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Skyline of Singapore's Central Business District and the Old Parliament House, 2018. Photo by Basile Morin (Permission under CC BY-SA 4.0).

INTRODUCTION

The theme of this issue is climate change and the decarbonisation of economies.

The Energy and the Environment Division at ESI is actively engaged in a wide portfolio of projects related to this theme. These range from energy systems modelling and emissions accounting to climate change negotiations tracking and educational outreach activities for various Singapore student communities. In this issue, we showcase a small selection of the research projects undertaken by the Division members.

In the first article, ESI Research Fellow Dr. Zhong Sheng proposes a novel aggregate fuel economy indicator using vehicle-level microdata. Road transport constitutes a major source of CO_2 emissions worldwide, conventionally driven by the combustion of fossil fuels that has caused substantial externalities such as harm to health and damage to the environment. Development and implementation of effective environmental mitigation strategies continue to be of keen national interest for road transport policy-makers. An important aspect is the study and analysis of the actual fuel economy of road transport modes. Using data from the state of Massachusetts, the key objective of Dr. Zhong's research was to determine which factors caused temporal shifts in the aggregate fuel economy in the state between 2008 and 2014. To accomplish this, a comprehensive indicator for fuel economy which incorporates the heterogeneity of vehicles and their utilisation (vehicle mileage) was developed. In addition, the indicator was also designed to account for the impacts of the entry and exit of vehicles into and out of the state over the study period. Decomposition analysis was then performed to quantify the contributions of the aggregate fuel economy into four factors of interest. An example of a key result was that while the total vehicle mileage increased, the aggregate fuel economy improved by about 8.57 per cent. This was primarily due to cars with low fuel efficiency exiting the state while cars with good fuel efficiencies were entering. Such findings are invaluable for policy-makers tasked with formulating new mitigation strategies.

In this issue ...

Jurong East, Singapore, 2016. Photo by Edsel Little (Permission under CC BY-SA 2.0).

The second article summarises work carried out by Dr. Su Bin, Professor Ang Beng Wah and Dr. Li Yingzhu (ESI Senior Research Fellow, ESI Executive Director and ESI Senior Research Fellow, respectively). Singapore has pledged to reduce the city state's emission intensity by 36 per cent from the 2005 level by 2030 with the aim of peaking around 2030. Being alternative energy- and primary fuels-deficient, Singapore faces limited mitigation options in the short and medium terms, and the identified strategies thus far are mainly focused on energy efficiency for all sectors of the economy and switching from oil to natural gas in power generation. Although the emissions intensity is reported to have dropped by 33 per cent from 2000 to 2010, it is not certain to what extent this reduction was the result of the mitigation measures taken, changes in the structure of the economy or demand patterns. Hence, the authors undertook an extensive analysis of Singapore's emissions intensity situation. First, carbon emissions were analysed from the demand perspective using an input-output (I-O) framework based on Singapore I-O tables.

The study strongly suggests that Singapore's total emissions were driven mainly by exports, in particular in embodied manufacturing exports. Next, a structural decomposition analysis was performed to estimate the drivers of embodied emission changes by final demand categories, including energy and emission efficiency improvements, changes in inputs structure, final demand structure and total final demand. Among the many reported results, the main drivers of increased emissions over the study period were found to be total final demand effects, especially from the increase in exports and household consumption. On the other hand, improvements in the emissions intensity helped to reduce emissions significantly. Also, structural changes in exports led to significant increases in emissions, in particular those from petrochemical and petrochemical products, semiconductors and the industrial chemicals and gases sectors in 2010. The emissions intensity effect was further decomposed into several important sub-effects. The results of the study enable a clear delineation of the influencing factors behind changes in emissions intensity.

The third article in this issue, by ESI Research Fellow Ms. Melissa Low, discusses recent climate change negotiation events, as well as Singapore's views and positions on the future of carbon market mechanisms. The use of carbon market mechanisms is a potentially effective approach to removing carbon from the atmosphere through technology transfer and investment. It also helps other countries with commitments meet their pledged targets. Although market mechanisms are not new to the international climate change regime (e.g. the Kyoto Protocol), operationally there remain several challenges yet to be resolved and consensus is yet to be achieved in the current Paris Agreement climate negotiations. This includes, for instance, the use of internationally transferred mitigation outcomes (ITMOs) towards nationally determined contributions (NDCs), where guidelines must promote sustainable development, ensure environmental integrity and maintain robust accounting to ensure the avoidance of double counting. Singapore is supportive of and already participates in market mechanisms, including several clean development mechanism (CDM) projects, and the passing of a carbon pricing bill, the first in Southeast Asia.

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

Associate Professor Adam Ng Tsan Sheng,
Head of ESI's Energy and the Environment Division
and Associate Professor in the Department of
Industrial and Systems Engineering Management
at the National University of Singapore
(On behalf of the ESI Bulletin Team)

Decomposition of the Aggregate Fuel Economy: Micro-evidence from Massachusetts

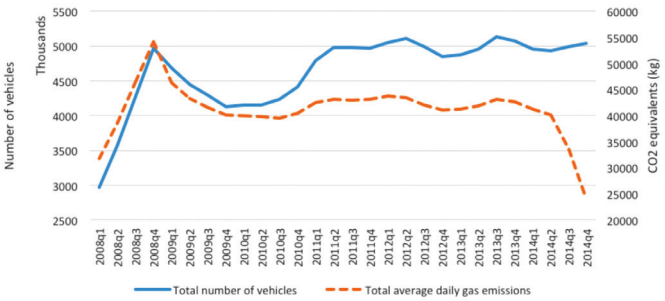
Dr. Zhong Sheng, ESI Research Fellow

Boston Traffic is Re-routed from the Ted Williams Tunnel during Rush Hour in Boston, 2006. Photo by Anthony Citrano (Permission under CC BY 2.5).

Sustainable development is a process that has many dimensions, such as efficient use of resources and raw materials, reducing CO_2 emissions, etc. Addressing all of these dimensions requires a wide range of policies supported by thorough analyses. One dimension is sustainable transport, as the gas emissions from the transport sector are substantial. Of the world's total fuel combustion in 1975, the share of CO_2 emissions from the transport sector was 20 per cent. In 2014, it increased to 20.4 per cent. [1] In the United States, the transport sector contributed the most gas emissions in 2016 (about 28 per cent of total emissions).[2] The modes of transport which rely primarily on fossil fuels have caused substantial externalities such as harm to human and animal health and damage to the environment.

This article is derived from an earlier working paper by the author using updated data. It specifically focuses on the aggregate fuel economy of road vehicles (broadly speaking, cars and trucks) in the state of Massachusetts, using comprehensive vehicle-level microdata.[3] Vehicle fuel economy measures the distance travelled by consuming one unit of fuel. It plays a crucial role in reducing gas emissions from the road transport sector. To understand the potential importance of improving the fuel economy, the following example is helpful. As shown in Figure 1, in recent years, there has been a significant decrease in transport emissions in Massachusetts while the vehicle population has continued to increase. Given the dominant share of vehicles running on fossil fuels in the total vehicle population, this can be explained by the improvements made in their fuel economy.

Figure 1: Total Number of Vehicles and Average Daily Emissions in Massachusetts: 2008q1 to 2014q4



Note: The rapid growth of total vehicles between 2008q1 and 2008q4 was probably due to more people completing the census questionnaire than in earlier years, and the fact that in the early years, the census likely did not cover the entire population.

Source: Own elaboration using Massachusetts Vehicle Census (2016 release).

Hence, the analysis presented here sought to investigate the influential factors that caused the dynamics of the aggregate fuel economy in Massachusetts from 2008 to 2014. To do so, the first step was to develop an aggregate indicator for the fuel economy that was able to incorporate the heterogeneity of vehicles. It measured the fuel economy of the entire state as a weighted average of each individual vehicle's fuel economy, in which the weight reflects consumer behaviour with respect to the use of vehicles (as measured by the share of miles travelled per day). The development of this indicator drew heavily from previous studies on firm productivity that used longitudinal microdata).[4] Second, once the aggregate indicator was obtained, the growth of the aggregate fuel economy was decomposed into four factors: "within effect", "between effect", "entry effect" and "exit effect".

At the macro-level, the logarithmic mean Divisia index (LMDI) decomposition of energy use and energy intensity has been well-documented.[5] At the micro-level, however, the literature has been limited. In addition, the conventional index decomposition technique works in the situation where data are available in both the start and end periods. But this is not the case here due to the large shares of the entry and exit of vehicles. For example, about 51.37 per cent of the vehicles in 2008q4 left Massachusetts in 2014q4, while about 53 per cent of the vehicles in 2014q4 entered the state after 2008q4. The entry and exit of vehicles would lead to 0 in the denominator and logarithmic term in the International Development Association (IDA) formulas. This paper applied the decomposition technique from the productivity literature.

