Revisiting the Social Cost of Carbon after INDC Implementation in Malaysia: 2050

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Abstract

This article projects the social cost of carbon (SCC) and other related consequences of climate change by using Malaysia's intended nationally determined contribution (INDC) and climate vision 2040 (CV2040) by 2050. It compares the projections derived from the Dynamic Integrated Model of the Climate and Economy (DICME) based on the respective INDC and CV2040 scenario. The results reveal that industrial emissions would incur a substantial increase every five years under the scenario CV2040, while Malaysia would experience lower industrial emissions in the coming years under the scenario INDC. Emission intensity in Malaysia will be 0.61 and 0.59 ton/capita in 2030 for scenario CV2040 and scenario INDC respectively. Malaysia would face climate damage of MYR456 billion and MYR 49 billion by 2050 under CV2040 and INDC scenario respectively. However, climate damage could be much lower if the INDC regime were adopted, as this scenario would decrease climatic impacts over time. The estimated SSC per ton of CO2 varies between MYR74 and MYR97 for scenario CV2040 and MYR44 and MYR62 for scenario INDC in 2030 and 2050 respectively. Considering different aspects, including industrial emissions, damage cost, social cost of carbon, INDC is the best policy compared to CV2040. Thus, Malaysia could achieve its emissions reduction target by implementing INDC by 2050.

Keywords: Social cost of carbon, carbon emission, INDC, climate vision, scenario, Malaysia

Introduction

There are solid evidences that Greenhouse Gases (GHGs) as a whole and carbon dioxide (CO_2) emissions from fossil fuel combustion in particular, increase with the expansion of economic activities globally over time (IPCC, 2014a). Human activities are largely influencing the rising emissions of those gases, which have led to a substantial increase in global warming (EPA, 2014). Global emissions of GHGs are estimated to be 46 billion metric tons (CO_2 equivalents) in 2010 which increased by 35% compared to levels of emission in 1990 (EPA, 2014). Emissions of CO_2 from fossil fuel uses are increasing faster in different parts of the world, especially in some countries of Asia (EPA, 2014; Olivier et al., 2014; Sarkar, et al., 2018). Thus, it is clear that the climate system is influenced by human activities, and recent anthropogenic emissions of GHGs have reached the highest levels in history (Karl and Trenberth, 2003, McMichael, et al., 2006; IPCC, 2014a). Human activities are largely dominating the changes in atmospheric concentration through increasing GHG emissions associated with energy consumption, urbanization and land use changes (Karl and Trenberth, 2003; McMichael, et al., 2006). A continued increase in GHGs is resulting in further warming and negative change in the climate system which could have an inevitable and overwhelming impact for people, economy and ecosystems (IPCC, 2014b).

The United Nations Framework Convention on Climate Change (UNFCCC) is one of the major instruments deployed to promote global initiatives for managing climate change and global warming, by organizing an annual conference of parties (COP). After a long effort, a historic global climate deal was signed by 195 countries at COP21 (the 21st annual Conference of Parties) in Paris, which is known as Paris Agreement (Agreement, 2015). Under this agreement, every nation who attended COP21 made emission-cutting pledges through their Intended Nationally Determined Contributions (INDC) (UNFCCC, 2015). In COP21, world leaders agreed to keep the rise in global temperature below 2^0C and, if possible, below 1.5^0C. For example, China intends to reduce CO_2 emissions by 60% - 65% of its 2005 GDP by 2030 and to increase the share of non-fossil energy supply of the total primary energy supply by about 20%, whilst the European Union (EU) wants to reduce their emissions by 40% by 2030 compared to 1990 levels (UNFCCC, 2015).

Many countries are presently working to reduce carbon emissions under the mechanisms of INDC initiatives. Malaysia, like other countries, finds itself in the same boat and has also submitted an INDC target to UNFCCC with a commitment to reduce its greenhouse gas (GHG) emissions intensity by 45% by 2030 in relation to the GDP of 2005 level (UNFCCC, 2015). This commitment consists of 35% on an unconditional basis, and another 10% reduction is based on the receipt of climate funding, technology and capacity building from developed countries (Rassiah et al. 2016). In spite of taking mitigation actions and strategies, global emissions have increased in the past years where Malaysia is also facing an increasing rate of GHG emissions over the year with the expansion of population and economic activity (Begum et al. 2017). This result adds to global warming, and hence climate change and its consequences become even more alarming. Therefore, the reduction in temperature can only be possible if countries can maintain their pledges in significantly reducing the emission of GHGs.

The impact of climate change due to rising emissions needs to be assessed for a better understanding of climate change consequences in terms of social cost of carbon (SCC)[1] as it is a comprehensive estimate of climate change damages including agricultural production, infrastructure, human health, property damage, and energy production and transmission costs and so on (EPA, 2017). It cannot be denied that increased emissions of mostly carbon dioxide (CO_2) have a widespread social and economic impact that ultimately increases the social cost of carbon (EPA, 2017). According to Nordhaus (2017), SCC simply means the economic cost caused by an additional ton of CO_2 emissions or its equivalent. This estimate is conceptually valid and needs to be taken into account by countries for developing policies and agreeing to address climate change (Gayer, 2017).

Greenstone (2013) has also defined the SCC as monetary damages related to an additional increase in carbon emissions by which policy options can be compared. The SCC is also known as the marginal damage cost of CO_2, which is defined as the net present value of the incremental damage due to an incremental increase in CO_2 emissions (Toll, 2011). Many estimates of the marginal costs of climate change based on the total costs of climate change are to be found in literature (Cline 1992; Fankhauser 1995; Maddison 2003; Nordhaus 1991, 2006; Nordhaus and Boyer 2000; Nordhaus and Yang 1996; Rehdanz and Maddison 2005; Tol 1995, 2002). However, the total cost estimates ignore some impacts of climate change and avoid interactions between different impacts (Toll, 2008). Most of the recent studies are derived from a few detailed studies and executed in a changing climate on a static society; they did not consider uncertainties.

Table 1: Social Cost of Carbon from 2015-2050 (Ringgit[2] per metric ton of CO_2)

Year	5% average discount rate	3% average discount rate	2.5% average discount rate	High impact of 95th percentile at 3%
2015	45.0	147.2	229.0	429.5
2020	49.1	171.8	253.6	503.1
2025	57.3	188.1	278.1	564.4
2030	65.4	204.5	298.6	621.7
2035	73.6	225.0	319.0	687.1
2040	85.9	245.4	343.6	748.5
2045	94.1	261.8	364.0	805.7

[1]Social cost of carbon also known as the marginal damage cost of carbon dioxide, is defined as the net present value of the incremental damage due to a small increase in carbon dioxide emissions (Toll, 2011). It is called an estimate of monetary damages caused by one ton increase in GHG emissions in a given year.
[2]US$ 1=RM4.09 (RM~Ringgit Malaysia)

2050	106.3	282.2	388.6	867.1

Source: Adopted from IAWG, 2010.

