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Assessing climate change mitigation proposals for Malaysia: Implications for emissions and abatement costs

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A B S T R A C T

In accordance with the Paris Accord to cap global temperature rise to1.5°Celsius over the next 100 years, Malaysia submitted its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) seeking to reduce emissions by 45% by 2030, which was changed to 2050 following the Marrakech Proclamation in 2016. This paper analyzes the implications of Malaysia's INDC and an additional proposal of continuing further climate control to cap temperature rise over the next century against the existing scenario in the country. The results show that the cumulative damage from climate change over the period 2010–2100 will amount to MYR2.1 billion under the present climatic regime. It will fall to MYR1.1 billion under scenario 2 and to MYR0.6 billion under scenario 3. Since the total abatement costs for scenario 2 (MYR14.3 billion) is close to that of scenario 3 (MYR14.6 billion) against the significant reduction in climate damage of the latter, the third proposal is the best alternative for Malaysia.

1. Introduction

Climate change was first scientifically investigated in the early 19th century when the melting of ice caps and other natural changes were first suspected to cause greenhouse gas (GHG) effect (Neumann, 1985; Fleming, 1990; Holli Riebeek, 2005). It was not until the late 19th century that scientists discovered that human emissions of greenhouse gases could adversely change the climate (Sawyer, 1972; Neville, 2007), which triggered a series of discussions on the dangers and mitigation measures to prevent them (Rhodes, 2016; Rajamani, 2016); Obergassel et al., 2016; Chaisson, 2008). However, mean temperatures over the globe reached a new peak in May 2016, which exceeded the highest 20th century peak by 0.87 °C (Brown et al., 2016; Rogelj et al., 2012; IPCC, 2013; Hansen et al., 2016; NOAA, 2016). Research shows that human activity is the prime cause of rising carbon concentration in the atmosphere (Den Elzen et al., 2016; Liu et al., 2015; Van Vuuren et al., 2016; Leygraf et al., 2016; Sigman et al., 2010), which is the main cause of global warming (McGrath, 2013; IPCC, 2013; NOAA, 2016; Kellstedt et al., 2008; Crutzen, 2006; Hautier et al., 2015; Rosenzweig et al., 2008; Foley et al., 2013; Beniston, 2016). Consequently, GHG emissions has been escalating (Reisinger et al., 2013; Romero-Lankao and Dodman, 2011; Tilman et al., 2011; Miles and Kapos, 2008). The WMO has confirmed that 2011–2015 was the hottest five-year period ever recorded in history, and expected 2016 to be hotter still with global average temperatures of 1.2 °C above the long-term average (Morena, 2016; COP 22; Frieler et al., 2013; Piao et al., 2010).

The UNFCCC has played a major role in sensitizing governments to formulate policies to reduce GHG emissions. Indeed, by 2016 it had organized 22 Conference of Parties (COP) by bringing together regional and world leaders to deliberate on capping temperature rise globally. It was at COP21 that the “Paris Accord” became a

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milestone in the history when 186 countries pledged to limit earth's temperature increase to 1.5^0 Celsius over the next century. This landmark agreement has provided a framework for meaningful progress towards climate mitigation (Farid et al., 2016; Burleson, 2016). These countries submitted emission reduction pledges, covering 96 percent of global emissions, and agreed on procedures for evaluating progress, and updating these pledges (Bodansky, 2016; Falkner, 2016; Le Quéré et al., 2016; Rogelj et al., 2016). Without mitigation of man-made climate change, global temperatures are projected to rise by about 3–4 °C over the pre-industrial levels by 2100 with risks of catastrophic warming (Christoff, 2016; Van Asselt, 2016). Many developing countries, (especially areas that are coastal or highly agriculture-dependent) are vulnerable to climate change impacts (Huq et al., 2015; Pettengell, 2010; Antwi-Agyei, Lahsen et al., 2010; Dulal et al., 2010; Khan et al., 2016). Hence, it is important to identify policies best suited for making progress on these man-made climate change mitigation pledges (Rajamani, 2016; Savaresi, 2016; Morgan et al., 2014; Clémençon, 2016). This exercise seeks to offer policy relevant findings to promote sustainable development.

Malaysia is an excellent laboratory to test proposals currently available to cap man-made carbon emissions as it has pledged to the UNFCCC to reduce GHG emissions intensity of GDP by 45% by 2050 relative to the emissions intensity of GDP in 2005, which consists of 35% on an unconditional basis and a further 10% on condition of obtaining climate finance from the developed countries to transfer technology and capacity building.[1] Quantitative targets are attractive, and their desirability in projecting emission prices is widely accepted, which is partly why the INDCs have a strong appeal as they state explicitly carbon pricing, and annual average emission targets even if actual emissions fluctuate to deviate from projected figures in reality. Potential revenues from carbon taxes also have an appeal on fiscal grounds. Therefore, the purpose of this paper is to analyze the climate change projections and abatement costs under two different scenarios against the no intervention scenario. The first scenario assumes that existing economic activities are continued unabated. The second scenario takes the revised INDC following the Marrakesh proclamation for Malaysia till 2050 and thereafter no new policies to reduce further carbon emissions. The third scenario takes on the full Paris Accord period to reduce carbon emissions so as to cap man-made temperature rise over the next century to 1.5 °C. The results will offer policymakers a useful set of results to formulate made-made climate change mitigation policies.

