is that Chinese green bonds use the People's Bank of China's issued Green Bond Guidelines, as well as the National Development and Reform Commission (NDRC)'s Guidance and Green Bond Endorsed Project Catalogue. On the other hand, Indian issued green bonds tend to follow international guidelines and standards such as the Climate Bonds Standard and Sustainalytics. These have been instrumental in ensuring international investor confidence in the green credentials of the Indian green bond market. The non-conformity of Chinese green bonds with international standards does not currently seem to be a problem in China, as much of the bonds issued are bought by domestic investors, who tend to agree on the definition of "green" as being able to deal with immediate environmental problems such as air pollution. India faces a separate set of challenges in terms of its green bond issuances and investor relations. While the challenge of credit enhancements is present in both markets, India faces an additional issue of forex hedging costs due to issuances in foreign denominations and the presence of international investors. Specifically, there is a need for credit enhancement from the current average bond rating of BBB- to AA onwards in order to be competitive in the global bond market. Indian bond issuers also face additional disclosure requirements from international investors.

Despite broad differences in the development models of the two countries, the development of national green bond markets follows similar patterns in that policy borrowers and financial institutions are typically the first to tap the market. Specific challenges and barriers exist in both the Indian and Chinese green bond markets. For example, both countries face challenges in scaling up due to the overall lack of financial market maturity and transparency (disclosure), which can hinder investor confidence and understanding of the risk-return opportunities that green bonds may present.[7]

Conclusion

In both the Chinese and Indian markets, the green bond market has continued to mature, judging from the increase in quantity and quality of issuances. However, the market needs to grow at speed if the financing gap for green investments is to be closed. Globally, HSBC's preliminary estimate for 2017 green bond investments reaches USD120 billion while the Climate Bonds Initiative estimates USD150billion. Moody's estimates are the most confident, at around USD200 billion.

However, greater harmonisation and international alignment of the market is needed to build investor confidence and to secure scalability. Both countries have policy developments that are underway and have identified best-practices in leading jurisdictions that they can learn from. These include preferential risk weighting, exemption from loan-deposit ratio, fast-track approval and tax incentives for the issuance of green bonds. However, more studies need to be done to assess if these will indeed increase the issuances and liquidity in the market.

To ensure that the environmental impacts of financed projects are addressed, investors are increasingly requiring data to be disclosed about the "use of proceeds" from the green bond. Currently, the proper use of proceeds is difficult to verify in the absence of market-wide standardisation and because *ex post* assessments of projects are voluntary. If the green bond market is to grow, more attention should be paid to enhancing investors' confidence and trust that the environmental goals of the projects will be met. Issuers need to engage more with investors and they should consider hiring independent assurance providers in order to verify the environmental integrity and impact of green bonds, as well as the processes by which such bonds are issued, managed and reported on.

1 OECD, *Mobilising Bond Markets for a Low-Carbon Transition* (Paris: OECD Publishing, 2017), p. 18. Available at http://dx.doi.org/10.1787/9789264272323-en.

2 CICERO Centre for International Climate Research, *Green Bonds and Environmental Integrity: Insights from CICERO Second Opinions*, CICERO Policy Note 2016:01, 2016, p. 3.

3 Ibid., p. 5.

4 Ibid., p. 6.

5 CICERO Centre for International Climate Research and Climate Policy Initiative (CPI), *Background Report for G7 on Long-term Climate Finance*, prepared for the German G7 Presidency, June 2015. Available at: https://www.cicero.uio.no/en/publications/internal/2831.

6 Climate Bonds Initiative, "Bonds and Climate Change: The State of the Market India", 2016.

7 CICERO, *Green Bonds and Environmental Integrity*, 2016, op. cit., p. 6

An Ex-Post Evaluation of the Rebound Effect

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HDB Flats at Choa Chu Kang, Singapore, 2006. Photo by Terence Ong (Permission under CC-BY-SA-3.0).