However, a proper estimation of SCC can instigate policies and initiatives geared towards policy decisions on reducing GHG emissions. Estimating SCC using different discount rates is critical as higher level SCC makes mitigation costly while lower SCC puts a question mark on mitigation potential (Table 1). Malaysia is not out of the realm. Moreover, the country-level assessment of SCC is highly important for mapping domestic impacts that can be useful as a determinant of international cooperation, climate agreements and regional impacts (Barrett, 1994; Pizer, et al., 2014; Ricke et al., 2018). Country-level estimates of SCC can also grow national interest regarding INDC implementation through enhancing bargaining power, regulatory decision for choosing adaptation and compensation measures (Ricke et al., 2018). Therefore, this study on SCC has been highlighted in the Malaysian case which provides monetary estimates of the economic damages associated with CO_2 emissions in order to justify regulatory action. This study estimated in particular, economy-wide impacts from the social cost of carbon (SCC) that outweigh the previous lack of evidence on SCC as indicated by Toll (2008) and emphasized its assessment for future climate science and economics largely in Malaysia. The quantitative SCC estimations indicate how Malaysia would likely benefit over the study period as a result of the INDC regime with a flexible carbon price to reduce industrial emissions.

Materials and Methods

This study considers a multidisciplinary background that combines economy, ecology, and earth science concepts to undertake a SCC assessment. A long-term dynamic model deploying DICME model (Dynamic Integrated Model of Climate and the Economy) is considered, which takes account of the schemas for the Malaysian local government roadmap for climate is presented in COP21. Eventually, it compares the projections derived from the computable general equilibrium-based model (CGE) of DICME using the Malaysia Climate Vision 2040 (CV2040) and Malaysia's Intended Nationally Determined Contribution (INDC) submitted to UNFCCC proposals, henceforth referred to as scenario 1 and 2. The DICME model is one of the major IAMs (Integrated Assessment Model) used for estimating the SCC (Nordhaus, 2014 & 2017). This study also closely followed the recent study of Greenstone (2013) concerning the assumption required for estimates of the SCC and discussed how these SCC estimates can be used to inform regulatory decisions and identified priorities in Malaysia. Estimates of the SCC[3] involve the full range of impacts from emissions, through the carbon cycle and climate change, and include economic damages from climate change. The DICME model of this study has been used with the following 2 equations:

[3]At present, there are few established integrated assessment models (IAMs) that are available for estimation of the entire path of cause and effect and can therefore calculate an internally consistent SCC.

The social cost of carbon is:

$$scc_t = {}^{1000 * eeq.m_t}/_{cc.m_t} \ (1)$$

The emissions and damages are:

$$eeq_t = EIND_t + etree_t \ (2a)$$

$$CCA_{t+1} = CCA_t + EIND_t \ (2b)$$

Where, CCA_t is cumulative industrial carbon emissions (mTC), eeq_t is emissions equation, $EIND_t$= industrial emissions (mtCO2 per year) and $etree_t$ is the emissions from deforestation. The model adopted links to climatic factors, such as climatic damage, carbon emissions, (which affect economic growth) and carbon cycle with the endogenous variables of population, yield, capital stock, fossil fuels and technological innovation. Technological change is considered as a backstop option over time, and the exogenous variable is the policy modeled which is used in the following equation:

$$GA_T = (GA_0/\delta_A) * (1 - EXP(ORD_T - 1))$$

Where, GA_T is the backstop technology change, GA_0 is the technological innovation in the base year, δ_A is the endogenous variable of resources, and EXP is the exponent of technology for the future, ORD_T. The measurable units are the value of goods and services, including vulnerabilities, stated at current prices. The estimations also consider national monetary growth projections by considering national development, investment, consumption, interest rate, and technology against related climatic effects and vulnerabilities toward growth and development in years to come. There are several uncertainties in the projections as they are sensitive to time-line, consumer, technical efficiency, and producer preferences, national and world actions, relevance, and the availability of technology (Rassiah et al., 2016). The emission calculations and projections follow the references in the Fourth Assessment Report (FAR) (IPCC, 2007). However, non-carbon emissions and non-industrial carbon emissions are also considered in the damage valuation as suggested by the Third and Fourth Assessment Reports (IPCC, 2001, 2007). Details of our study tools and technical approaches are presented in Appendix 1.

The scenario and assessments using DICME assume an empirical downscaling route to observe the interaction between climate change and damage in the economy (e.g. Appendix 1). The downscaling measurement produces a range of rational climatic consequences over the years from 2020 to 2050 with an endogenous in nature. The top-down modeling method focuses on the effects, taking account of a wide range of likely climate effects by moving from a global to national level. The methods adopted are applied using a national observational large-scale data set to predict the annual cycle of observed (a) temperature and (b) large-scale rotation ecological effects in West and East Malaysia. The predicted annual cycle is downscaled by considering (i) industrial discharge, (ii) production with net damage, (iii) climatic loss (fraction of gross production), (iv) price of carbon, (v) rate of emission control, (vi) social cost of carbon, and (vii) adjusted rate of return of capital. These estimations are made with the assumption that the neighboring states follow the pledges made at the Paris Declaration.

The measurement tools are then incorporated in the yearly average circulation parameters as predictor parameters and yearly average fluctuations of temperature as predicted parameters so as to evaluate the climatic effects. The data from 1967 to 2015 were taken from the national Malaysian Meteorological Department (MMD, 2009). The historical temperature data have been used to project changes in large-scale variations in the carbon concentration. The yearly cycle of local temperature adopted is based on climate data drawn from Kuching (1°25'0"N, 110°20'0"E) and Kota Kinabalu (5°58'50″N, 116°4' 37″E) in East Malaysia, and Kuantan (3°48' 0"N, 103°20' 0"E) and Petaling Jaya (3°5' 0"N, 101°39' 0"E) in West Malaysia to capture long-term temperature effects with a standard elevation set-up for the years 2010 to 2110.

Discount rate and carbon price

This study used a discount rate of 1.5% from 2015 to 2050 to translate the future values to the present values with net inflation of about 3 percent per annum. All national inflation data were taken from the national accounts (DOS, 2010, 2013a, 2013b). On the other hand, the cost of carbon emissions is estimated with the notion of social cost of carbon estimation with its present values to future values. The adopted carbon price in this study was considered to be as close as the study done by Rassiah et al. (2016).

Technological change

The IAM model has been used widely in climate policy research but some adjustments are necessary to overcome its limitations in treating technological change, especially because technological change significantly affects the derivation of an optimal carbon policy. Thus, we propose to modify the IAM model by incorporating technological change within the original Dynamic Integrated Model of the Climate and Economy (DICE), which allows the adjustment of costs of CO2 abatement. DICE uses two distinct forms of technological change, viz., total factor productivity (TFP), and carbon saving technological change (σ), which is modeled to reduce the carbon intensity of economic activity over time. TFP represents increased output resulting from technical change. Sigma plays a similar role in the abatement cost equation. Nordhaus (2008) notes this and several other potential problems with using a learning model of endogenous technological change[4]. Despite growing empirical evidence linking environmental policy and innovation, most economic models treat technology as an exogenous variable. In the long run, this shortcoming can

[4]There is little doubt that learning models pose certain obstacles, and therefore, efforts were made to address them by drawing on Yu et al. (2011) and Soderholm and Sundqvist (2007) who advocate the use of multi-factor learning curves. This approach decomposes the drivers of technological change into potentially any number of components. For example, scale, learning, and scarcity in theory could all be separately modeled. Soderholm and Sundqvist (2007) also discussed the importance of choosing the appropriate proxy for learning, viz., installed capacity, demand, and total output.

be significant. Thus, we modified the IAMs to allow for endogenous innovation in the energy sector so that the results do not distort the welfare costs of reducing emissions. The innovation is to be influenced by shifting the amount of adoption level of technological change (δB) and possibility of knowledge (δh) with energy efficiency ($H_{e,t}$), cost innovation possibility frontier ($H_{B,t}$) or accumulation of research and development R&D, $hR_{i,\,t}$ as:

$$\boldsymbol{H_{i,t} = hR_{i,t} + (1 - \delta h).H_{i,t-1}}$$

$$\boldsymbol{i = E, B}$$

In addition, because of the cumulative effects of R&D, the welfare gains are appropriated more rapidly when induced innovation is considered under both scenarios.