Data

Microdata from the Massachusetts Vehicle Census (2016 release), constructed by the Metropolitan Area Planning Council of Massachusetts (MAPC) was used. The current census covers almost every registered vehicle in Massachusetts from 2008q1 to 2014q4 (around 3 – 5 million vehicles in each quarter). In the data, each vehicle was assigned an ID which was unique and stable. This allowed us to track each vehicle over time. Each individual vehicle's fuel economy was reported as adjusted miles per gallon (MPG). Also, the odometer of each vehicle during the quarter under investigation was recorded twice, so that the average miles per day the vehicle travelled could be obtained.

Methodology

Based on the indicator proposed by Baily et al. (1992); Bartelsman and Doms (2000),[6] the relationship between state-level aggregate fuel economy and individual fuel economy can be expressed as:

$$\ln MPG_t = \sum_i \theta_{i,t} \ln MPG_{i,t}$$

Where at time t. MPG_t, is the aggregate fuel economy of Massachusetts; $MPG_{i,t}$ represents the fuel economy of vehicle i, as measured by the vehicle's adjusted MPG; $\theta_{i,t}$ is vehicle i's share of miles per day in the state, defined as ; $\theta_{i,t} = \frac{m_{i,t}}{\sum_i m_{i,t}}$; $m_{i,t}$ is the vehicle i 's miles per day.

The share, θ, reflects the consumer behaviour, i.e., to what extent the vehicle has been used. Shifts in the shares of miles per day from low fuel economy vehicles to high fuel economy vehicles will contribute positively to the growth of aggregate fuel economy. The basic idea behind this formula is that the aggregate fuel economy of the entire vehicle population depends not only on the technological design (i.e., the individual fuel economy) of the vehicle itself, but also on the way the vehicle is used.

Then the growth of the aggregate fuel economy between time $t-1$ and i can be approximated by the first order difference of its log function. Following the decomposition technique proposed by Aw, Chen, and Roberts (2001);[7] Baily, Bartelsman, and Haltiwanger (2001),[8] the growth decomposition of the aggregate fuel economy is:

$$\begin{aligned}\Delta \ln MPG_t = & \sum_{i \in stayer} \left(\frac{\theta_{i,t} + \theta_{i,t-1}}{2}\right)(\ln MPG_{i,t} - \ln MPG_{i,t-1}) \\ & + \sum_{i \in stayer} (\theta_{i,t} - \theta_{i,t-1}) \left(\frac{\ln MPG_{i,t} + \ln MPG_{i,t-1}}{2} - \frac{\ln MPG_t + \ln MPG_{t-1}}{2}\right) \\ & + \sum_{i \in Entry} \theta_{i,t} (\ln MPG_{i,t} - \frac{\ln MPG_t + \ln MPG_{t-1}}{2}) \\ & - \sum_{i \in Exit} \theta_{i,t-1} (\ln MPG_{i,t-1} - \frac{\ln MPG_t + \ln MPG_{t-1}}{2})\end{aligned}$$

Where:
Stayer: the set of the vehicles that stay in Massachusetts at both i and $t-1$.
Entry: the set of the vehicles that are in Massachusetts at time i, but not at time $t-1$.
Exit: the set of the vehicles that are in Massachusetts at time $t-1$, but not at time i.

The contribution of the stayers consists of two terms: the effect due to changes in vehicle-level fuel economy (also known as the "within effect", the first term) and the effect due to changes in individual vehicles' shares of miles per day, holding vehicle-level fuel economy constant (also known as the "between effect", the second term). The last two terms indicate the effects due to the entry and exit of vehicles, respectively, which are weighted by using the deviation between the individual fuel economy and the average of aggregate levels. This implies that the exit of energy-inefficient vehicles is equivalent to the entry of energy-efficient vehicles in improving aggregate fuel economy.

Results and Discussion

Table 1 below presents the results of the growth decomposition of the aggregate fuel economy. Figure 2 plots the decomposition results. For the entire period, 2008q4 to 2014q4, the aggregate fuel economy of Massachusetts increased by about 8.57 per cent. As time progressed, the aggregate fuel economy increased. The "within effect", the effect due to changes in the individual fuel economy of staying vehicles, was negative in all of the decompositions, indicating the deterioration of the aggregate fuel economy. This was probably due to the aging of staying vehicles. The "between effect", the effect due to changes in the vehicle usage of staying vehicles, was negative over the period 2008q4 to 2009q4. But it became positive afterwards and indicated a growth-increasing trend. This reflects the reallocation within staying vehicles: more (less) usage of energy efficient (inefficient) vehicles. However, from 2011q4 and later, the

gain in the aggregate fuel economy from the "between effect" was largely offset by the deterioration of the "within effect". The two effects related to the reallocation due to structural change in the vehicle population, i.e., the "entry effect" and the "exit effect", contributed the most to the growth of the aggregate fuel economy. In particular, the "entry effect" was the most influential factor. This shows that the entering vehicles overall had a larger fuel economy. In all the decompositions, the "exit effect" was positive, indicating that the exiting vehicles were also those with lower fuel economy.

In summary, the gas emissions from the road transport sector in Massachusetts in recent years have significantly fallen while the vehicle population has steadily increased. Using newly developed microdata of vehicles, this paper measured the aggregate fuel economy of the state by incorporating the heterogeneity of vehicles, and decomposing the growth of aggregate fuel economy into four contributing factors. The results show that the aggregate fuel economy improved by about 8.57 per cent between 2008q4 and 2014q4. This was mainly due to the entering of energy-efficient vehicles. Changing the usage of exiting vehicles, however, was largely offset by the deterioration of the fuel economy due to vehicle aging. This implies policy opportunities regarding the timing and different impacts of vehicles' life cycles. To reduce gas emissions from the road transport sector, government policies should be directed towards reducing the life cycle of the existing vehicles that have low fuel economy, and encouraging the inflow of new, more efficient vehicles.

1 World Bank, *World Development Indicators, 2019*. [Retrieved from https://databank.worldbank.org/source/world-development-indicators.]

2 United States Environmental Protection Agency. *Sources of Greenhouse Gas Emissions*, 2017. Retrieved from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

3 This ESI Bulletin article is derived from and extends the following working paper: Sheng Zhong, "The Dynamics of Vehicle Energy Efficiency: Evidence from Massachusetts Vehicle Census", UNIDO Inclusive and Sustainable Development Working Paper Series 7/2016. The figures and tables produced in this article are based on new data and reflect new results.

4 M. N. Baily, C. Hulten and D. Campbell, "Productivity Dynamics in Manufacturing Plants", *Brookings Papers on Economic Activity* (1992): 187–267; E. J. Bartelsman and M. Doms, " Understanding Productivity: Lessons from Longitudinal Microdata", *Journal of Economic Literature 38* (3) (2000): 569–94. doi:10.1257/jel.38.3.569.

5 Ang, B. W. " LMDI Decomposition Approach: A Guide for Implementation", *Energy Policy 86* (2015): 233–38. doi:10.1016/j.enpol.2015.07.007.

6 Op cit.

7 Aw, B. Y., Chen, X. M. and M. J. Roberts, " Firm-Level Evidence on Productivity Differentials and Turnover in Taiwanese Manufacturing", *Journal of Development Economics, 66* (1) (2001): 51–86. doi:10.1016/s0304-3878(01)00155-9; M. N. Baily, E. J. Bartelsman and J. Haltiwanger, "Labor Productivity: Structural Change and Cyclical Dynamics" *Review of Economics and Statistics, 83* (3) (2001): 420–33. doi:10.1162/00346530152480072.

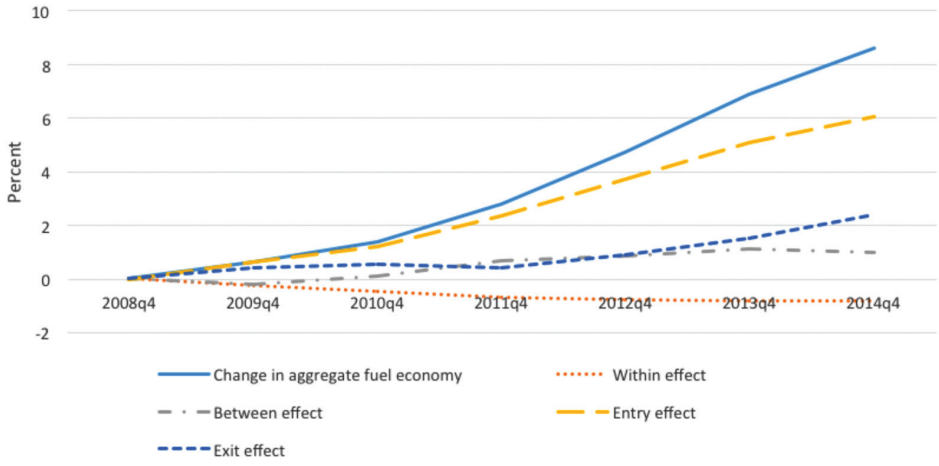
8 Op cit.