Overview and Motivation

Since the implementation of the Mandatory Energy Labelling Scheme (MELS) in January 2008, Singaporean households have gradually been exposed to more information about the choice of energy efficient (EE) air-conditioners and refrigerators made available to them in the market. The purchase of such appliances, as compared to less efficient ones, should ideally lead to electricity and cost savings that match the theoretical estimates made by the manufacturers. Such claims are however based on the strict assumption that energy lifestyles remain constant before and after the EE purchase. But more often than not, as documented by studies done in other countries, appliance energy usage *increases* after such purchases or retrofits.[1] This is partly due to awareness of future cost savings, which increases disposable income and may lead to a desire for greater thermal comfort and hence more electricity consumption. There may also be indirect increases in energy use as well, if households choose to engage more in other activities that require energy.

Such increases are termed the "rebound effect" and cause actual energy savings to be lower than expected energy savings. Comparatively, developed countries usually experience lower rebound than developing nations as appliances such as air-conditioners and refrigerators are often replaced with other used ones rather than purchased as a new stock for the households. The rebound effect is expected to be small in Singapore as well, where air-conditioner ownership has remained relatively stable at around 75 per cent over the last five years. Here, we aim to understand the possible rebound effect from an ex-post evaluation study, aimed at evaluating the actual energy savings from households who have recently replaced their air-conditioner with a more efficient model.

Data and Methodology

Policy evaluation studies, including those estimating energy savings, are typically done with regression and related methods, such as a before-after comparison, fixed effects modelling, as well as difference-in-differences estimation. These methods require panel data, or at least multiple cross-sectional information on energy use and household characteristics such as demographics and dwelling attributes. The period of policy intervention for such studies is usually fixed by setting specific timelines for the introduction and removal of intervention instruments such as additional feedback on energy use or new public campaigns. Also, these interventions usually involve some form of subsidy, notably free energy audits or subsidies for new appliance purchases. Although these measures can reduce the level of complexity for the experiment and increase participation rates, these are typically trial experiments that are done in preparation for future larger scale interventions.

Our study evaluated the ongoing MELS scheme and its role in energy savings, which was implemented nationwide in 2008. Hence, there was no control over the duration of intervention. In addition, we did not offer direct subsidies for participation, as this could result in an upward bias on our rebound analysis due to the increased income derived by the households from this procedure. In this study, we utilised a subsample of 232 households for analysis, complete with survey information, energy billing data and weather information provided by various public agencies. We separated the households into two groups: a control group in which households had not replaced an air-conditioner since 2008, and a treatment group in which households had replaced their entire air-conditioning (AC) system once within two years prior to their recruitment (See Table 1). The period of analysis was 34 months between 2014 and 2016. The subsample excluded approximately 20 households from this analysis due to various anomalies detected in their data, such as excessively large negative values in electricity use, households that were new owners of their dwellings and households that displayed unusual/irregular fluctuations in monthly load profiles. Such anomalies are related to data problems and lifestyle events that we could not control, and which if not removed would severely skew the results of our analysis. Compared to the national average household characteristics, those of our households were roughly the same, though the location of these households was slightly skewed towards the eastern part of Singapore.

The following equation shows the main specification for analysis:
Here, the coefficient of interest is α_1, which measured the percentage reduction of energy use after the purchase of a new and efficient AC system. The assumption here was that households in both the control and treatment groups did not exhibit significant fundamental differences in their electricity usage patterns. We used ordinary least squares (OLS) and fixed effects (FE) regression for the analysis,

- $\text{Ln(Energy Demand)}_{i,t} = \alpha_0 + \alpha_1\text{(Month of Replacement)} + \alpha_{2i}\sum \mathit{Weather\ Effects} + \alpha_3\text{(Electricity Price)}_t + \sum \mathit{Seasonal\ Month\ Dummies} + \sum \mathit{Household\ Specific\ Effects} + \varepsilon_{i,t}$

Block of HDB Flats at Woodlands Avenue 9, Singapore, 2006. Photo by Slivester Nuenenorl (Permission under CC BY-SA 2.5).

fixing the month specific effects, weather variations from temperature and any unobserved household-specific effects to properly estimate the treatment effect from our sample.