Technology adoption

Having defined climate change and relationship with energy use, total energy use in this study is modeled as a combination of green energy-related capital and carbon-based fossil fuels. Energy-based capital is considered as knowledge that permits production to be manufactured with less carbon discharge, either because of effective emissions control or increased energy efficiency, which can be estimated as follows:

$$E_t = \left(H_{E,t}^{\rho} + \left(\frac{F_t}{\Phi_t} \right)^{\rho} \right)^{\frac{1}{\rho}}, \rho \leq 1 \qquad (1)$$

Equation (1) indicates that national manufacture must be met either by the use of non-fossil or fossil fuels, the latter through the development of backstop technologies. Technical change expected here includes efficiency improvements in energy use and the substitution of brown technology with green technology. The case of perfect substitution is ρ=1. The elasticity of substitution between them is 1/(1–ρ). Following Popp (2002), a distributed lag model was used to estimate the energy R&D elasticity with a mean lag period of 3.7 years.

Data sources

There are two types of data namely, (i) macroeconomic and (ii) climatic & meteorological are considered to estimate the study objectives. The macroeconomic data are taken from Malaysian national accounts' datasets (DOS, 2010, 2013a, 2013b; Unit, 2010). Adjustments of data are considered to make data uniform to fulfill the study outcomes as the sources are different in terms of years and units. In contrast, the meteorological and climatic data are taken from national meteorological sources (MMD, 2009; NAHRIM, 2006). The meteorological data are used based on two monsoons and four seasons from year 1969 to 2007. The monsoon data are categorized by northeast monsoon and southwest monsoon. The northeast monsoon data are influenced by the climate from November to February and southwest monsoon data are influenced by the climate from May to September. The temperature values are taken with the fluctuations between 0.8 and 3.1°C. All studied data are then adjusted with the global standard in line with the study of Nordhaus (2017).

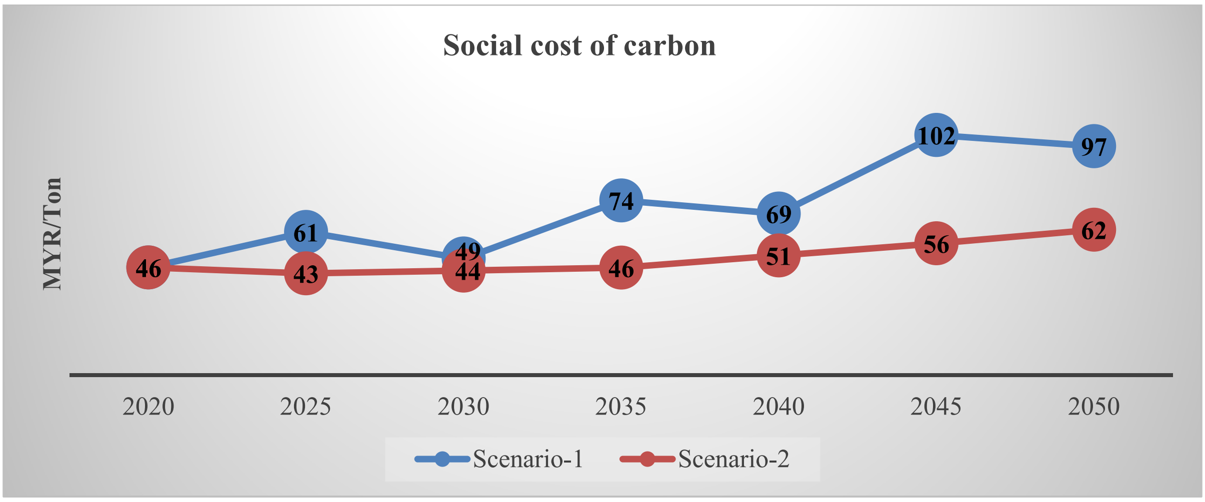
Results and Analysis

The social cost of carbon and its consequences for Malaysia have been examined by two scenarios such as Scenario 1 (CV2040) and Scenario 2 (INDC of COP21)[5]. Scenario 1 is considered where no substantial emission reductions take place until 2020, but a gradual reduction in emissions begins from 2020. In contrast, scenario 2 is set on capping temperature rise to 1.5° Celsius over the next century. Scenarios 1 and 2 were estimated using a five-year interval over the 30-year period of 2020–2050. Social cost of carbon (SCC) is presented in Figure 1 under scenario 1 and scenario 2. The emission projections provide likely emission outcomes under scenario 1 and scenario 2 over time based on the elasticity of marginal utility of consumption with a pure rate of social time preference (STP[6]). The elasticity of the marginal utility of consumption with the STP is calibrated until 2050 as shown in Figure 3. To maintain neutrality, this study has used the pure rate of calibration for the rate of return on capital estimates and resource allocations based on the calibrated national total factor productivity (TFP) (Figure 4), consumption per capita (Figure 5) and savings rate (Figure 6). The backstop technological option is considered for emissions intensity from 2020 to 2050 (Figure 11). The TFP of industrial production results from savings achieved through a reduction in carbon emissions[7].

Figure 1 presents social cost of carbon between the scenarios where scenario 1 shows a fluctuating trend of SCC in the coming decades and scenario 2 shows a slower increase of SCC over the period. Under scenario 1, the estimated SCC per ton was found to be MYR49, MYR74 and MYR97 for the years 2030, 2040 and 2050 respectively. In contrast, SCC will be MYR44, MYR51 and MYR62 in 2030, 2040 and 2050 respectively based on scenario 2. Thus, SCC for climate vision is found to be higher compared to the INDC scenario[8]. Moreover, the changes in the rate of return will also affect the projections of SCC, which is likely given the uncertainty expected over time (Figure 1). It is obvious from the results that the economic benefits would increase carbon prices or the social cost of carbon over the coming decades targeted at reducing carbon emissions to control climate damage. The SCC based on scenario 1 is higher yet fluctuating, while SCC based on scenario 2 is comparatively lower but reveals a slow and steady increase over time.

[5]This study has analyzed and compared between the results from the scenarios based on several indicators of Malaysia.
[6]Following the studies of Spackman, (2015); Rasiah et al., (2018)
[7]The TFP was estimated using national data as recommended by Nordhaus (2008) and Stern (2007).
[8]However, Nordhaus (2017) also found a substantial increase in the estimated SCC over time using IPCC scenario.