Table 1. Results of Growth Decomposition of the Aggregate Fuel Economy

Time	Change in Aggregate Fuel Economy	"Within Effect"	"Between Effect"	"Entry Effect"	"Exit Effect"
2008q4 – 2008q4	0	0	0	0	0
2008q4 – 2009q4	0.0059	-0.0024	-0.0021	0.0063	0.0041
2008q4 – 2010q4	0.0137	-0.0047	0.0009	0.0121	0.0054
2008q4 – 2011q4	0.0277	-0.0067	0.0065	0.0238	0.0040
2008q4 – 2012q4	0.0470	-0.0077	0.0086	0.0370	0.0090
2008q4 – 2013q4	0.0686	-0.0082	0.0108	0.0508	0.0151
2008q4 – 2014q4	0.0857	-0.0080	0.0096	0.0604	0.0237

Note: the sum of all four effects is equal to the change in the aggregate fuel economy.

Figure 2: Growth Decomposition of the Aggregate Fuel Economy



Source: Author's drawing using Massachusetts Vehicle Census (2016 release).

Singapore's Carbon Emissions and Their Driving Forces

Dr. Su Bin, ESI Senior Research Fellow; Professor Ang B.W., ESI Executive Director; and Dr. Li Yingzhu, ESI Senior Research Fellow

Skyscrapers in Singapore, 2018. Photo by Dudva (Permission under CC BY-SA 4.0).

Singapore is an island city-state which lacks conventional energy resources. It has a land area of only 719 square kilometres and in 2015 had a population of 5.54 million. It currently contributes around 0.11 per cent of global GHG emissions. Although there is no obligation under the Kyoto Protocol, Singapore embarked on policies and measures in 2010 to reduce its emissions by 7 to 11 per cent below the 2020 business-as-usual level. From 2015, it further aimed to reduce emissions intensity, given by the ratio of total GHG emissions to GDP, by 36 per cent from the 2005 level by 2030 and to stabilise its emissions with the aim of peaking around 2030. An inter-ministerial committee on climate change has been tasked to drive the whole-of-government effort to develop Singapore's climate change mitigation measures.

Singapore has limited access to alternative energy sources. Its energy consumption has been heavily dependent on imported oil, and in recent years, imported natural gas as well. There are very few options it can take to mitigate emissions in the short and medium terms. The strategies it has so far identified and implemented are energy efficiency in all sectors of the economy and switching from oil to natural gas in electricity generation. Over the last decade (2000-2010), Singapore's GDP increased by 72 per cent but its carbon emissions increased by only 18 per cent. This translates into a reduction in the emissions intensity of 33 per cent from 2000 to 2010. It is not certain to what extent this reduction was the result of the mitigation measures taken as part of the above strategies, or due to changes in the structure of the economy or demand patterns.

In 2015, Singapore's international trade (both imports and exports combined) amounted to SGD 884 billion, or 2.2 times its GDP of SGD 402 billion. With a strong export-oriented manufacturing base, Singapore's energy-related carbon emissions are fairly unique and are heavily dependent on the international demands of the goods and services it produces. Given the constraints it is facing in switching to clean alternative energy sources, it is doubly important to conduct a rigorous assessment of the progress it has made in emissions mitigation. This includes, for example, how the growth in emissions has been driven by the various final demand categories (including exports) and energy efficiency, as well as the effectiveness of the mitigation measures it has undertaken.

Table 1. Social-economic and Emission Indicators for Singapore

Year	Population (Thousand)	GDP (Million SGD at 2005 Market Prices)	Carbon Emissions (kt-CO_2)		
			Industrial Sector	Households	Total
2000	4,028	165,245	33,291	4,465	37,756
2010	5,077	284,561	40,934	3,454	44,388

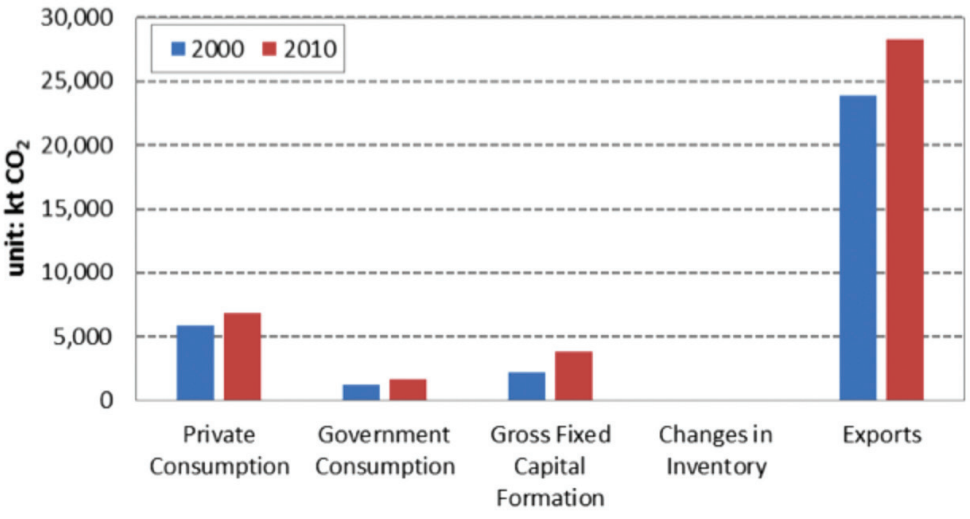
Source: B. Su, B.W. Ang and Y. Z. Li "Input-Output and Structural Decomposition Analysis of Singapore's Carbon Emissions", *Energy Policy* 105 (2017): 487.

Singapore's social-economic and emissions indicators in 2000 and 2010 are summarised in Table 1. From 2000 to 2010, Singapore's population increased by 25 per cent while its GDP grew by 72 per cent. Per capita GDP increased by 37 per cent, from SGD 41,025 to SGD 56,049. In the same period, its total carbon emissions increased by 18 per cent, from 37,756 to 44,388 kilo-tonnes CO_2 (kt-CO_2). Energy-related emissions for industry increased by 23 per cent, while those from direct energy consumption in households decreased by 23 per cent. The increases in emissions were mainly the result of direct consumption of oil and natural gas in final sectors. In 2000, the electricity generation sector accounted for the largest share, or 55.6 per cent, of total emissions. This share decreased to 46.8 per cent in 2010 as a result of the substitution of natural gas for oil in electricity production.

Using Singapore Input-Output Tables and its energy/emission data, Singapore's energy-related carbon emissions can be analysed from the demand perspective using an input-output (I-O) framework. From the results shown in Figure 1, it can be seen that Singapore's total emissions were driven mainly by exports, followed by household consumption (or private consumption) and investment (or gross fixed capital formation). From 2000 to 2010, the embodied emissions in exports were estimated to increase from 23,863 kt-CO_2 (63.2 per cent of the total emissions) to 28,309 kt-CO_2 (63.8 per cent of the total emissions), the embodied emissions in household consumption increased from 5,878 kt-CO_2 (15.6 per cent of the total emissions) to 6,841 kt-CO_2 (15.4 per cent of the total emissions), and the embodied emissions in investment increased from 2,251 kt-CO_2 (6.0 per cent of the total emissions) to 3,900 kt-CO_2 (8.8 per cent of the total emissions).

The changes in Singapore's embodied emissions from 2000 to 2010 could have been due to a number of factors, including energy/emission efficiency improvement, changes in inputs structure, final demand structure and total final demand. Using structural decomposition analysis (SDA), the drivers of embodied emission changes by final demand categories were estimated and the results are shown in Figure 2. The main drivers of the increases were total final demand effects (20,578 kt-CO_2), especially the increase in exports (12,367 kt-CO_2) and the increase in household consumption (4,785 kt-CO_2). At the same time, improvements in the emissions intensity helped to reduce emissions by 29,018 kt-CO_2. The contribution of

Figure 1. Embodied Carbon Emissions by Final Demand Category, 2000-2010

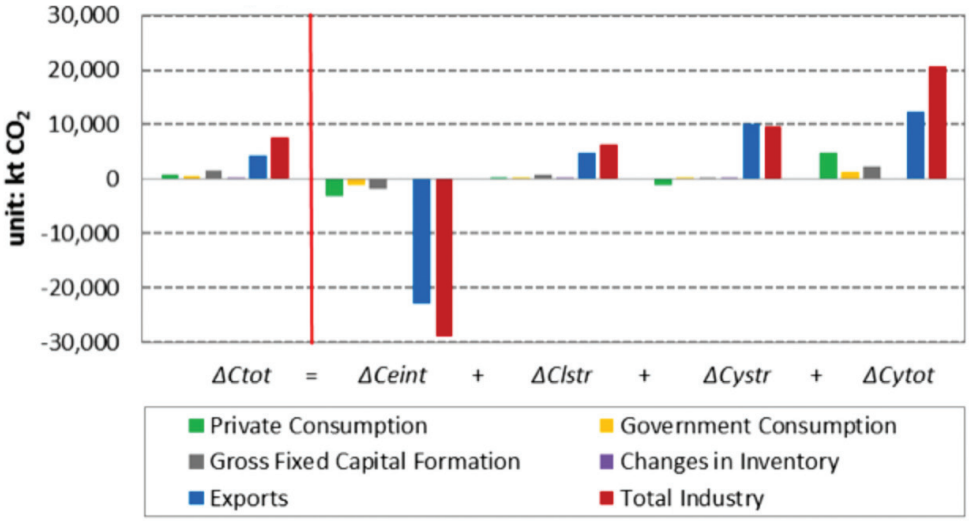


Source: B. Su, B.W. Ang and Y. Z. Li "Input-Output and Structural Decomposition Analysis of Singapore's Carbon Emissions", *Energy Policy* 105 (2017): 487.