2. Materials and methods

This study uses a multidisciplinary top-down dynamic model with ‘Climate and Ecology’ variables that combine economic and earth science concepts. The modelling starts with a detailed description of variables that are deemed responsible for climate change with a focus on backstop technologies, abatement costs, and carbon concentration (e.g. ppm[2] under 650) and temperature cap below 1.5 °C over the next 100 years to analyse the long-run climate damage effects.[3] The study model considers three scenarios. The first is the business as usual scenario with no efforts to reverse climate change. The second uses Malaysia's INDC submitted to UNFCCC following the Marrakesh Proclamation with carbon concentration to be lowered from under 900 ppm[2] in 2005 to under 650 ppm[2] in 2050 and no additional interventions to reduce carbon emissions further. The third scenario focuses on initiatives to continue temperature capping over the next century to 1.5 °C.

Thus, the essential variables, such as the rate of social time preference, initial growth rate of backstop technology, level of total factor productivity, marginal atmospheric retention rate, emissions-output ratio, and discount rates are used to project long-run effects (see Appendix 1). This non-linear model also considers population growth rate, capital stock, fossil fuel stock, and cumulative improvement in energy efficiency.

Two major decision variables are considered in the ‘Climate and the Economy’ model, namely, (a) rate of physical capital (*K(t)*) accumulation (equation (1)) as a function of investment (*I(t)*) with depreciation rate (δ_k) to be substituted with green growth in future, and (b) rate of emissions control in the production function, *Q(t)* (e.g. equation (2)) with factor productivity, *A(t)* for GHGs over time with a damage, $\Omega(t)$and abatement cost, $\Lambda(t)$functions:

$$K(t) = I(t) + (1-\delta_k)K(t-1) \tag{1}$$

$$Q(t) = \Omega(t)[1-\Lambda(t)]A(t)K(t)^{\gamma}L(t)^{1-\gamma} \tag{2}$$

The two decision variables are closely linked with temperature limit over time (equations (3) and (4)), carbon-saving and capital accumulation for green financing. Capital accumulation is endogenously determined by optimizing the flow of vulnerability over time, while carbon-saving is endogenously linked with the abatement through alternative green technology adoption, and is modelled to reduce the ratio of carbon emission in the production process. Production is determined using the cross elasticity substitution (CES) and cross elasticity transformation (CET) productivity functions, which takes the form of either carbon-based or non-carbon-based energy in output production ratios over the long run. However, technology substitution and abatement costs will fall over time as a consequence of the switch from carbon-based to non-carbon-based technologies as the conventional energy option would become expensive due to rigorous climate change mitigation policies.

$$\begin{aligned} T_{AT} = T_{AT}(t-1) + \zeta_1\{F(t) - \zeta_2 T_{AT}(t-1) \\ - \zeta_3 T_{AT}(t-1)T_{LO}(t-1)\} \end{aligned} \tag{3}$$

$$T_{LO}(t) = T_{LO}(t-1) + \zeta_4\{T_{AT}(t-1) - T_{LO}(t-1)\} \tag{4}$$

The model projects economic growth of Malaysia by considering national growth, investment in capital, marginal damage of climate change, marginal cost of controlling climate damage, and backstop technologies and abatement costs against related climate effects and vulnerabilities based on three scenarios, namely, (a) climate change with no abatement (b) climate change under Malaysia's INDC submitted to UNFCCC following the Marrakesh Proclamation but no further reduction in carbon emissions after 2050, and (c) carbon concentrations targeted at capping temperature rise to 1.5 °C over the next 100 years. The details of variables, parameter definitions, notations of mathematical equations and units used in the estimation are shown in Appendix 1. The General Algebraic Modelling System (GAMS) software (Konopt 4 version) was used to run all the projections.

The assumptions of Hick's neutral technical change, i.e. perfect substitution between capital and labour that is assumed when projecting from input-output tables, and the technical coefficients estimated without due consideration to both incremental and radical innovations (see Schumpeter, 1934, 1943) does constrain the

[1] The Marrakesh proclamation also called for an injection of USD50 million from the developed nations to support temperature capping initiatives in the developing countries.

[2] PPM stands for parts particulate matters.

[3] This model runs using mathematical optimization with geometric algebraic modelling system (GAMS) programming.

preciseness of the projections. Also, consumption patterns and the utility function of the environment may also shift unexpectedly so as to alter the gap between actual and projected emissions. Nevertheless, one can assume that the recognition of such deviations from these shortcomings shall drive governments and stakeholders to recalibrate projections to guide future carbon capping interventions. Moreover, CGE modelling addresses economic and climate effects over the whole economy, which makes it superior to the alternative methodology of econometric equations. While the jury on the methodology typically used to project climate change impacts is still open, which largely uses computable general equilibrium (CGE) models, it offers a reasonable pathway to guide policy direction to mitigate man-made climate damage. Hence, the exercise to deploy CGE modelling to project climate change scenarios is important.