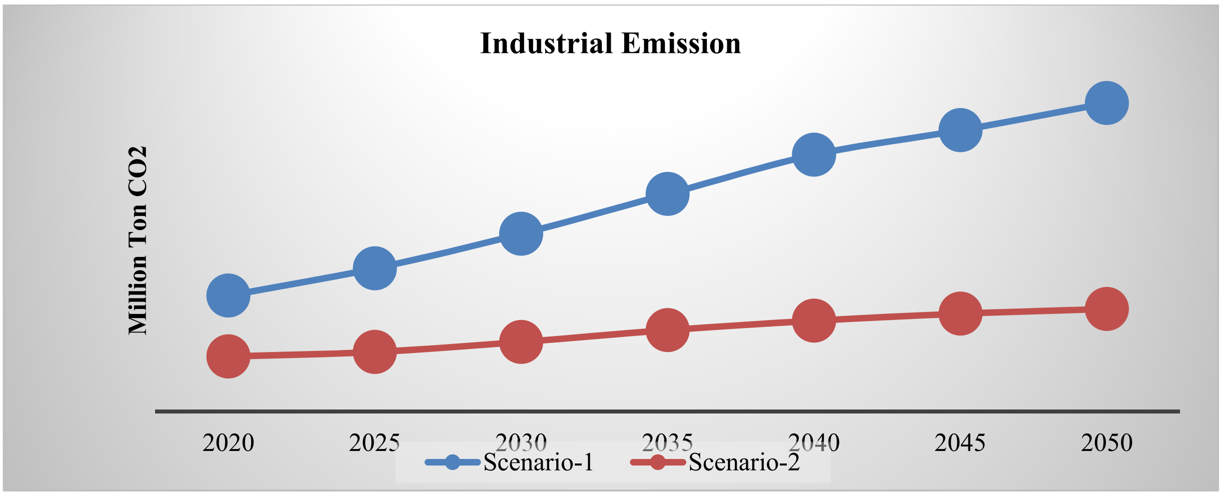
Figure 1 Social cost of carbon (MYR per metric ton) for Malaysia from 2020-2050



Source: Computed by authors

Figure 2 presents the industrial emissions of Malaysia from 2020-2050 based on scenario 1 and scenario 2. The result indicates that if Malaysia were to apply scenario 1, CO2 emissions from industry in Malaysia would increase sharply from 270 million tons (MT) per year in 2020 to 720 million tons per year in 2050. In contrast, CO_2 emissions would increase at a slower rate from 128 million tons in 2020 to 239 million tons in 2050 under scenario 2. Thus, the projection under scenario 1 indicates that industrial emissions would have a substantial increase every five years. If based on scenario 2, Malaysia would experience lower industrial emissions. Therefore, under the INDC regime, the annual increase of industrial emissions will be 3.58% over 2020-2050, which is much lower compared with scenario 1 (14.52%).

Figure 2 Industrial emissions in Malaysia (million tons CO_2) from 2020-2050



Source: Computed by authors

The STP factor is presented in Figure 3, indicating that it will gradually decrease over time for both scenarios. Social time preference (STP) rate is referred to as the sum of 'pure' time preference for marginal utility and an adjustment for the decreasing utility of marginal income as incomes increase over time. The total factor productivity which is an important source of output growth is revealed in the Figure 4, which will gradually increase over time.

Figure 3 Social Time Preference Factor for Malaysia from 2020-2050

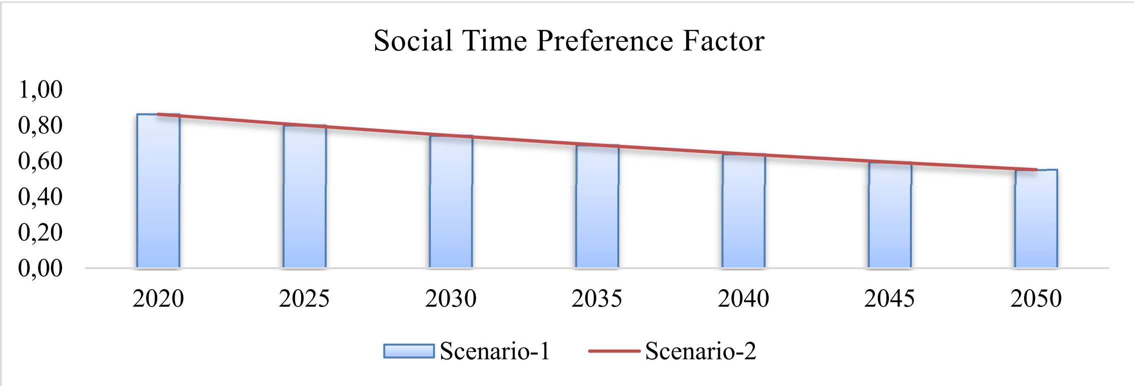


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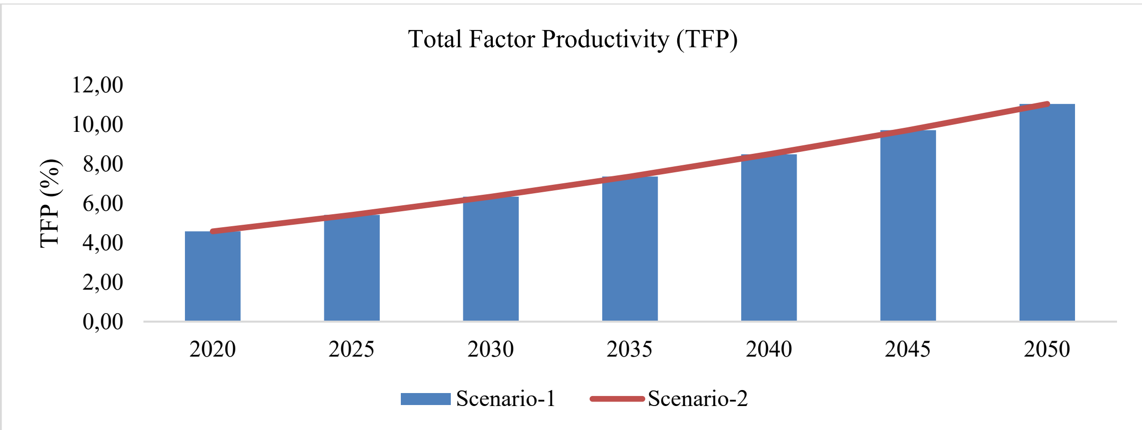
Figure 4 Total Factor Productivity of Malaysia from 2020-2050

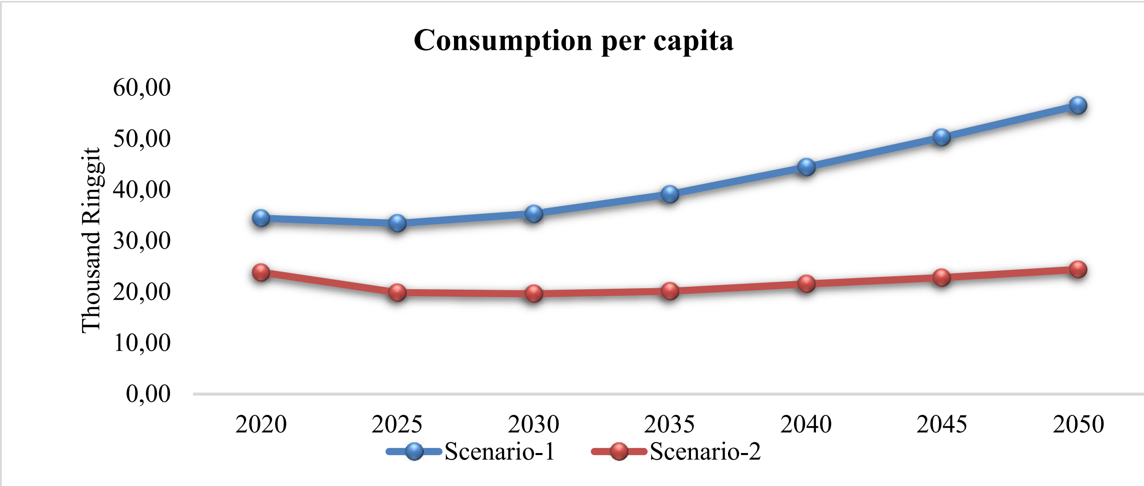


Source: Computed by authors

Malaysia's energy consumption per capita (thousand Ringgit per year) from 2020-2050 is presented in Figure 5. Under scenario 1, energy consumption per capita is estimated at MYR 34.41 (thousand) in 2020 which will decrease slightly to MYR 33.38 (thousand) in 2025, and then a steady increase will be found for the subsequent interval. On the other hand, after 2020 per capita energy consumption will fall and remain virtually constant for the upcoming years under scenario 2. The projected per capita energy consumption in 2050 under scenario 1 is MYR62.94 (thousand) which is more than double compared to the per capita energy consumption in 2050 under scenario

2 (MYR25680). Thus, energy consumption per capita, under the INDC regime, will be reduced up to 2030 and will then gradually increase from 2035 to 2050.