the Leontief production structure change was relatively small. As for the final demand structure change effect, only structural change in exports led to a significant increase in emissions (10,087 kt-CO_2). In other words, a higher volume of energy/emissions intensive products, such as those from petrochemical and petrochemical products, semiconductors and industrial chemicals and gases sectors, were exported in 2010. The emissions intensity effect was further decomposed into three sub-effects (emissions coefficient, energy mix and energy intensity effects), whose contributions accounted for 26.3 per cent, 7.8 per cent and 65.9 per cent of the total emissions intensity effect respectively.

This study used the I-O method to analyse Singapore's carbon emissions from the demand perspective and the SDA method to investigate the drivers of emission changes from 2000 to 2010. The emissions were found to be driven mainly by exports, which accounted for about 63 to 64 per cent of total emissions. The bulk of the embodied emissions in exports were associated with the manufacturing industry. To a very large extent, the growth in emissions over the last decade was export-driven. Emissions increased as export-oriented industries and export volume expanded. At the same time, fuel switching in electricity production from oil to natural gas,

Figure 2. SDA Results of Embodied Carbon Emission Changes, 2000-2010



Source: B. Su, B.W. Ang and Y. Z. Li "Input-Output and Structural Decomposition Analysis of Singapore's Carbon Emissions", *Energy Policy* 105 (2017): 488.

and various energy efficiency measures helped to lower growth in emissions.

More detailed discussion of the findings, e.g. at detailed sectoral and household income levels, and their policy implications for Singapore, can be found in the journal paper published by Su et al from which this article is derived.[1]

This article is summarised from the following journal article by the authors: B. Su, B.W. Ang and Y. Z. Li "Input-Output and Structural Decomposition Analysis of Singapore's Carbon Emissions", Energy Policy 105 (2017): 484–92

1 B. Su, B.W. Ang and Y. Z. Li "Input-Output and Structural Decomposition Analysis of Singapore's Carbon Emissions", *Energy Policy* 105 (2017): 484–92.

The Role of Market Mechanisms in the Implementation of the Paris Agreement

Melissa Low, ESI Research Fellow

Market mechanisms are not new to the international climate change regime. The Paris Agreement's predecessor, the Kyoto Protocol, featured mechanisms that stimulate sustainable development through technology transfer and investment. These mechanisms also help countries with commitments meet their pledged emission reduction targets or remove carbon from the atmosphere in other countries in a cost-efficient manner.

The Paris Agreement has continued to recognise the role that carbon markets can play in the wider context of climate action despite their controversial nature. Carbon markets can foster greater climate ambition, and support sustainable development in developing countries through the application of the UN Framework Convention on Climate Change's (UNFCCC) principle of "common but differentiated responsibilities".

Market mechanisms feature in the Paris Agreement under Article 6, in particular, Articles 6.2 and 6.4. Article 6.2 contains a series of binding requirements for Parties engaging in cooperative approaches that involve the use of internationally transferred mitigation outcomes (ITMOs) towards their nationally determined contributions (NDCs). Guidance under Article 6.2 must promote sustainable development, ensure environmental integrity and have robust accounting to ensure the avoidance of double counting.

ArtScience Museum at Marina Bay Sands, Singapore, 2012. Photo by S Pakhrin from DC, USA (Permission under CC BY 2.0).

The mechanism established by Article 6.4 is said to represent a successor to the Clean Development Mechanism (CDM), which is the market mechanism for emissions reductions in the Kyoto Protocol. The Article 6.4 mechanism has been called the "Sustainable Development Mechanism" (SDM) in some quarters, given that it calls for the mechanism to "contribute to the mitigation of greenhouse gas emissions and support sustainable development".

Article 6.4 is envisaged to retain several elements of the CDM, including voluntary participation authorised by each Party involved; the need for real, measurable and long-term benefits related to the mitigation of climate change; reductions in emissions that are additional to those that would otherwise occur; the need for verification and certification of emissions reductions, supervision by a body under the authority of the Conference of Parties to the UNFCCC (COP); and for an obligatory transferral of a share of the proceeds to cover the administrative expenses and adaptation.

Singapore's View on Market Mechanisms

As a small, low-lying city-state with an open economy, Singapore is particularly vulnerable to the consequences of climate change. The refining and petrochemical sector remains a large source of carbon emissions in Singapore. Steps to reduce carbon emissions must take this operating environment into account and consider how the country can maintain a balance between development and conserving the environment.

On 3 July 2015, Singapore submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC, formally putting forward its proposal to reduce its greenhouse gas (GHG) emissions intensity (per unit of GDP at 2010 prices) by approximately 36 per cent compared to 2005 levels by 2030, and to stabilise its emissions with the aim of peaking around 2030.[1]

Singapore presented its views on Article 6 of the Paris Agreement on 9 November 2016. The submission noted that "market-based mechanisms can help support the intended outcomes of the Paris Agreement by reducing the cost of mitigation and enhancing the feasibility for the development and deployment of low GHG emission technologies". Singapore was also of the view that all Parties should be able to participate in cooperative approaches. The submission pointed out that the use of ITMOs should not be limited to Parties with certain types of targets under the Kyoto Protocol so as to help enhance participation, and that this would be in line with the spirit of the Paris Agreement.

Earlier that year at an *Asia Pacific Regional Workshop on Integrating Market Mechanisms to the Implementation of INDCs/NDCs* held in Bangkok, Thailand on 15 February 2016, a representative of the Singapore Government presented views on post-2020 market mechanisms.[2] The presentation unpacked Article 6 of the Paris Agreement, and highlighted the need for the development of guidance (by the Subsidiary Body for Scientific and Technical Advice (SBSTA)) for Article

Table 1: Registered CDM Projects in Singapore

Registered Date	Title	Estimated Emission Reductions (tonnes CO_2eq per annum)
18 November 2008	Thermal energy recovery for new applications at 5 Sungei Kadut Street 6 by Bee Joo Industries Pte Ltd, Singapore	15,205
13 September 2010	Dehydration and incineration of sewage sludge in Singapore	101,577
12 December 2012	Kim Hock Biomass Energy and Wood Recycling Plant	31,360
31 December 2012	Chew's biogas plant for treatment of poultry waste and recovery of biogas for electricity generation in Singapore	31,837
5 June 2014	Demand side energy efficiency measures in building lighting systems	6,291
14 July 2014	Grid connected electricity generation plant using natural gas at Jurong Island in Singapore	286,755

Source: National Environment Agency, 2019.

6.2, rules, modalities and procedures for Article 6.4 as well as a work programme for Article 6.8. The presentation also noted the linkages in Article 6 with Article 5 (Reducing Emissions from Deforestation and Forest Degradation (REDD+)), Article 13 (Transparency) and Article 15 (Compliance). Singapore also presented views on international carbon markets, noting that over 80 INDCs mention the use of such market mechanisms to complement their carbon mitigation measures. It is also apparent that the linkage of markets helps countries expand the range of abatement opportunities, provides greater liquidity, ensures a level playing field and points towards greater convergence towards a global carbon price.

Singapore already participates with market mechanisms. The CDM mechanism under the Kyoto Protocol allows emissions-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. CERs can be traded and sold, and used by industrialised countries to a meet a part of their emissions reduction targets under the Kyoto Protocol. According to the National Environment Agency (NEA), Singapore's Designated National Authority (DNA) for CDM projects, Singapore has six registered CDM projects: thermal energy recovery, dehydration and incineration of sewage sludge, biomass and biogas, and energy efficiency technology applications. These together save between 6,291 and 286,755 tonnes of CO_2eq per year.

Singapore's Carbon Tax as Foundation for a Market Mechanism

On 20 February 2017, Singapore's Minister of Finance, Mr. Heng Swee Keat, announced that Singapore would be introducing a carbon tax by 2019. That same year at the UNFCCC COP23 held in Bonn, Germany, Minister for the Environment and Water Resources, Mr. Masagos Zulkifli, announced that Singapore would become the 20th nation to join the Ministerial Declaration on Carbon Markets, where interested countries work together to develop standards and guidelines for using market mechanisms that ensure environmental integrity for avoiding any double-counting or double-claiming of emissions reduction units.