Preliminary Results and Policy Implications

All of our data for weather and categorical household characteristics were tested for correlations with annualised electricity demand for the year 2015 prior to the estimation of our econometric model. Our preliminary results suggested that there was evidence of rebound effect after the purchase of a new and efficient AC. The actual energy savings measured here ranged from 4 to 9 per cent. However, theoretical estimates of savings from such purchases should have been 40 per cent, if we consider the efficiency improvements purely from the co-efficient of performance (COP) perspective.[2] This resulted in a rebound effect of at least 77 per cent after the replacement of an air-conditioning system. This is likely to be an over-estimate, as we calculated theoretical savings assuming that households were all using much less efficient models prior to their AC replacement. In addition, we had to assume that their old and new air-conditioners had the same capacity because we did not have such information available.

Despite the limitations of our sample, we could still deduce that the rebound effect was present, and it is likely that it

Table 1: Household Characteristics of the Control and Treatment Groups

	Control	Treatment
Sample Size	158	74
Average Electricity Demand 2014	5227.98	5909.97
Average Electricity Demand 2015	5495.29	5840.3
Proportion in Private Apartments	19.0%	10.8%
Median Household Income	6000-6999	6000-6999
Household Size	3.785	3.716
Auto-Bill Payment of Electricity Bills	70%	60%
Number of Children per Household Below 12 years	0.56	0.4
Number of Children per Household Below 18 years	1	0.69
Proportion of Households with Children Below 12	34.2	25.7
Proportion of Households with Children Below 18	54.4	43.2
Proportion of Households with Elderly (65+ years)	35%	34%
Average Usage of AC Per Day (hours)	10.3	16.2
Number of Households with Clothes Dryers	20	5
Average Lease Year of Dwelling	1991	1989
Year of Education Per Household Member	12.1	11.9

varied across household segments due to the heterogenous nature of energy lifestyles. Despite this limiting factor to energy savings, the rebound did not eliminate theoretical electricity savings from an EE purchase. In addition, given that there are positive externalities for households from increased energy use, the rebound should not be taken solely as being detrimental to welfare.

Future work will explore the rebound using a more holistic approach by which attempts will be made to segregate direct and indirect rebound effects from a larger sample and metered data. Welfare improvements in the households from such purchases will also be investigated to check if increased use of the AC has led to increased household productivity and other benefits.

1 L. W. Davis, A. Fuchs and P. Gertler, "Cash for Coolers: Evaluating a Large-Scale Appliance Replacement Program in Mexico" *American Economic Journal: Economic Policy* 6/4 (2014): 207-38; and J. G. Zivin and K. Novan, "Upgrading Efficiency and Behavior: Electricity Savings from Residential Weatherization Programs" *The Energy Journal* 37/4 (2016): 1-24.

2 The benchmark we used to calculate electricity savings was a weighted COP value of 2.64, which was registered as the threshold value differentiating a 0 tick to a 1 tick model in 2008 when the MELS first started. We calculated weighted energy efficiency improvements from the 74 households to estimate the average theoretical electricity savings from their AC purchases.

Staff Publications

Internationally Refereed Journals

Brantley Liddle, "Accounting for Nonlinearity, Asymmetry, Heterogeneity, and Cross-sectional Dependence in Energy Modeling: US State-level Panel Analysis", *Economies*, 5 (3), 30, 2017.

S. Parker and **Brantley Liddle,** "Analyzing Energy Productivity Dynamics in the OECD Manufacturing Sector", *Energy Economics*, 67 (2017): 91-97.

Wang Hui, **Ang B.W**, **Su Bin**, "Accessing Drivers of Economy-wide Energy Use and Emissions: IDA versus SDA" *Energy Policy* 107 (2017): 585-99.