2.1. Study area and adoption of empirical downscaling

Malaysia is the study area with climate data obtained from the four locations of Kuching (Sarawak) and Kota Kinabalu (Sabah) in East Malaysia, and Kuantan (Pahang) and Petaling Jaya (Selangor) in West Malaysia (MMD, 2009), which are located at 1°25′0″N and 110°20′0″E, 5°58′50″N and 116°4′37″E, 3°48′0″N and 103°20′0″E and 3°5′0″N and 101°39′0″E respectively. The data used in this study abstracts from the global level to the local level through empirical downscaling to observe the interaction between global warming, climate change and damage on Malaysia. The adopted techniques are applied using a national observational data set to predict the annual cycle of observed (a) temperatures and climate effects, (b) GHGs warming parameters, and (b) large-scale unforeseen climate shocks. The predicted annual cycle is downscaled and adjusted by considering (i) national emission, (ii) net damage, (iii) climate vulnerability, (iv) abatement costs, and (v) emission control.[4] The annual cycle of observed parameters of predicted variables (i.e. climate vulnerabilities with their likely impacts) and predictor variables (i.e. yearly average circulation parameters) are closely followed by the probability of unforeseen climate shocks in future.

2.2. Damage considerations

The damage estimation in the ‘Climate and the Economy’ model assumes that climate changes are proportional to the output or national economic production process and can be captured through polynomial functions of mean temperature fluctuation (equation (5)). Aggregate climate change is a function of damages over time, and hence, it is a function ($\Omega(t)$) of climatic effects and fraction of output, climatic vulnerability parameters (ψ_1, ψ_2) and fluctuation of mean atmospheric temperatures (^{o}C), $T_{AT}(t)$ from 1990. Climate change is estimated with tangible and intangible losses based on monetary value and the utility function with GHG emission effects. Thus, moving intangible losses of climate change from the production function to the utility function shall enhance the prospects for achieving sustainable economic growth. Lastly, climate change estimation is evaluated in this study after factoring in the emission reduction schedules contained in Malaysia's NDC that was revised to meet the Marrakesh proclamation goals at COP22.[5]

$$\Omega(t) = 1\Big/\left[1 + \psi_1 T_{AT}(t) + \psi_2 T_{AT}(t)^2\right] \tag{5}$$

2.3. The discount rate and social preference

The ‘Climate and the Economy’ model uses the neoclassical economic growth assumptions in which sustainable economic growth is optimized under the constraint of a discount rate (ρ) of 1.5% to translate future costs into present values based o.[6] The discount rate over time ($R_{(t)}$) is assessed in the present and future as goods and takes a monetary value in Ringgit Malaysia (MYR)) with a net inflation rate of 3 per cent per annum (equation (6)). The discount rate was drawn from the Stern (2007) report, while we used the mean inflation rate of 3.0% over 2013–15 for Malaysia (Bank Negara Malaysia, 2016). The model is assumed to have a social preference of sustainable economic growth as defined by a social welfare function that ranks different paths of future growth that are constrained by both climate and economic relationships.

$$R(t) = (1 + \rho)^{-t} \tag{6}$$

2.4. Data

Two types of data are used in this study, namely, (a) macroeconomic data, and (b) climate and meteorological data. The macroeconomic data is derived from Malaysia's national accounts, including the Department of Statistics (DOS), and Economic Planning Unit (EPU) (DOS, 2010, 2013a, 2013b; Unit EP, 2010), while the climate and meteorological data are derived from Malaysia's Metrological Department (MMD) (MMD, 2009, 2015). Macroeconomic data from 2010 to 2015 is used to derive the macro baseline estimation in 2015, while meteorological data is based on two monsoons and four seasons from 1969 to 2007. National temperature fluctuations are derived from historical records from 1969 to 2015 to project changes in GHGs (280–927 parts per million (ppm)) concentrations to derive the climate baseline from 2015.[7]

The study also used for calibration (i) temperature fluctuations between 0.8 °C and 1.5 °C, (ii) carbon concentration (CO_2) with a maximum limit of 650 ppm level of variations until 2050, (iii) maximum carbon concentration in upper and lower strata of 950 ppm, (iv) equilibrium temperature impact of 26 °C, (v) initial lower stratum temperature change of 0.8 °C, (vi) final atmospheric temperature change from 1900s, and (vii) optimal abatement costs from guidelines defined in IPCC (2007; 2011), Nordhaus (2008) and Stern (2007). However, some modifications have been made to the data from MMD (2009,<comment message=The citation(s) 'MMD (2019' has been changed to match the author name in the reference list. Please check here and in subsequent occurrences.></comment> 2015), IPCC (2007; 2011), Nordhaus (2008) and Stern Review (2007) to meet the scope of the study.