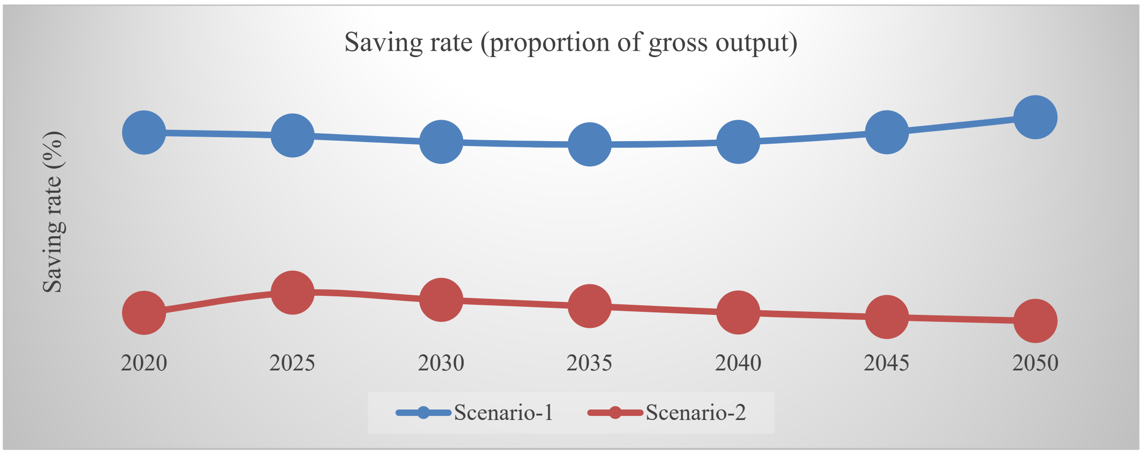
Figure 5 Consumption per capita (thousand Ringgit per year) from 2020-2050



Source: Computed by authors

The saving rate as a proportion of gross output is presented in Figure 6. The projections indicate that the saving rate under scenario 1 will fall from 0.33 in 2020 to 0.32 in 2025 and 0.31 in 2030 and 2035 before rising to 0.35 in 2050. By contrast, the saving rate is very much lower under scenario 2. The figure will rise to 0.07 in 2025 from 0.04 in 2020, and after 2025 it will decrease gradually over the period. The causes of the lower saving rate would be the result of climate change mitigation through INDC.

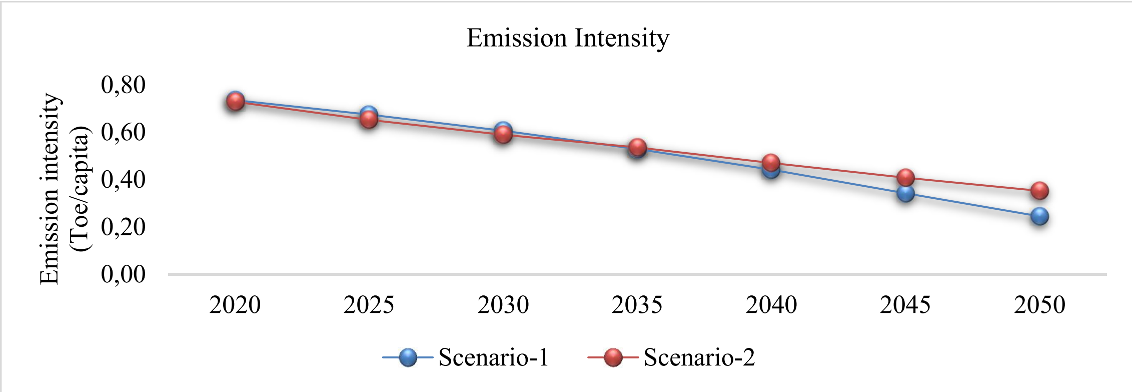
Figure 6 Saving rate (as a proportion of gross output) in Malaysia from 2020-2050



Source: Computed by authors

Figure 7 presents an interesting result, notably that Malaysia will experience a decrease in emission intensity over time for both scenarios. For instance, Malaysia's emission intensity per capita will be reduced from 0.73 in 2020 to 0.24 in 2050 under scenario 1, while emission intensity will be 0.73 and 0.35 for 2020 and 2050 respectively based on scenario 2. However, emission intensity in 2030 will be 0.61 and 0.59 ton/capita for scenario 1 and scenario 2 respectively. It is therefore evident that emission intensity will be lower in 2030 for scenario 2 compared to scenario 1. Moreover, if emission intensity in 2050 is considered, scenario 1 emission intensity will be much lower than that of scenario 2.

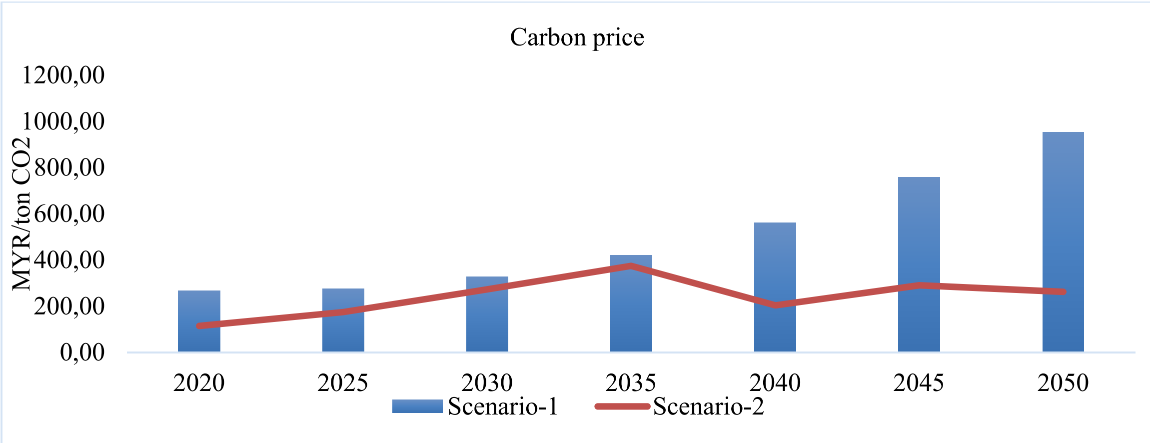
Figure 7 Emission intensity in tons per capita of Malaysia from 2020-2050



Source: Computed by authors

Carbon pricing in this study is an important aspect in order to understand the implications of SCC. It is a sensitive issue in terms of emission reduction and economic growth (Jia et al 2018). Higher carbon tax may discourage investors or industry owners from making business decisions, and thus discounts rates are important for future policy options. The result of this study indicates an increasing trend of carbon prices from MYR266/ton CO2 to MYR953/ton CO2 over 2020 to 2050 respectively under scenario 1 (Figure 8). In contrast, the projected carbon price under scenario 2 has been estimated at MYR115/ton CO2 in 2020, 375/ton CO2 in 2035 and MYR262/ton CO2 in 2050. After 2035, carbon price would decrease under scenario 2 which reveals a flexible carbon price as compared to scenario 1.