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Li Y., Shi X. and Su, B., "Economic, Social and Environmental Impacts of Fuel Subsidies: A Revisit of Malaysia" *Energy Policy* (A, ABDC**)** (110) (2017): 51-61.

Other Publications

Melissa Low and Jonathan Ren "Climate Transparency among Southeast Asian Countries: Developments since COP16", *ESI Policy Brief 19*, 18 July 2017.

Shi Xunpeng (施训鹏),"中美"百日计划" 能源贸易可先行' (Energy Trade Can Lead China-US Cooperation Plan", 21 世纪经济报道 *(21st Business Herald)*, 2 August 2017.

Staff Presentations and Moderating

31 August Melissa Low presented "Climate Change Research in Singapore" at Environmental Law Careers Seminar, NUS Law Faculty, Singapore.

30 August Yao Lixia presented, "Belt and Road Initiative and ASEAN's Energy Sector: A 'Going Out' Strategy 2.0?" at the *33rd International Academic Conference* organised by the International Institute of Social and Economic Sciences, Vienna, Austria.

20 August Su Bin moderated the "Low Carbon Development" session in the *5th National Conference on Low Carbon Development and Management*, 19-20 August, Beijing, China.

6 August Brantley Liddle presented, "Warming and GDP Growth in the United States: A Heterogeneous, Common Factor Dynamic Panel Analysis" at the *7th Congress of the East Asian Association of Environmental and Resource Economics*, Singapore.

6 August Su Bin presented "Structural Decomposition Analysis Applied to Energy and Emissions: Recent Developments and Future Trends" at *4th Energy and Climate Economics Forum*, 6-7 August, Qingdao, China.

28 July Su Bin presented "Energy Efficiency and Climate Change" at the Institute of Science and Development, Chinese Academy of Sciences, Beijing, China.

27 July Melissa Low presented "Leaving Paris: Implications for the Environment and US Leadership" at the *Singapore Institute of International Affairs (SIIA) Talk Series*, at International Involvement Hub, I2H, Singapore.

20 July Philip Andrews-Speed presented, "Factors Shaping the Outlook for Nuclear Energy" at *World Engineers Summit*, Singapore.

20 July Nur Azha Putra presented, "The Dynamics of Nuclear Energy in Southeast Asia" at *World Engineers Summit*, Singapore.

17 July Melissa Low presented "Energy Equity in Singapore" at the *Conference on Governance for Sustainable Energy Transitions: The Perspective of the Asian-Pacific Region*, Hong Kong Baptist University, Hong Kong, China.

Staff Media Contributions

Philip Andrews-Speed was interviewed by *Bloomberg* on the Shenhua-Guodian merger in China, 29 August 2017.

Jacqueline Tao was interviewed for "Singapore's Solar Deployment" on *Hello Singapore*, 10 August 2017.

Philip Andrews-Speed was quoted by *Nikkei Asian Review* on South China sea disputes, 18 July 2017.

Christopher Len was interviewed by *Eco-Business* on sustainable energy in Southeast Asia, 3 July 2017.

Recent Events

18 August, Full Retail Competition: What Consumers Can Expect and How Will the Industry Evolve? (ESI Seminar)

Mr. Julius Tan delivering his presentation (ESI Photo).

Mr. Julius Tan, Co-Founder and CEO and Mr. Martin Lim, Co-Founder and Chief Operations Officer at ELECTRIFY.SG delivered a presentation on the upcoming launch of full retail competition in Singapore's electricity market. Mr. Tan explained that with the upcoming full deregulation of the energy market, led by the Energy Market Authority (EMA), Singaporean consumers will experience changes in the way they purchase and consume energy. He added that as the industry evolves through various stages of maturity, it will be useful to consider how consumers may eventually benefit from this deregulatory effort.