3. Results and analysis

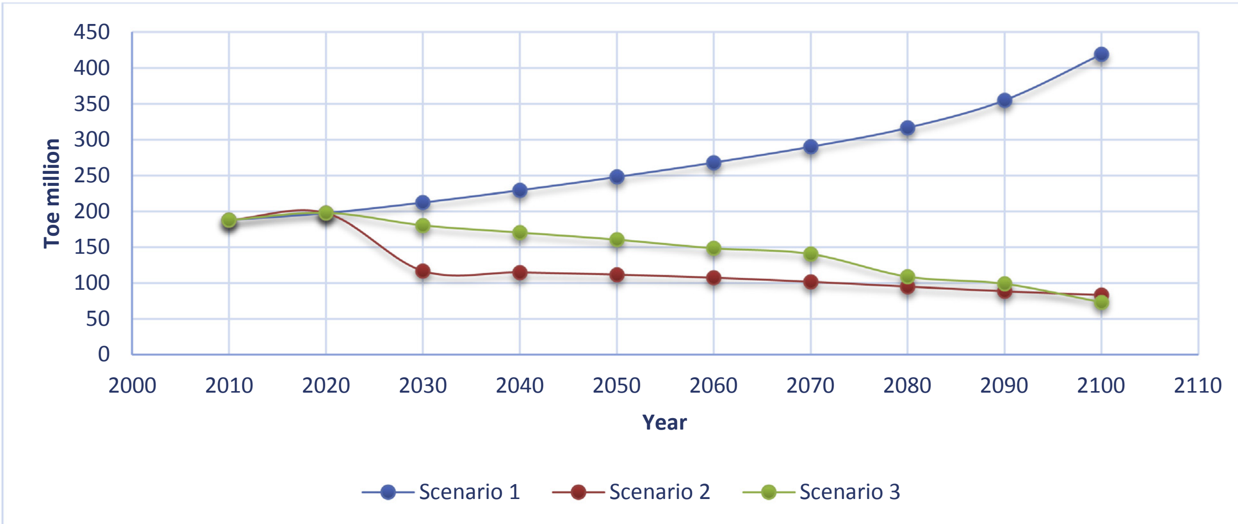
This study examined three scenarios of climate change mitigation for Malaysia, namely, (a) baseline case with no climate control

[4] The scenario estimations are considered using the assumption that neighbouring countries follow the recommendations on reducing carbon emissions made in the IPCC (2007, 2011) and COP agendas and guidelines report. Otherwise, the projections will be affected as the environment – being a global common – is permeable, and hence, emissions from the neighbours can diffuse into Malaysia.

[5] A separate scenario using existing patterns of production to project climate damage over the period 2010–2105 can be found in Al-Amin et al. (2015).

[6] While this assumption may not produce an accurate estimation of the projections, it is still useful in allowing a reasonable forecast.

[7] Details of the southwest monsoon and northeast monsoon that influences Malaysia's climate from May to September, and from November to February can be found in Al-Amin and Filho, (2014).



Source: Authors' simulations.

Fig. 1. Carbon emissions, 2010–2100 (million toe).

interventions (Scenario 1), (b) Malaysia's INDC pledged to UNFCCC (2015, 2016) that was subsequently revised following COP22 with no further interventions after 2050 (Scenario 2),[8] and (c) planned climate control intervention to cap global temperature rise to 1.5 °C over the next century and capping carbon concentration to a maximum of 650 ppm from the 1990 level (Scenario 3).

Fig. 1 presents carbon emissions projections by the three scenarios over the years from 2010 to 2100. Scenario 1 indicates a rapid increase in carbon emissions from 188 million ton in 2010 to 248 million ton in 2050 and 419 million ton in 2100 with existing environmental practices. In scenario 2, carbon emissions would decline from 188 million ton in 2010 to 112 million ton in 2050 and to 83 million ton in 2100 once Malaysia implements its climate change commitments to UNFCCC (2015) that was revised following the Marrakesh proclamation in 2016 (UNFCCC, 2016). However, carbon emissions would fall from 188 million ton in 2010 to 160 million ton in 2050 and to 73 million ton in 2100 under scenario 3.

However, the pace of emission reduction in the second and third scenarios are different, though eventually they end up being similar with the latter showing the highest fall. The findings indicate that the final outcomes in carbon emission reduction of scenarios second and third are close, but the gradient of reduction varies sharply between 2020 and 2070. The second scenario shows better emission reduction outcomes over the period 2030 to 2080, while the third scenario shows better outcomes over the period 2090 to 2100.

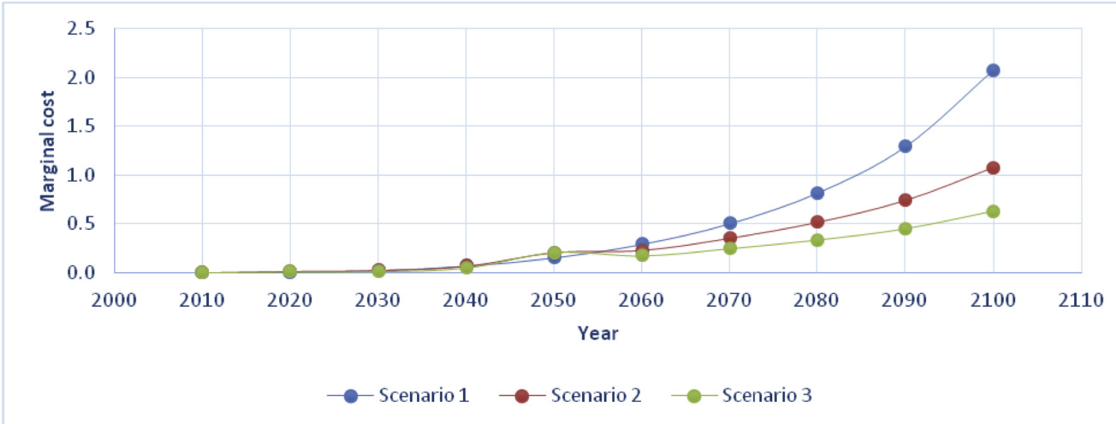
To understand better the second and third scenarios, the important sub-components of carbon emission reduction actions under various marginality conditions require evaluation. Figs. 2–4 indicate the sub-components of carbon emission reduction actions by marginal damage cost, marginal abatement cost and marginal control rate for the three scenarios over the period 2010–2100. The elasticity of the marginal utility of consumption with a pure rate of social time preference, discount factor, capital stock and investment projections are estimated to capture the relevant and real long-term projections. The findings indicate differences in relative costs trends for the three scenarios over the period 2010–2100.