A Carbon Pricing Bill was introduced in Parliament on 2 March 2018 and passed on 20 March 2018. The carbon tax, which came into force on 1 January 2019, operates as a Fixed Price Credit Based (FPCB) system where a single uniform carbon price of SGD 5 per tonne of CO_2eq is to be applied over five years from 2019–2023. The tax covers six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

The carbon tax affects two major categories of facilities. The first are reportable facilities, which emit more than 2,000 tCO_2eq of GHG emissions annually. These facilities are already mandated to have reporting requirements under the Energy Conservation Act (ECA) and are not liable for the carbon tax but must continue to submit emissions reports. The second, taxable facilities, are those which emit more than 25,000 tCO_2eq of GHG annually. These 30 to 40 large emitters not only have to pay the carbon tax, but are required to develop a monitoring plan and submit verifiable emissions reports. The NEA serves as registrar for the carbon tax under the Carbon Pricing Act.

As a nod to Singapore's leadership in carbon pricing in the region, the Carbon Pricing Leadership Coalition (CPLC), a voluntary partnership of national and sub-national governments, businesses and civil society organisations that agree to advance the carbon pricing agenda, launched their first official chapter in Singapore on 19 November 2018.[3] CPLC Singapore announced

that it would focus on the business case for carbon pricing, and aim to offer leadership in emissions reduction through knowledge sharing, targeted technical analysis, public-private dialogues and the setting of internal carbon pricing mechanisms.

Singapore has a "long history of preparation for carbon pricing" to meet the 2020 target.[4] The first public communication on the need to price carbon and send the right signals, should there be a global deal on climate change, occurred in 2007.[5] Since then, the Singapore government has been working towards putting the necessary policy architecture in place, such as the National Climate Change Strategy (2012), Energy Conservation Act (2013) and Climate Action Plan (2016). In 2017, Singapore introduced enhancements to the ECA and tightened energy monitoring and reporting requirements further.

Singapore delivered a presentation at the *Global Forum on the Environment and Climate Change*, organised by the Climate Change Expert Group (CCXG) of the OECD on 26 March 2019 in which it was explained that the FPCB carbon tax mechanism was intended to be simple at the start so as to minimise the burden on companies. However, the FPCB tax mechanism also provides "building blocks (e.g. credit registry infrastructure) to facilitate use of carbon credits". It was also noted in the presentation that Singapore was "open to linking our carbon tax framework to external markets where feasible".[6]

At the *Innovate4Climate Week* held in Singapore from 4–7 June 2019, there was a significant focus on the role of carbon markets in helping countries meet their NDCs under the Paris Agreement. Singapore officials spoke on several panels throughout the week, noting their willingness to learn from existing carbon markets.

As a small market with just 30 to 40 large emitters, Singapore has a clear interest in linking its domestic carbon market to others. Articles 6.2, 6.4 and 6.8 could provide the opportunities for Singapore to do so. However, key elements of the international carbon market architecture have yet to be agreed upon, and it currently remains unclear whether participation in ITMOs will be inclusive. Furthermore, countries with carbon markets are at different stages of planning and implementation, and it will therefore be important to develop a common understanding of measurement, reporting and verification (MRV) and accounting before linking carbon markets.

Nevertheless, Singapore continues to be a strong supporter of a carbon tax and is developing the domestic institutional structure and capabilities for administering market mechanisms under the Paris Agreement. In its INDC submission, Singapore noted that it intends to achieve the mitigation objectives under its INDC through domestic efforts, but will continue to study the potential of international market mechanisms. The country has described its target as a "stretch goal", given that it has no indigenous natural resources and is heavily dependent on the global supply chain for food and energy security. Thus, it is possible that Singapore might need to look to international carbon markets in the achievement of its INDC, or to subsequent and more ambitious NDCs in its bid to implement the Paris Agreement.

Article 6 is a key tool for international cooperation under the Paris Agreement. Although the Parties were not able to reach consensus at the Katowice Climate Change Conference (COP24), they were able to take stock of progress on this complex issue, particularly on how to ensure that the mechanisms promote sustainable development, ensure environmental integrity and have robust accounting to ensure the avoidance of double counting. The recent meeting of the Parties at the Subsidiary Body intersessionals in Bonn, Germany from 17–27 June 2019 further provided that ample opportunity would be given to develop more clarity and consensus on the rules of how the new market mechanisms under the Paris Agreement would look before adoption by the Chile COP25 in December 2019.

1 "Singapore's Intended Nationally Determined Contribution (INDC) and Accompanying Information", UNFCCC, 3 July 2015. Available online at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Singapore%20First/Singapore%20INDC.pdf.

2 "Singapore's INDC Experience and Views on Post-2020 Market Mechanisms", *Asia Pacific Regional Workshop on Integrating Market Mechanisms to the Implementation of INDCs/NDCs* held in Bangkok, Thailand, 15 February 2016. Available online at: https://unfccc.int/sites/default/files/resource/Session%202_Singapore%27s%20INDC.pdf. For the programme and list of speakers, see: http://cp-asiatica.com/wp-content/uploads/2016/02/Asia-Pacific-Regional-Workshop-on-Integrating-Market-Mechanisms-to-the-Implementation-of-INDCs-NDCs.pdf.

3 "Singapore Declares 2018 as 'Year of Climate Action'", *Today Online*, 17 November 2018. Available online at: https://www.todayonline.com/singapore/spore-declares-2018-year-climate-action.

4 "Singapore's Carbon Tax", *Global Forum on the Environment and Climate Change*, organised by the Climate Change Expert Group (CCXG), OECD, 26-27 March 2019. For Singapore's slides, see: https://www.slideshare.net/OECD_ENV/ccxg-march-2019-anshari-rahman-challenges-and-opportunities-for-implementing-ndcs/6.

5 Speech by Mr. Lee Hsien Loong, *Singapore Prime Minister, at Singapore International Energy Week*, 1 November 2010. See: https://www.pmo.gov.sg/newsroom/speech-mr-lee-hsien-loong-prime-minister-singapore-international-energy-week-01-november.

6 "Singapore's Carbon Tax", op. cit., For Singapore's slides, see: https://www.slideshare.net/OECD_ENV/ccxg-march-2019-anshari-rahman-challenges-and-opportunities-for-implementing-ndcs/6. For programme and full list of speakers, see: http://www.oecd.org/environment/cc/GlobalForumontheEnvironmentandClimateChange-organisedbytheClimateChangeExpertGroupCCXGMarch2019.htm.

Staff Publications

Internationally Refereed Journal Articles

Jiayu Wang, Ke Wang, **Xunpeng Shi** and Yi-Ming Wei, "Spatial Heterogeneity and Driving Forces of Environmental Productivity Growth in China: Would It Help to Switch Pollutant Discharge Fees to Environmental Taxes?", *Journal of Cleaner Production* 223 (2019): 36–44.

Nan Liu, Zujun Ma, Jidong Kang and **Bin Su**, "A Multi-region Multi-sector Decomposition and Attribution Analysis of Aggregate Carbon Intensity in China from 2000 to 2015", *Energy Policy* 129 (2019): 410–21.

Jun Li, Dayong Zhang and **Bin Su,** "The Impact of Social Awareness and Lifestyles on Household Carbon Emissions in China", *Ecological Economics* 160 (2019): 145–55.

Chi Zhang, **Bin Su,** Kaile Zhou and Shanlin Yang, "Decomposition Analysis of China's CO_2 Emissions (2000–2016) and Scenario Analysis of Its Carbon Intensity Targets in 2020 and 2030", *Science of the Total Environment* 668 (2019): 432–42.

Xiaoyong Zhou, Dequn Zhou, Qunwei Wang and **Bin Su**, "How Information and Communication Technology Drives Carbon Emissions: A Sector-level Analysis for China", *Energy Economics* 81 (2019): 380–92.

Hongye Wang, **Bin Su,** Hailin Mu, Nan Li, Bo Jiang and Xue Kong, "Optimization of Electricity Generation and Interprovincial Trading Strategies in Southern China", *Energy* 174 (2019): 696–707.

Fanyi Meng, **Bin Su** and Yang Bai, "Rank Reversal Issues in DEA Models for China's Regional Energy Efficiency Assessment", *Energy Efficiency* 12 (4) (2019): 993–1006.

Ken E. Giller, **Ira Martina Drupady**, Lorenza B. Fontana and Johan A. Oldekop, "Editorial Overview: The SDGs – Aspirations or Inspirations for Global Sustainability", *Current Opinion in Environmental Sustainability* 34 (2018): A1–A2.

Conference Proceedings

Liu Yang, "Demand Response as a Tool of the Power System Flexibility – Insights from Singapore's Electricity Market", *ECEEE Summer Study Proceedings* (2019): 2-256–19.