With an additional 1.3 million consumers being given contestability or freedom to choose their electricity retailer by the end of 2018, competition in the electricity market is heating up with more electricity retailers entering the market offering new power plans and benefits. In the short term, it is expected that there will be discounts from the SP tariff, shorter contract terms, bundled services (telco, transportation, lifestyle and petrol), blended energy (solar), carbon credits or renewable energy credits and remand response offering for households.

However, in the long term, the market will experience greater efficiencies in processing through automation and self-service, resulting in a lower cost of acquisition per kWh. Consumers will likely also have a greater awareness of energy markets, Uniform Singapore Energy Price (USEP) and wholesale risk. The market will also likely develop novel products to cater to more sophisticated consumers at which time monitoring and storage technology will also change consumption behaviour according to price signals.

Mr Lim explained the role of ELECTRIFY.SG as Singapore's first ecommerce site and introduced Fibonacci™, their proprietary electricity pricing engine that sifts through millions of possible price permutations to simplify consumers' buying decisions and deliver the best value.

6 July, Catastrophic Nuclear Accidents: Procedural Implications of the Handling of Mass Tort Claims in a Transboundary Context (ESI Seminar)

This event was hosted by the Centre for International Law (CIL) which is based at NUS. Professor Günther Handl is Eberhard P. Deutsch Professor of Public International Law at Tulane University Law School and also serves as the senior project consultant for the ESI-CIL Nuclear Governance Project. He began by noting that the claims for compensation following any nuclear accident are notoriously challenging,

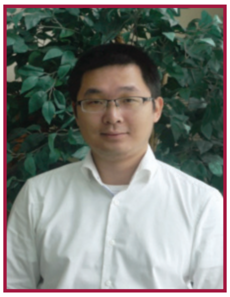
Professor Günther Handl delivering his seminar (ESI Photo).

especially in the absence of guidance from international legal instruments. The nuclear civil liability instruments themselves do not address the procedural aspects of compensating claims for nuclear damage, except for the establishment of exclusive jurisdiction over claims under respective conventions in the courts of the contracting party. Catastrophic accidents, in particular, may entail mass tort claims with transboundary consequences. In this regard, the domestic procedural laws of each country become pertinent in that they determine the nature and format of how mass torts claims will be handled.

Professor Handl went on to focus on the examples of the United States, Japan and India in order to illustrate the different ways in which claims may be processed and also the challenges faced in trying to ensure prompt and fair compensation for victims of nuclear accidents. He also stressed that where significant transboundary nuclear harm is a possibility, concerned states ought to reach an understanding as to how claims for compensation might be handled expeditiously and fairly in accordance with the requirements of international law. Ultimately the procedural arrangements for nuclear mass tort claims must ensure prompt, full/adequate and effective compensation.

New Staff

Dr. Zhong Sheng



Dr. Zhong Sheng joined the Energy Studies Institute in August 2017 as a Research Fellow. He was previously a PhD Fellow at the United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT) in the Netherlands funded by the United Nations Industrial Development Organization (UNIDO). Sheng obtained a PhD in Economics from Maastricht University in the Netherlands. Prior to that, he completed an MA in Development Economics at the University of Warsaw in Poland, funded by the European Commission Erasmus Mundus Programme. Before that, Sheng earned a Bachelor's Degree from Fudan University, China.

His research interests include sustainable development, innovation and technological change, with a focus on energy efficiency. His research field also covers areas such as applied econometrics and quantitative methods. He has extensive academic and professional working experience. He tutored in the bachelor's programme at the Maastricht University School of Business and Economics and in the master's programme at Maastricht Graduate School of Governance. In addition, he served as thesis supervisor for several bachelor-students at the same University. He also previously worked at UNU and UNIDO on various projects, including the International Social Protection Studies Programme (funded by GIZ Germany), UNIDO Industrial Development Report 2016 and UNIDO Inclusive and Sustainable Industrial Development Working Paper Series.

Contact

- Collaboration as a Partner of ESI (research, events, etc)
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