Fig. 2 shows marginal climate damage cost of the three scenarios from 2010 to 2100, which is estimated using temperature and a carbon concentration change cap. The marginal climate damage costs show that at each level of climate action higher additional costs are generated in the second scenario due to additional costs that will have to be borne to reduce climate damage from 2020 to 2100. This damage costs gradually decline in scenarios 2 and 3 after 2050 to 2100. Therefore marginal climate damage cost is the highest in scenario 1 followed by scenario 2 and scenario 3 over the period 2010–2100. The climate damage cost will amount to MYR2.1 billion in scenario 1, which will fall to MYR1.1 billion in scenario 2 and MYR0.6 billion in scenario 3. Thus, the marginal damage cost estimations indicate that the third scenario is more economic than the second scenario, particularly after 2050 onwards.

Fig. 3 shows marginal abatement costs under the three different scenarios. The projections in scenario 2 is based on emission intensity falling by 45% by 2050. The findings indicate marginal abatement costs and relative outcomes for scenarios 2 and 3 over the period 2010 to 2100. The marginal abatement cost from 2020 to 2050 under scenarios 2 and 3 are similar. However, the results are different from 2050 to 2100. Importantly, it shows that the abatement cost in scenario 2 is relatively modest and there is relatively less increase in trend terms compared to scenario 3. The marginal abatement costs will be rising since the reduction of GHG emissions requires greening technology. The marginal abatement cost for scenarios 1, 2 and 3 will be nil, MYR12 million and MYR21 million respectively per ten thousand tons of carbon emission from 2010 to 2100. The total abatement costs for scenarios 1, 2 and 3 will then be nil, MYR14.3 billion, and MYR14.6 billion respective from 2010 to 2100.

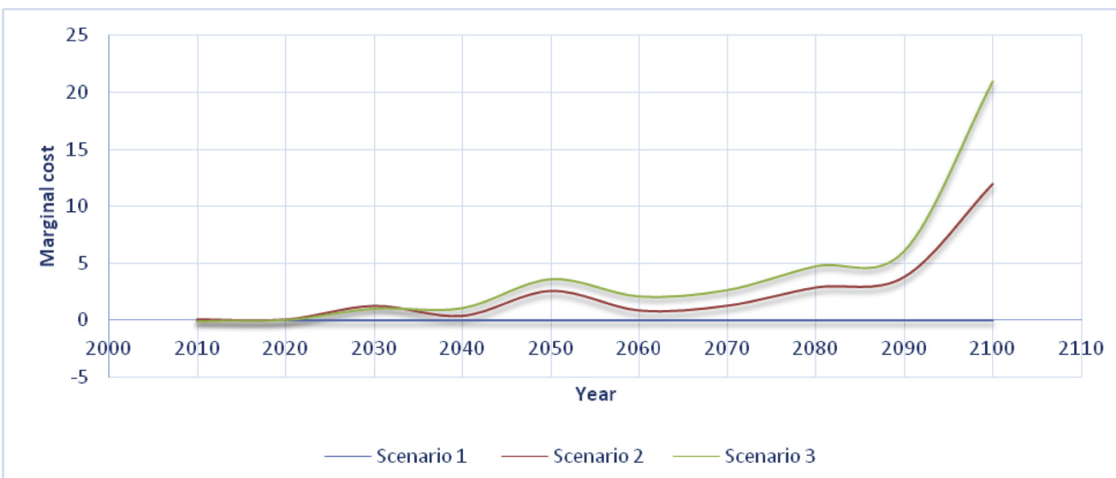
Fig. 4 presents the marginal control rate from 2010 to 2100 under the three scenarios. The findings indicate similar marginal control rates in both scenarios 2 and 3 over the period 2010 and 2020. However, the marginal control rates diverge over time, particularly from 2030 to 2090. The control rates in scenario 2 increases faster than the control rates in scenario 3 over the period from 2030 to 2090. However, the control rates in scenario 2

[8] Malaysia planned to reduce greenhouse gas emissions intensity by 45% by 2030, 35% on an unconditional basis and a further 10% upon receipt of climate finance, technology transfer and capacity building from the developed countries (UNFCCC, 2015). Malaysia contributed 0.62% of global emissions with an average of 6.7 metric tons/person of carbon emission, which raised mean surface temperature by 0.14–0.25 °C every 10 years.



Source: Authors' simulations.

Fig. 2. Marginal climate damage cost, 2010–2100 (MYR billion).



Source: Authors' simulations.

Fig. 3. Marginal abatement costs, 2010–2100 (MYR million/ten thousand tons).