ESI Policy Briefs

Liu Yang and Tey Sovannaroth, "Harmonising Energy Efficiency Standards and Labelling Programmes: Current Trends and Future Developments" *ESI Policy Brief* 29 (25 June 2019).

Books and Chapter Contributions (edited volumes)

Aydin Ulviyye and **Dina Azhgaliyeva**, "Assessing Energy Security in Caspian Region: The Geopolitical Implications to European Energy Strategy", in F. Taghizadeh-Hesary, N. Yoshino, Y. H. Chang and A. Rillo (eds.) *Achieving Energy Security in Asia: Diversification, Integration and Policy Implications* (Singapore: World Scientific, 2019), pp. 257–90.

Liu Yang, Zhong Sheng and Dina Azhgaliyeva, "Towards Energy Security in ASEAN: Impact of Regional Trade, Renewables and Energy Efficiency", in F. Taghizadeh-Hesary et al (eds.) Ibid., pp. 291–318.

Dina Azhgaliyeva, Zhanna Kapsalyamova and Linda Low, "Implications of Fiscal and Financial Policies on Unlocking Green Finance and Green Investment" in J. Sachs, W. W. Thye, N. Yoshino and F. Taghizadeh-Hesary (eds.) *Handbook on Green Finance: Energy Security and Sustainable Development* (Singapore: Springer, 2019), pp. 427–57.

Fakhri J. Hasanov, **Brantley Liddle**, Jeyhun I. Mikayilov and Carlo A. Bollino, "How Total Factor Productivity Drives Energy Consumption in Saudi Arabia", in M. Shahbaz and B. Balsalobre (eds.) *Energy and Environmental Strategies in the Era of Globalization: Green Energy and Technology* (Basel: Springer Nature Switzerland, 2019), pp. 195–220.

Kim Jeong Won, "서울시 에너지자립마을의 지속가능성에 관한 고찰 (Sustainability of Seoul Energy Self-sufficient Villages)" in Y. Kim (ed.) 한국의 에너지전환: 관점과 쟁점 (*Energy Transition in South Korea: Perspectives and Issues*) (Paju: HanulMPlus, 2019), pp. 415–52.

Staff Presentations and Moderating

28 June Elena Reshetova presented "Does Accountability Matter for Sustainability? Urban Energy Transitions in Southeast Asia" at the *4th International Conference on Public Policy*, organised by the International Public Policy Association (IPPA), Montreal, Canada.

24 June Christopher Len presented "Southeast Asia: Security, Energy and Cooperation" at the *2019 Graduate School of Public Policy (HOPS) and the Slavic Eurasian Research Center (SRC) Border Studies Summer School, Hokkaido University*, Sapporo, Japan.

20 June Liu Yang presented "Integrating Demand Side Management in Urban Cooling Systems" at the *Asian Clean Energy Forum 2019*, organised by the Asian Development Bank (ADB), Manila, Philippines.

19 June Dina Azhgaliyeva presented "The Effectiveness

of Policy Support in Promoting Green Bonds: Empirical Evidence" at the Astana International Financial Centre, Nur-Sultan, Kazakhstan.

18 June Dina Azhgaliyeva presented "Energy Storage and Renewable Energy Deployment: Empirical Evidence from OECD Counties" at Nazarbayev University, Nur-Sultan, Kazakhstan.

18 June Dina Azhgaliyeva presented "Opportunities for Collaboration and Funding: Energy Studies Institute, National University of Singapore" at Nazarbayev University, Nur-Sultan, Kazakhstan.

18 June Dina Azhgaliyeva presented "Accessing Global Renewable Energy and Energy Storage Data Using Bloomberg Terminal" at Nazarbayev University, Nur-Sultan, Kazakhstan.

17 June Liu Yang presented "Innovative Solutions to Scale-up Energy Efficiency Financing in the Industrial Sector in Singapore" at the *Asian Clean Energy Forum 2019*, organised by the Asian Development Bank (ADB), Manila, Philippines.

17 June Liu Yang presented "Demand Side Management/ Demand Response in Singapore" at the *Asian Clean Energy Forum 2019*, organised by the Asian Development Bank (ADB), Manila, Philippines.

17 June Shi Xunpeng presented "Future of Energy Trade in Asia: Opportunities and Challenges" at *Workshop on Doing Business with Asia: Opportunities and Challenges*, NSW Parliament, Sydney, Australia.

10 June Dina Azhgaliyeva moderated a session at the *Economics of Integrating Variable Renewables in Liberalised Electricity Markets Workshop*, organised by ESI, Singapore.

10 June Anthony D. Owen moderated a session at the *Economics of Integrating Variable Renewables in Liberalised Electricity Markets Workshop*, organised by ESI, Singapore.

10 June Liu Yang moderated a session at the *Economics of Integrating Variable Renewables in Liberalised Electricity Markets Workshop*, organised by ESI, Singapore.

6 June Liu Yang presented "Demand Response as a Tool of the Power System Flexibility" at the *ECEEE 2019 Summer Study on Energy Efficiency*, organised by the European Council for an Energy Efficient Economy (ECEEE), Hyeres, France.

4 June Melissa Low presented "Climate Reporting and Climate Justice in Southeast Asia" at the *Hanoi Law Workshop,* organised by the Institute of Legal Sciences, Hanoi Law University and University of Victoria Center for Asia Pacific Initiatives (CAPI), Hanoi, Vietnam.

30 May Liu Yang presented "Evaluation of Energy Efficiency Rebound Effects: Historical Evidence and Cross-Country Comparison" at the *42nd International Conference of the International Association for Energy Economics (IAEE)*, Montreal, Canada.

28 May Elena Reshetova presented "Nuclear Energy Governance: Important Lessons from Russia and Belarus" at an *ESI-Centre for International Law* (CIL at NUS) *Seminar*, Singapore.

24 May Dina Azhgaliyeva presented "The Effectiveness of Policy Support in Promoting Green Bonds: Empirical Evidence" at the *7th International Symposium on Environment and Energy Finance Issues*, organised by the Centre of Geopolitics of Energy and Raw Materials (CGEMP) and Institut de Préparation à l'Administration et à La Gestion (IPAG) Centre for Energy Economics (ICEE), Paris, France.

23 May Melissa Low presented "Climate Change: The Challenge of Our Generation" at *Pint of Science Festival,* Singapore.

22 May Melissa Low presented "Sustainable Development Goals and Climate Change" at an *ESI Seminar for Pre-U Teachers, MOE Syllabus Update Briefing*, Singapore.

19 May Su Bin presented "The Volatility Spillover Effect of the EU Carbon Financial Market" at the *2019 International Conference on Energy Finance*, organised by the China Energy Finance Network, Yunnan University of Finance and Economics and Chinese Society of Optimization, Overall Planning and Economic Mathematics, Kunming, China.

18 May Victor Nian presented "The Prospects of CO_2 Systems in Southeast Asia in the Mid- to Long-term", at the *Northern China Heating, Ventilation, Air-conditioning, and Refrigeration Summit and New Technology and Product Exhibition*, organised by the Chinese Association of Refrigeration, Tianjin, China.

17 May Victor Nian presented "Techno-economic, Market and Policy Analysis of Cooling Systems" at Tianjin University of Commerce, Tianjin, China.

14 May Melissa Low presented "Global Agenda on Climate Change" at the *Humanities Scholars Programme Seminar*, organised by Saint Andrew's Junior College, Singapore.

5-6 May Shi Xunpeng presented "The Ecological Impact of Hydrogen Export: A Methodological Framework for Measuring Water Footprint" at the *2nd Meeting of the Working Group on Synergies of Energy Use with Economic, Social and Environment: A New Approach to Support Sustainable Development*, organised by the Economic Research Institute for ASEAN and East Asia (ERIA), Bangkok, Thailand.

30 April Dina Azhgaliyeva presented "The Effectiveness of Policy Support in Promoting Green Bonds: Empirical Evidence" at *Workshop on Scaling Up Green Finance in Asia: The Role of Policies and Regulations*, organised by ESI, Singapore.

26 April Melissa Low presented "Politics and Climate

Change" at the Latitude Programme at Eunoia Junior College, Singapore.

24 April Zhong Sheng presented "Impacts of EV on Singapore's Energy Demand and Emissions" at the *2nd Meeting of ERIA Research Project FY2018, Working Group on Preparation of Energy Outlook and Analysis of Energy Saving Potential in the East Asia Region*, organised by ERIA, Bangkok, Thailand.

10 April Liu Yang participated as a panellist in the *Energy Market Transition: Its Impact on Power Development and Investment in Asia Seminar*, organised by the Singapore Manufacturing Federation, Singapore.

8 April Christopher Len presented "Climate and Energy Security" at the *2nd Conference of the Jean Monnet Network on EU-Asia Security and Trade* (EAST), organised by Maastricht University and the S. Rajaratnam School of International Studies, Nanyang Technological University, Singapore.