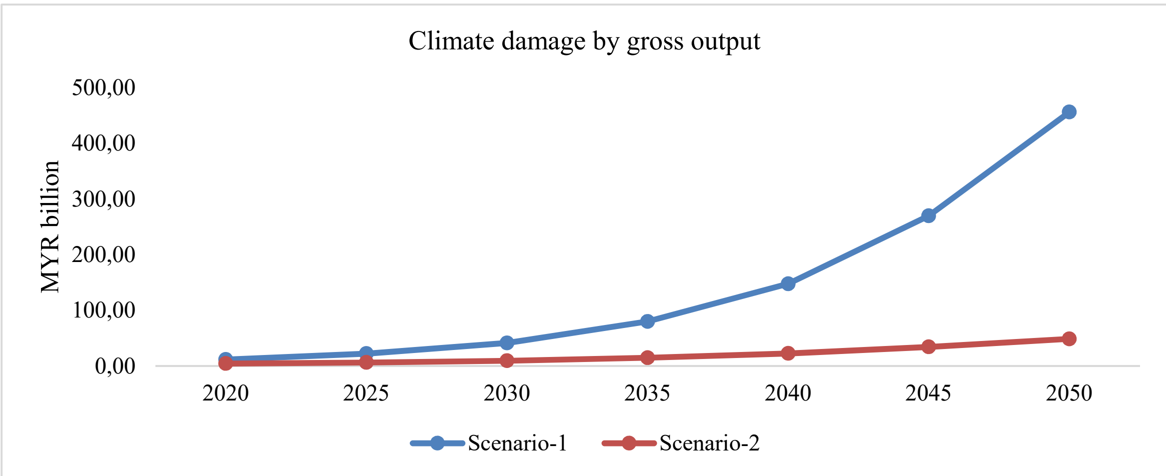
Figure 8 Carbon price (MYR per ton CO2) in Malaysia from 2020-2050



Source: Computed by authors

This study has projected higher damage cost for scenario 1 compared to scenario 2 which is presented in Figure 9. Climate damage sharply increases under scenario 1, where Malaysia would face climate damage to the tune of MYR456 billion by 2050. However, climate damage could be much lower in scenario 2, which would slowly increase over the period and reach MYR 49 billion by 2050. This study shows that climate change damages would reduce greatly under Scenario 2 compared to scenario 1. Climate change damage is one of the important consideration to evaluate overall cost of carbon as indicated by Johnson and Hope (2012).

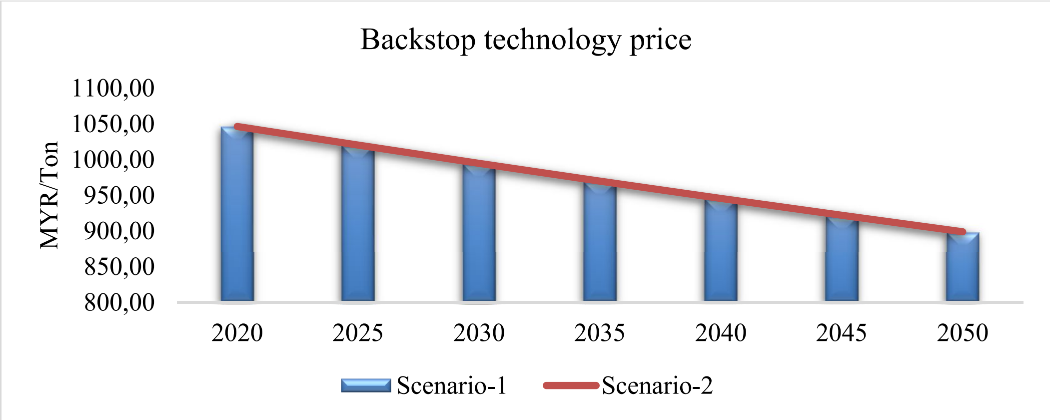
Figure 9 Climate damage by gross output (MYR billion) from 2020-2050



Source: Computed by authors

Backstop technology concept as a feature of most energy commodities was introduced in this study by means of analyzing the timing of entry of such technologies in markets for factors that are finite in supply (Liski and Murto, 2006). The backstop technology entry depends on the overall factor supply that is exhausted before it is profitable for the new technology to enter. However, the price of backstop technology gradually decreases over time which is shown in the Figure 10. It is mentioned that at the initial stage, price of backstop technology become high and after the time goes on, the price of green and renewable energy technology will be cheaper (Johnson and Hope, 2012).

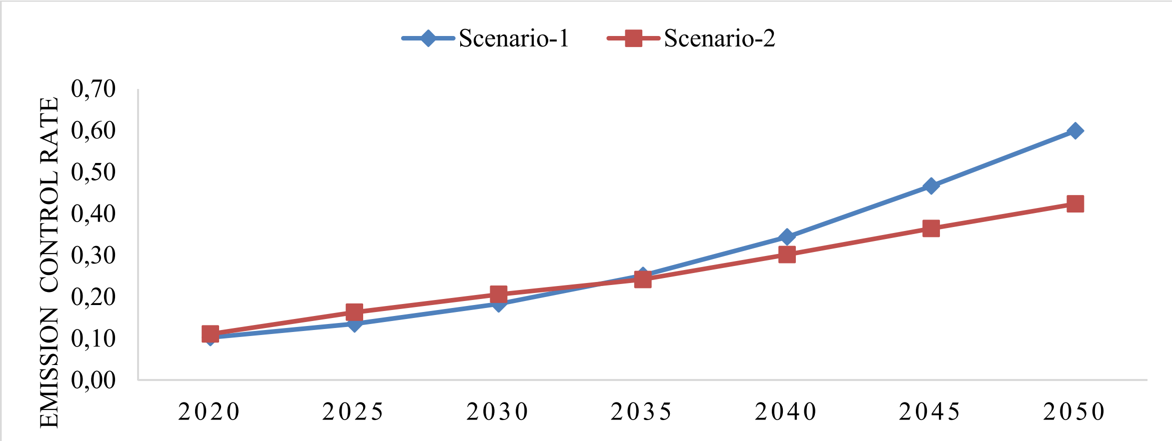
Figure 10 Backstop technology price (MYR/ton) form 2020-2050



Source: Computed by authors

Emission control is one of the target priorities for decisions concerning Malaysian environmental policy. Malaysia has already set the target of reducing emissions by 45 % based on the 2005 level. Figure 11 presents the emission control rate under the two scenarios where the emission could possibly be higher in scenario 2 before 2035 compared to scenario 1. However, by scenario 1 and 2, emission control rate would increase by 18% and 21% for 2030 and 2050 respectively. Moreover, Malaysia's emission control rate would be much higher in case of scenario 1 (60%) compared to scenario 2 (42%) by 2050.