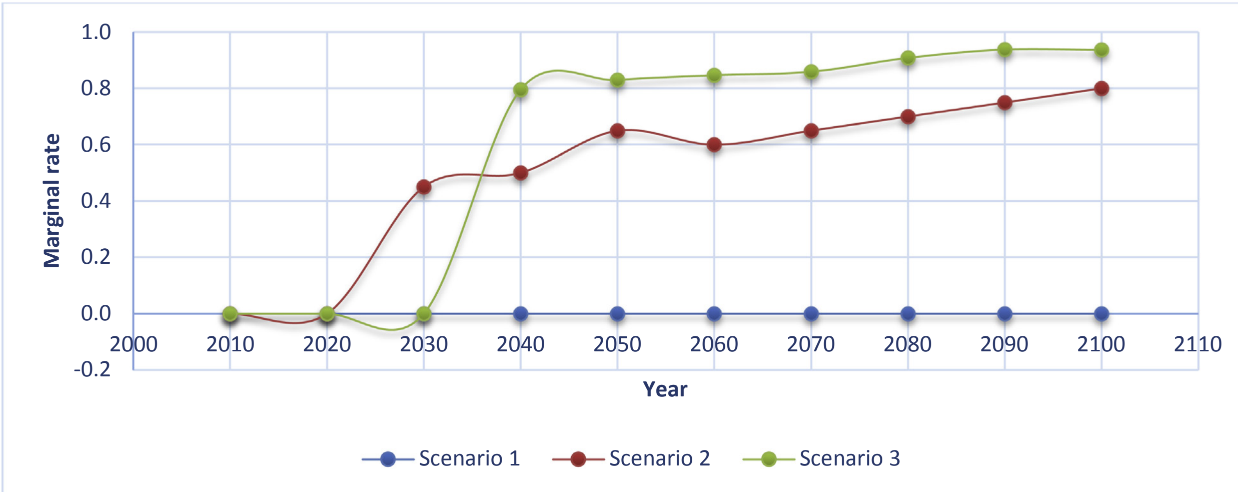
increases more slowly than in scenario 3 from 2035 to 2095. Notably, under the revised COP22 proposal carbon emissions would fall gradually and at a faster pace from 2035 to reach the commitment made to UNFCCC by the middle of century. Yet, the emission scenarios cannot on their own indicate the best options, and hence, we examine emission intensities and marginal cost contractions in the next sections.

Figs. 5–7 present emission intensities under scenarios 1, 2 and 3 respectively, which were estimated on the basis of per-capita and per-output over the period 2010 to 2100. The findings indicate an increasing rate over time both for per-capita and per-output basis scenarios in the second and third scenarios. However, the carbon emission intensity in per-capita terms is higher than carbon emission intensity in scenarios 2 and 3. Emission intensities per-output shows a more rapid decline compared to emission intensities per-capita in scenario 2, particularly from 2050 after Malaysia successfully implements its INDC commitment to UNFCCC. Under scenario 3, emission intensity of per-output declines faster than emission intensity per-capita. These findings call into question Malaysia's INDC commitment to the UNFCCC given that the measurements used are based on per-capita rather than per-output.

The emission intensity per capita and per output in scenario 1 will be rising since no reduction of GHG emission will take place. The Emission intensity per capita and per output in scenario 1 will be MYR 0.09 billion and MYR 0.14 billion respectively from 2010 to 2100 (Fig. 5). The emission intensity per capita and per output in scenario 2 will fall because of reductions in GHG emissions. The Emission intensity per capita and per output in scenario 2 will be MYR 0.03 billion and MYR 0.01 billion respectively from 2010 to 2100 (Fig. 6.

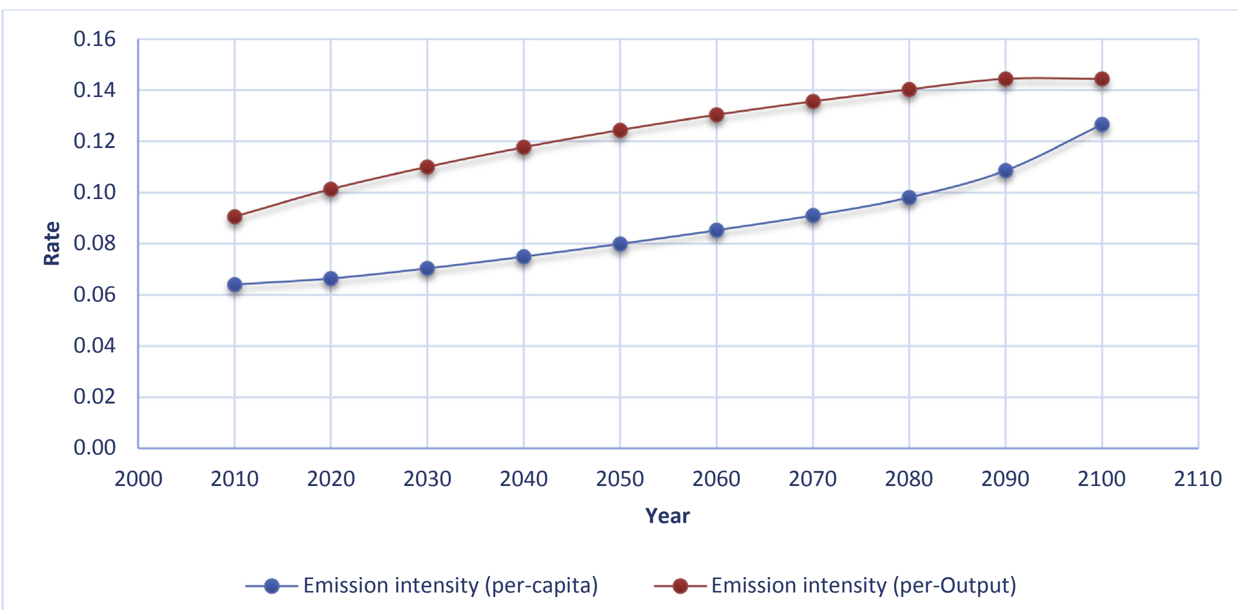
The emission intensity per capita and per output in scenario 3 are quite different from the outcomes of scenario 2. The Emission intensity per capita and per output from 2010 to 2100 in scenario 3 will be MYR 0.10 billion and MYR 0.02 billion respectively (Fig. 7).