1-2 April Liu Yang participated as a panellist in *Interactive Knowledge Exchange Workshop on Regulatory Sandboxes to Enable Smart Grid Deployment*, organised by the International Smart Grid Action Network (ISGAN), Stockholm, Sweden.

1 April Melissa Low presented "Singapore's Participation at the UNFCCC" at Anglo-Chinese Junior College, Singapore.

Staff Media Contributions

Philip Andrews-Speed was interviewed by *the South China Morning Post* on global developments in nuclear power, 24 June 2019.

Melissa Low was interviewed by *Eco-Business* on the impact of Singapore's Energy Efficiency Fund and Energy Conservation Act, 21 June 2019.

Melissa Low was interviewed by *Eco-Business* on youth climate activism in Singapore, 20 June 2019.

Ira Martina Drupady was quoted in "What Is the Future of Energy for Myanmar's Rural Population?", *Eco-Business*, 30 May 2019. See https://www.eco-business.com/news/what-is-the-future-of-energy-for-myanmars-rural-population/.

Philip Andrews-Speed was interviewed by *the BBC* on China's rare earth minerals industry, 29 May 2019.

Philip Andrews-Speed was interviewed by *Radio Free Asia* on PetroChina's plan to spin off its pipeline business, 27 May 2019.

Philip Andrews-Speed was interviewed by *the South China Morning Post* on the implications of escalating US-China trade and technology tensions on China's energy sector, 21 May 2019.

Philip Andrews-Speed was quoted in "China's Shale Gas Production Comes Up Short", *Radio Free Asia*, 20 May 2019. See https://www.rfa.org/english/commentaries/energy_watch/chinas-shale-gas-production-comes-up-short-05202019110353.html.

Philip Andrews-Speed was interviewed by *Radio Free Asia* on foreign investment in China's shale gas production, 3 May 2019.

Philip Andrews-Speed was interviewed by Damon Evans, independent Asia-focused journalist, on the implications of Shell's winning its arbitration case in the Philippines, 30 April 2019.

Philip Andrews-Speed was interviewed by *the New York Times* on China's likely reaction to tightening US sanctions on Iranian oil exports, 20 April 2019.

Philip Andrews-Speed was interviewed by *the Los Angeles Times* on the greening of China's energy Belt and Road Initiative, 5 April 2019.

Philip Andrews-Speed was interviewed by *the BBC* on the link between earthquakes and hydraulic fracturing in Sichuan Province, China, 2 April 2019.

Philip Andrews-Speed was interviewed by *Radio Free Asia* on China's coal consumption, 1 April 2019.

Recent Events

Participants of the Scaling Up Green Finance in Asia Workshop (Photo by ESI Staff).

30 April, Scaling Up Green Finance in Asia: The Role of Policies and Regulations (ESI Workshop)

At this workshop organised by ESI, seven experts from Kyoto Women's University (Japan), the Chinese University of Hong Kong, Council on Energy, Environment and Water (India), Institute for Policy, Advocacy and Governance (Bangladesh), Climate Policy Initiative (India) and ESI provided insights into the challenges and prospects for raising green finance in Asia. The afternoon session included presentations by students from Tsinghua University (China), Singapore Management University, King's College London (UK) and the National University of Singapore. The workshop ended with a presentation entitled "From Proposal to Publication: Academic Publishing in the Humanities and Social Sciences" and a presentation of BRILL's book series, "Political Ecology in the Asia Pacific Region", by an editor from BRILL Publishers. All of the speakers at this event were invited to submit their research to a special issue, "Scaling up Green Finance in Asia: The Role of Policies and Regulations" to *The Journal of Sustainable Finance and Investment*, for which two ESI researchers, Drs. Dina Azhgaliyeva and Brantley Liddle, are the guest editors. The call for papers for this special issue is open to the public and can be found on the Journal's website.

2 May, Joint ESI-ISAS Roundtable on Energy Transitions in Emerging Economies: Opportunities, Risks and Ways Forward (ESI-ISAS Roundtable)

This closed-door roundtable, jointly organised by ESI and the NUS Institute of South Asian Studies (ISAS), featured Dr. Arunabha Ghosh, Chief Executive Officer of the Council on Energy, Environment and Water (CEEW), a Delhi-based not-for-profit policy research institution, and Ms. Kanika Chawla, Director of the newly established CEEW Centre for Energy Finance.

The two speakers provided a snapshot of the current global energy landscape, noting the changes in oil prices over the past decade and how the definition of energy security has evolved over the years. In terms of energy transition, they identified five key drivers affecting its current progress, namely, the ambition of targets, integration of renewables for electricity generation, greenhouse gas emissions reduction efforts, the effect of taxation affecting the energy sector and risk perceptions on returns from renewable energy projects.

Next, they spoke about the International Solar Alliance as a basis for promoting new international energy partnerships, as well as opportunities and constraints in

Participants at the Joint ESI-ISAS Roundtable on Energy Transitions in Emerging Economies (Photo by ESI Staff).

the financing of renewable energy projects, particularly in developing countries such as Indonesia and India. This was followed by a lively free-flow discussion on topics ranging from energy access for rural and remote communities, to trends in promoting green finance, efforts to integrate energy systems and regulatory reforms to facilitate new sustainable business models for the energy sector. The event was moderated by ESI Senior Research Fellow, Dr. Christopher Len.

22 May, Certainties and Uncertainties in our Climate and Energy Futures (ESI Seminar)

Professor Koonin delivering his presentation at ESI (Photo by ESI Staff).

Professor Steven E. Koonin, Director of the Center for Urban Science and Progress at New York University and Professor in the Department of Civil and Urban Engineering at NYU's Tandon School organised his presentation into four components: consensus views of scientific reports, impacts observed, projections of climate models and responses on the impacts. He presented the consensus view of science whereby climate change is attributed to increasing human activities on top of natural change. He quoted a projection of future temperature increase from the Climate Science Special Report based on an assemblage of climate models embodied in the Representative Concentration Pathways (RCPs). He opined that the impacts of climate change will be complex and will be observed in a combination of extreme temperatures, rising sea levels, hurricanes (where the conclusion is arguably too early to make) and disappearing Artic sea ice, all of which will pose risks for agricultural activities and eventually damage the economy. He noted that the three strategies which humans have so far adopted to tackle the issue are mitigation of human influences, adaptation and geoengineering.

Professor Koonin believes that adaptation will be the dominant strategy as it is unlikely that human influences on the climate during this century will be stabilised. This drew some responses from members of the audience who believed that mitigation should be taken more seriously. This seminar was chaired by Professor Ang Beng Wah, Executive Director of ESI and Professor in the NUS Department of Industrial Systems Engineering and Management.

28 May, Nuclear Energy Governance: Important Lessons from Russia and Belarus (ESI Seminar)

Dr. Elena Reshetova, an ESI Research Fellow, spoke about the evolution of safety culture, and the strengths and weaknesses of Russia's nuclear energy governance system as it is the leading international vendor of nuclear energy technology and constructs the majority of new nuclear power plants abroad. In the second half of the seminar she discussed the importance of transboundary engagement between neighbouring countries using the examples of Belarus and Lithuania. Belarus is constructing a nuclear power plant less than 50 kilometres from Vilnius, the Lithuanian capital, and the Lithuanian government finds this location unacceptable. The presentation examined the actions of both countries with respect to transboundary engagement and the environmental and safety concerns. She queried whether these actions had been timely and sufficient, and whether the correct mechanisms exist to ensure that transboundary engagement takes place in a meaningful manner.

Dr. Elena Reshetova delivering her presentation (Photo by ESI Staff).

31 May, Green Revenues, Profitability and Market Valuation: Evidence from a Global Firm Level Dataset (ESI Seminar)

Dr. Misato Sato delivering her presentation (Photo by ESI Staff).

Dr. Misato Sato, Deputy Director of the Economic and Social Research Council (ESRC) Centre for Climate Change Economics at the London School of Economics, and Assistant Professorial Research Fellow in the Grantham Research Institute at Imperial College London, outlined her recent research on firms' green revenues and performance. The main focus of this research was how diversifying production towards low carbon goods and services impacts firms' performance. The seminar began with an overview of previous studies on the environment and economic development. Dr. Sato discussed gaps in the research carried out to date, the general classifications of green activities at the firm level and several well-defined measures of profitability and valuation. She then explained the data sources and econometric strategies that have been used to investigate the impacts of green revenues on firms' profitability and valuation. The data source that she used in this research was unique and comprehensive, covering approximately 95 per cent of global market capitalisation between 2008 and 2016. The results showed that firms with higher shares of green revenues exhibited a higher ability to earn income and had higher market valuations. She also found that green production imposed a downward drag on firms' profitability.