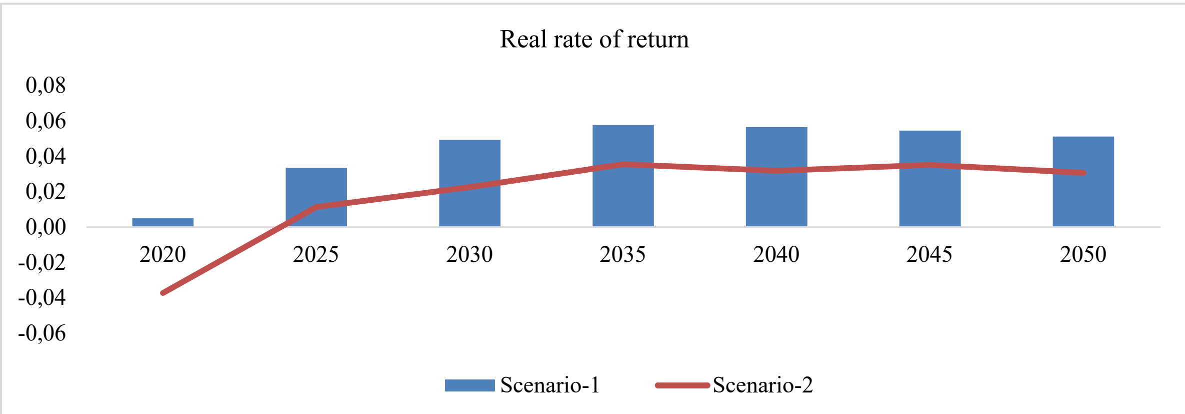
Figure 11 Emission control rate for Malaysia from 2020-2050



Source: Computed by authors

The real rate of return bears utmost importance to policy makers regarding climate change policy. The result shows that the estimated real rate of return under scenario 1 is fluctuating over time. It would increase sharply from 0.01 to 0.06 between 2020 and 2040. By contrast, the real rate of return in scenario 2 gradually increases until 2035 and then maintains a stable trend over time (Figure 12). The real rate of return is higher in scenario 1 compared to scenario 2. However, the real rate of return reflects the positive impact of the scenarios on outputs over the years. It is worth noting that Malaysia would reduce climate damage under both scenarios by lowering carbon emissions over the period 2020–2050.

Figure 12 Real rate of return for Malaysia from 2020-2050



Source: Computed by authors

Discussion

The social cost of carbon (SCC) for Malaysia has been estimated and compared along with different related macroeconomic indicators by using scenario 1 and scenario 2. The likely effect of SCC has emerged as a key estimate of climate dialogue and climate change negotiation in recent years. The SCC represents the marginal global damage cost of carbon emissions and can also be interpreted as the economic value of damages avoided for unitary GHG emission reduction. There are several uncertainties which still prevail in this estimation which influence the robustness of the SCC analytical framework, such as the choice of the discount rate as addressed by Markandya, et al. (2017). Hence, it is essential to determine the SCC in order to establish and maintain desirable economic growth under a regime of low carbon emissions. Desired economic growth and emission reduction could be mutually exclusive. Therefore, effective climate-change policies will be necessary in the long run through the introduction of either carbon taxes or a social cost of carbon with a flexible carbon price.

The study result shows that the social cost of carbon will increase with a fluctuating trend under scenario 1 while a slower increase is found under scenario 2 over the same period. For example, SSC per ton for the year of 2020 will be MYR46 which will increase to MYR97 and MYR62 for scenario 1 and scenario 2 respectively. It indicates that SCC for climate vision is found to be higher compared to the INDC scenario. However, Nordhaus (2017) also found a substantial increase in the estimated SCC over time using the IPCC scenario. It was shown that when governments measure the costs and benefits of a policy or investment decision regarding emissions, they need a value for carbon emissions which is very critical to determine. For example, if the SCC is high, then the benefits of cutting CO_2 are large and costly climate actions will be justified. If, however, it is low, regulations might be more trouble than they're worth as addressed by Carbon Brief (2017). Thus, higher or lower level of estimates for SCC thus need to evaluate by comparing the costs of carbon pricing to the benefits that is avoided costs raised by climate change damage (Johnson and Hope, 2012). However, our estimate of SCC is found to lower compared to IAWG (2010) as SCC varies across countries and regions. It is also mentioned that the climate change damages and impacts are not equally distributed on spatial level (Ricke et. al., 2018). Thus, a cost-benefit analysis is always carried out before taking any regulatory decision. Indeed, as the benefit would come in future, the estimates of the benefits must be discounted in order to compare and justify the expenditure to avoid future damage. Interagency Working Group has estimated SCC in 2010 ranged from \$5 -\$65 with a central value of \$21 per metric ton of CO_2 that need to evaluate by comparing the costs and benefits of climate change in different countries (Johnson and Hope, 2012). Interestingly, our estimation of SCC is revealed within the range of country level of SCC for 2020 by Ricke et. al. (2018). Thus, our study provides a more rigourous results for a dynamic components from 2020-2050 which colud be useful for the long term policy implications.

The SCC estimation can be considered as an alternative way to set the carbon price towards emission reduction (Gao and Chen, 2002). The Pigouvian approach indicates such consideration to determine carbon price on pollution equal to the social marginal damages of pollution (Pigou, 1932). Kaplow (2012) also support this approach including income redistribution for environmental tax reform. Though Bovenberg and Goulder (2002) suggest that optimal tax on pollution can be less than the social marginal damage from pollution, but they limit it around 20% compared to social marginal damages. Nonetheless, carbon tax could be similar to the SCC where it is estimated based on the business-as-usual emission scenario (Metcalf, 2017). Thus, our estimates of SCC provide a solid foundation for Malaysia to set it carbon tax for achieving its emission reduction targets.

Consequently, the discount rate is yet another major concern of SCC because an increase in the discount rate could reduce the SCC, thus suggesting a lower value is placed on preventing future damages which may be effective for emission reduction performance. Discounting can be rational because of the declining marginal utility of money, pure time preference, uncertainty and societal perspective. It would be perfect if the cost of carbon could be adjusted as a result of additional costs cutting further emissions which, in turn, are offset by the benefits of limiting further warming. However, this is difficult in practice. Nevertheless, changes in the rate of return will also affect the projections of SCC, which is likely given the uncertainty expected over time as shown in Figure 12. It is obvious from the results that the economic benefits would increase carbon prices or the social cost of carbon over the coming decades targeted at reducing carbon emissions to control climate damage. The SCC based on scenario 1 is higher but fluctuating while SCC based on scenario 2 is comparatively lower but increases slowly and steadily over time. Our study considers 1.5% discount rate which is adjusted by the rate of inflation in Malaysia. Thus, the result of SCC based on the adjusted discount rate found to be suitable for policy implications. After studying both scenarios, the estimate for the SCC based on the INDC scenario is generally preferred.

In order to achieve a significant reduction in greenhouse gas emissions, a changing consumption pattern is gradually recognized as an important pillar to meet the global climate change mitigation challenge as addressed in Figure 5. Malaysia has experienced a sevenfold increase in CO_2 emissions from energy consumption (e.g. 28 million tons in 1980 to 225.69 million tons in 2011) within three decades where per capita CO_2 emissions have increased from 2.02 tons in 1980 to 7.90 tons in 2011, with an average growth rate of 9.09% from 1980-2011 (Begum et al., 2017). The higher rate of carbon emissions is due to the consumption pattern. The consumption pattern should have adjusted rather than changed, with more alternative options in the production technology.

Our study shows that Malaysia would face climate damage to the tune of MYR456 billion and MYR 49 billion by 2050 under scenario 1 and scenario 2 respectively. The current estimates of the carbon emissions cost based on climate change damages are generally low as green energies are taking place where solar and wind energy is cheaper than coal and natural gas respectively (Johnson and Hope, 2012). Besides these, the price of backstop technology green and renewable energy technology would be cheaper as time goes on (Johnson and Hope, 2012). Thus, climate damage could be much lower in case of the INDC regime. In such a case, the INDC scenario gives better outcomes than other alternatives.