This study also considered climate control options by using emission intensities in the economy and limiting the concentration of GHGs to avert climate damage over the long run with planned optimal climate control conditions (Figs. 8 and 9). The outcomes from the simulations show that emission concentration is expected



Source: Authors' simulations.

Fig. 4. Marginal control rates, 2010–2100 (MYR/unit control).



Source: Authors' simulations.

Fig. 5. Emission intensity, scenario 1, 2010–2100 (MYR Billions/unit).

to rise to a maximum of 1746.6 ppm in scenario one, 574 ppm in scenario two, and 571.3 ppm in scenario three. Scenarios 2 and 3 meet the Marrakesh proclamation of COP22 ceiling of 650 ppm, but the latter is the lowest among them.

Also, emission control intensity is nil for scenario one. In scenarios 2 and 3, Malaysia's application of climate mitigation strategies will start to mature from 2030. Hence, emission control intensity will rise till 2030 and then fall gradually until 2100 (Fig. 9). In scenario 2, the emission control rate in 2030 shall be MYR0.5 billion but will rise to MRY0.8 billion in 2100. In scenario three, the optimal emission control intensity will also be nil in 2030 but will rise to MYR1.0 billion in 2100. Also, the yearly control rates in the period from 2040 to 2080 are more intense in scenario 3 compared to scenario 2.

Overall, both scenarios 2 and 3 provide a declining projection of emissions over time. However, there are differences in the intensity and pace of emission fluctuations, and abatement costs between the two scenarios. Scenario 3 is the best alternative when the emphasis is on reducing emission intensity, but Scenario 2 shows lower abatement costs. Since the objective is to lower emission intensity, efforts must be taken to stimulate the development of backstop technologies, which would inevitably raise the unavoidable abatement costs.

4. Implications for climate mitigation

Over the last few years, the INDCs submitted to UNFCCC – following COP21 in 2015 and the revised version after COP22 in

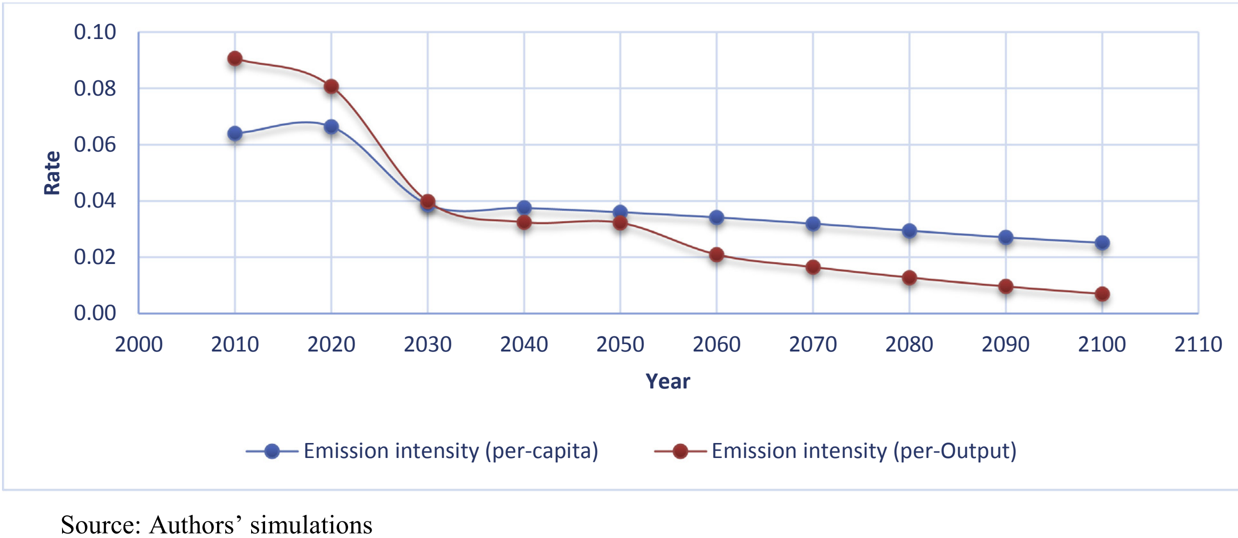


Fig. 6. Emission intensity, scenario 2, 2010–2100 (MYR Billions/unit control).