6 June, Should International Shipping join the EU ETS? A Conceptual Analysis (ESI Seminar)

Dr. Chai Kah Hin, Associate Professor and Deputy Head (MSc Programmes) in the NUS Industrial Systems Engineering and Management Department, focused on the international shipping sector, which accounts for more than 70 per cent of the global trade value and is largely powered by fossil fuels. He presented the ongoing international debates at the International Maritime Organization (IMO) over the establishment of an Emissions Trading Scheme (ETS) for the shipping sector, and highlighted the advantages and disadvantages of a shipping ETS joining the EU ETS. He provided a conceptual analysis by revisiting the basis of an ETS and argued that if a shipping ETS is joined with a larger ETS, there would be a risk of losing the ability to innovate in the long run. This outcome would depend on how the revenues from credit sales were allocated, and whether or not there was any technology spillover across sectors.

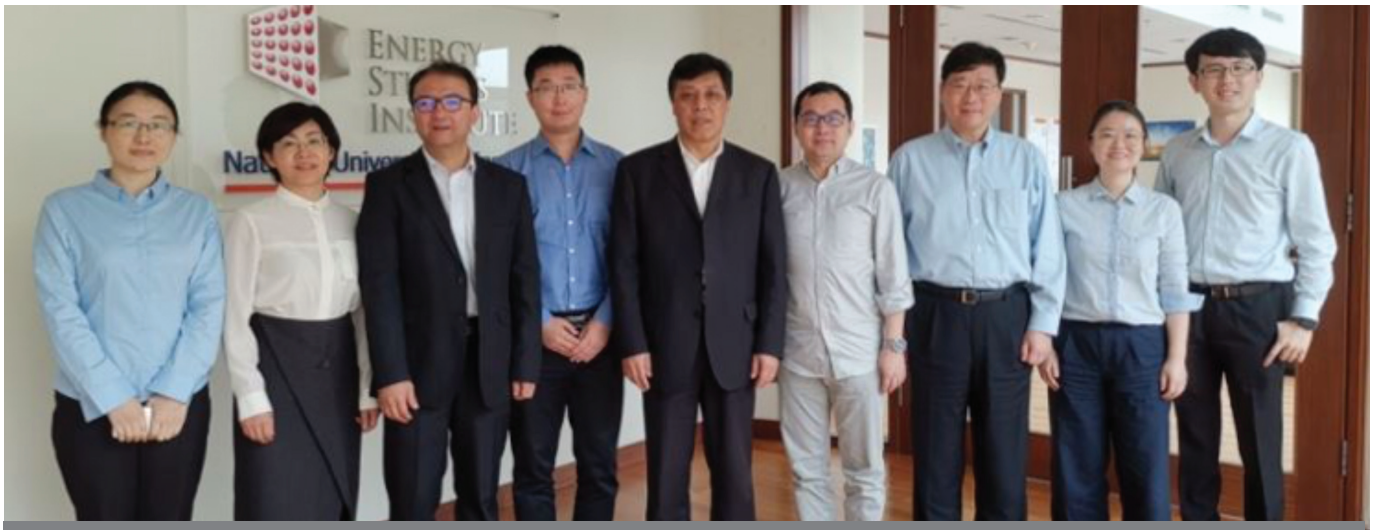
Dr. Chai Kah Hin delivering his presentation (Photo by ESI Staff).

9 June, Visit by the Institutes of Science and Development, Chinese Academy of Sciences (CASISD), China

The Institutes of Science and Development, Chinese Academy of Sciences [中国科学院科技战略咨询研究院] (CASISD) delegation led by Professor PAN Jiaofeng, President of CASISD, visited ESI and held a joint meeting with some ESI staff to share their current research interests and exchange ideas on strengthening research collaboration.

CASISD and ESI had signed an MOU on 9 February 2018. At this meeting, the two institutions discussed common research topics including carbon pricing in the EU, China and Singapore, emissions trading mechanisms, technological trends and the electricity market, among others.

Other members of the CASISD delegation included Professor WANG Yi, Vice President and Director of the Institute of Sustainable Development; Professor YANG Liuchun, Director of the Editorial Office; Professor GUO



Visitors to ESI from CASISD with ESI staff (Photo by ESI staff).

Jianfeng, Director of the Cooperation and Communication Department; and Dr. WANG Huizhong of the Academic Cooperation Office.

The following ESI staff took part in the meeting: Dr. SU Bin, Senior Research Fellow; Dr. LI Yingzhu, Senior Research Fellow; Dr. ZHONG Sheng, Research Fellow; Dr. YANG Xue, Research Fellow; and Dr. XIONG Jie, Research Fellow.

10 June, Economics of Integrating Variable Renewables in Liberalised Electricity Markets (ESI Workshop by Invitation Only)

This workshop, organised by ESI, brought experts together from five electricity markets to share their experiences in designing, implementing and operating new frequency response products and curtailment as a means to integrate intermittent renewables into the electricity grid. The participants noted that with the increasing penetration of intermittent and variable renewable energy sources in electricity grids, power systems are facing a number of challenges. Principally to cater to the problem of power system frequency management, a number of wholesale electricity markets have adopted new classes of frequency control products that are either fast-responding, and/or bidirectional, and/or cater specifically to increased ramping requirements. Additionally, markets are utilising curtailment to limit the intermittency impacts of renewables and are considering it as a means to enable additional penetration of variable renewables at lower costs compared to other approaches.

17 June, Scaling up Energy Efficiency with Simplified M&V Meters and ESCO Business Models (Joint Workshop)

ESI co-organised this event with The Efficiency Valuation Organization and The Asia-Pacific ESCO Industry Alliance at the Headquarters of the Asian Development Bank (ADB) in Manila. It was part of the Asia Clean Energy Forum (ACEF), a leading clean energy event in Asia. Nearly 1,600 participants from over 78 countries took part in the ACEF to share their experiences in addressing a wide range of issues.

The workshop covered two primary areas: (a) how measurement and verification (M&V) tools and methods can be used to effectively create an “energy efficiency

Participants of the ESI workshop on the Economics of Integrating Variable Renewables in Liberalized Electricity Markets (Photo by ESI Staff).

Participants of the ESI Joint Workshop on Scaling up Energy Efficiency with Simplified M&V Meters and ESCO Business Models (Photo credit: With permission by the organisers).

meter"; and (b) experience with testing and scaling up of business models for energy service companies (ESCOs). The experts from Singapore, China, India, Japan, Korea, Malaysia, Philippines and Taiwan all offered their insights into this topic. ESI Senior Research Fellow, Dr. Liu Yang, discussed energy efficiency financing in Singapore. ESI was a partner of the 2019 ACEF alongside a few international institutions, including the International Energy Agency and International Renewable Energy Agency.

New Staff

Dr. XIONG Jie
Research Fellow

Dr. Xiong Jie joined ESI in May 2019. He received his PhD degree from the Department of Industrial Systems Engineering and Management (ISEM) at NUS in November 2017. During his PhD candidature, Dr. Xiong's research scope encompassed the application of operations research techniques (i.e., stochastic programming and robust optimisation) and life-cycle assessment-based approaches to optimise waste-to-energy system design and operation from a sustainable perspective. His joint research involved game theorical methods to study self-interested agents' competitive behaviours for analysing policy interventions necessary for sustaining competitive waste management markets.

After graduating from NUS, Dr. Xiong joined the Energy and Environmental Sustainability Solutions for Mega-cities (E2S2) Programme under NUS and the Future Resilient Systems (FRS) Programme, also under NUS, as research staff. His research scope was therefore extended to energy system optimisation and simulation.

Dr. Ankit SACHAN
Research Fellow

Dr. Ankit SACHAN joined ESI in June 2019 after completing his PhD at the Center for Offshore Research and Engineering (CORE) at NUS. Prior to starting his PhD, Dr. Sachan worked in the power and renewable energy sector for 3.5 years at NTPC Ltd., the largest energy conglomerate in India. He worked on the installation of thermal and solar power plants and had exposure to other power generation facilities such as gas-based combined cycle and hydro power plants. He holds Master's and Bachelor's degrees from the Indian Institute of Technology Kanpur (IIT Kanpur), India.

Dr. Sachan is currently working on "Singapore's Energy and Decarbonaization Pathways" project funded by the National Research Foundation (NRF) and National Climate Change Secretariat (NCCS), Singapore. He is also working on the LNG and hydrogen value chain and waste-to-energy studies. His research interests include climate change, energy systems modelling, energy efficiency and economics.

Ms. HU Huijin
Research Associate

Ms. HU Huijin joined ESI in June 2019. She holds a Bachelor's degree in Sociology from NUS. Previously, she worked as a Communications Executive at the Public Utilities Board of Singapore and as a Junior Research Assistant at ESI. Her research interests include energy economics and policy, energy and climate change and social issues.

Contact

- Collaboration as a Partner of ESI (research, events, etc)
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Ms. Jan Lui
jan.lui@nus.edu.sg

Energy Studies Institute
National University of Singapore
29 Heng Mui Keng Terrace, Block A, #10-01 Singapore 119620
Tel: (65) 6516 2000 Fax: (65) 6775 1831
Email: jan.lui@nus.edu.sg www.esi.nus.edu.sg

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