Malaysia has pledged the INDC target. Nevertheless, there are a number of macroeconomic challenges to face in order to maintain the INDC. This study has given a snapshot of the likely challenges with other alternatives. It would be useful to use the INDC target to achieve Malaysia's commitment to reduce emission intensity while, at the same time, increasing the SCC more slowly. The lower pace of SCC will reduce industrial emissions and increase the real rate of return in Malaysia, and this is important in order to fulfill the carbon reduction target. However, as a developing country, Malaysia needs funding and technology transfer from developed countries for

achieving greater mitigation potential which is recommended by COP22 (Rasiah et al. 2017). The international effort, such as the UNFCCC's Technology Mechanism and the Climate Technology Centre and Network (CTC-N), should be promoted on an urgent basis.
In line with the process subsequent to the INDC Implementation in Malaysia, the following influential factors have been identified:

a. the levels of commitment of Parties to develop INDCs is not consistent: some countries such as those in the European Union attach a great emphasis to it, whereas many developing countries are still to implement effective monitoring systems. Malaysia is making visible efforts, but it needs to be taken into account that policy implementation is constrained by economic limitations;
b. the need to take into account that climate action is related to a general drive towards sustainable development in the country, and that climate change is one of the key components of this process;
c. apart from the right policies and incentives, private and public investment, new technologies, and greater innovation are needed to lower emissions.

Finally, INDC implementation may help towards economic growth on the one hand, but also to eradicate poverty, and foster sustainable development at all levels, on the other.

Conclusions

The work performed in the context of this article allows two main conclusions to be drawn. Firstly, the social cost of carbon (SCC) is one of the significant single economic notions in climate change economics, and essential to maintain desirable economic growth under a regime of low carbon emissions. This study estimated economy-wide impacts of the social cost of carbon (SCC) in Malaysia and emphasized its assessment for future climate science and economics. Secondly, the quantitative SCC estimations indicate that Malaysia would probably benefit by approximately MYR407 (456–49) billion over the study period with the INDC target. To have a better social benefit, a flexible carbon price is nevertheless essential in order to reduce industrial emissions. This is a way forward for Malaysia in order to have a better flexible carbon price regime over the longer period. Essentially, outcomes overall would be supportive for the national evaluations on various questions such as key estimate of climate dialogue and climate change negotiation under the INDC regime.

Although some assumptions on the social costs of carbon in Malaysia have proven beneficial in the long term, an effective climate change mitigation policy is necessary. This could be achieved by, for instance, introducing either carbon taxes or a social cost of carbon to lessen carbon emissions. This study may provide a basis for the design of suitable policies in Malaysia and to other countries with similar economic and ecological conditions.

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APPENDIX 1:

Mathematical statement of the study model
Equations in the model:

$$W = \sum_{t=1}^{T\max} u\left[c(t), l(t)\right] R(t) \quad (1)$$

$$R(t) = (1+\rho)^{-t} \quad (2)$$

$$U\left[c(t), L(t)\right] = l(t)[c(t)^{1-\alpha} / (1-\alpha) \quad (3)$$

$$Q(t) = \Omega(t)[1-\Lambda(t)]A(t)K(t)^{\gamma} L(t)^{1-\gamma} \quad (4)$$

$$\Omega(t) = 1/[1+\Pi_1 T_{AT}(t) + \Pi_2 T_{AT}(t)^2] \quad (5)$$

$$\Lambda(t) = \pi(t)\theta_1(t)\mu(t)^{\theta_2} \quad (6)$$

$$Q(t) = C(t) + I(t) \quad (7)$$

$$C(t) = C(t) / L(t) \quad (8)$$

$$K(t) = I(t) + (1-\delta_k)K(t-1) \quad (9)$$

$$E_{Ind}(t) = \sigma(t)[1-\mu(t)]K(t)^{\lambda} L(t)^{1-\lambda} \quad (10)$$

$$CCum \le \sum_{t=0}^{T\max} E_{Ind(t)} \quad (11)$$

$$E(t) = E_{Ind}(t) + E_{Land}(t) \quad (12)$$

$$M_{AT}(t) = E(t) + \phi_7 M_{AT}(t-1) + \phi_{11} M_{UP}(t-1) \quad (13)$$

$$M_{UP}(t) = \phi_{11} M_{AT}(t-1) + \phi_{11} M_{UP}(t-1) + \phi_{11} M_{LO}(t-1) \quad (14)$$

$$M_{LO}(t) = \phi_{12} M_{UP}(t-1) + \phi_{12} M_{LO}(t-1) \quad (15)$$

$$F(t) = \eta\left\{\log_2[M_{AT} / M_{AT}(1900]\right\} + F_{EX}(t) \quad (16)$$

$$T_{AT} = T_{AT}(t-1) + \zeta_1\{F(t) - \zeta_2 T_{AT}(t-1) - \zeta_3 T_{AT}(t-1) T_{LO}(t-1)\} \quad (17)$$

$$T_{LO}(t) = T_{LO}(t-1) + \zeta_4\{T_{AT}(t-1) - T_{LO}(t-1)\} \quad (18)$$

$$\prod(t) = \varphi(t)^{1-\theta_2} \quad (19)$$

Variable Definitions and Units (endogenous variables marked as asterisks):

$A(t)$= total factor productivity (TFP) in units)
*$c(t)$= capita consumption of goods and services (RM per person)
*$C(t)$= consumption of goods and services (RM)
$E_{Land}(t)$= emissions of carbon from land use (carbon per period)
*$E_{Ind}(t)$ = industrial carbon emissions (carbon per period)
*$E(t)$ = total carbon emissions (carbon per period)
*$F(t)$, $FEX(t)$ = total and exogenous radiative forcing
*$I(t)$ = investment (RM)
*$K(t)$ = capital stock (RM)
$L(t)$ = population and labor inputs (number)
*$M_{AT}(t)$, $M_{UP}(t)$, $M_{LO}(t)$ = mass of carbon in reservoir for atmosphere, upper oceans, and lower oceans (carbon, beginning of period)
*$Q(t)$ = net output of goods and services, net abatement and damages (RM)
T = time (decades from 2010–2020, 2021–2030, . . .)
*$T_{AT}(t)$, $T_{LO}(t)$ = global mean surface temperature and temperature of lower oceans (°C increase from 1900)
*$U[c(t), L(t)]$ = instantaneous utility function (utility per period)
*W = objective function in present value of utility (utility units)
* $\Lambda(t)$ = abatement-cost function (abatement costs as fraction of world output)
* $\mu(t)$ = emissions-control rate (fraction of uncontrolled emissions)
* $\Omega(t)$ = damage function (climate damages as fraction of world output)
* $\varphi(t)$ = participation rate (fraction of emissions included in policy)
* $\prod(t)$ = participation cost markup (abatement cost with incomplete participation as fraction of abatement cost with complete participation)
* $\sigma(t)$ = ratio of uncontrolled industrial emissions to output
$CCum$= maximum consumption of fossil fuels (tons of carbon)
γ = elasticity of output with respect to capita (pure number)
δ_k = rate of depreciation of capital (per period)
$R(t)$ = social time preference discount factor (per time period)
T_{max}= length of estimate period for model
η = temperature-forcing parameter (°C per watts per meter squared)
ϕ = parameters of the carbon cycle (flows per period)
σ = pure rate of social time preference (per year)
$\theta_{1....2}$ = parameters of the abatement-cost function
ζ = parameters of climate equations (flows per period)