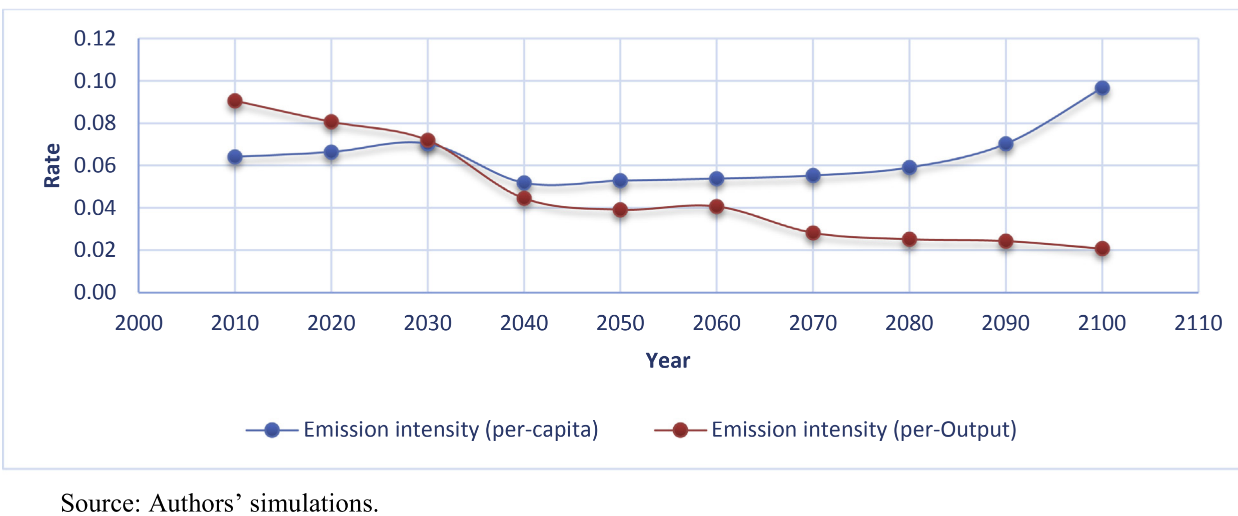
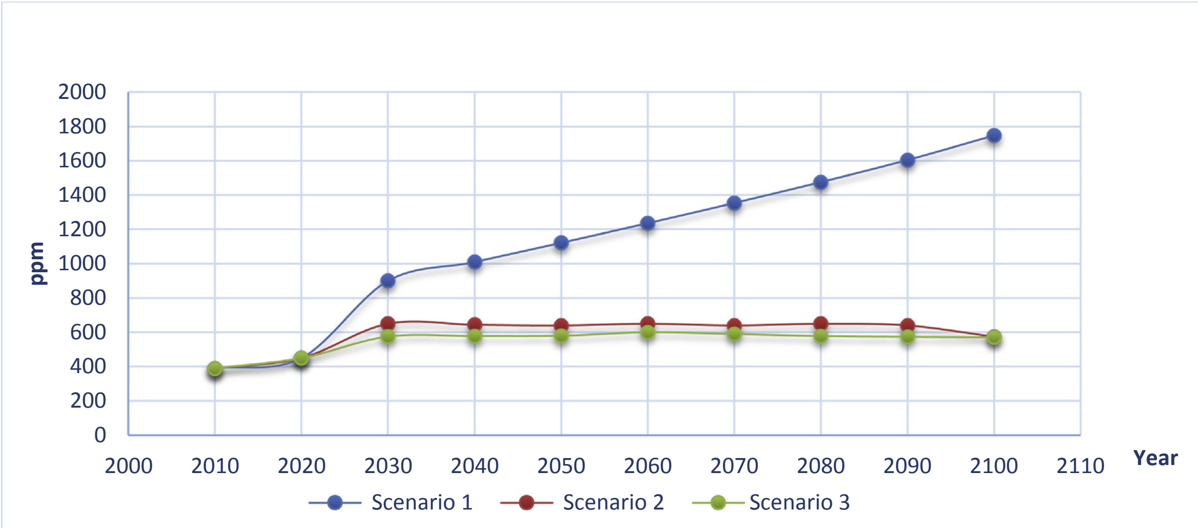


Fig. 7. Emission intensity, scenario 3, 2010–2100 (MYR Billions/unit control).

2016 - has become a priority of governments. This study evaluated the three possible scenarios facing Malaysia, in which GHG emissions fall significantly in scenarios 2 and 3. However, the marginal abatement cost and emission control rates or intensity per output also rises with increasing reduction in GHG emissions. This study supports the contemporary findings by Kameyama et al. (2016) and Fridahl and Linnér (2016) on finance for achieving low-carbon development in Asia. While the paths taken by countries to reduce carbon emissions and to cap temperature rise is becoming clear, it can only be carried out reasonably well if all countries cooperate as borders are porous. We distinguished the best path in this paper among the three scenarios facing Malaysia, albeit its efforts to comply with the revised INDC following the Marrakesh proclamation has to some extent faced uncertainties following President Donald Trump's call to revoke the countries' pledge to the 2015 Paris Accord (European parliament, 2016). Nevertheless, recent developments show that Malaysia remains committed to reduce carbon emissions to meet the Paris by 45% with the period extended from 2030 to 2060 following the Marrakesh Proclamation of 2016.

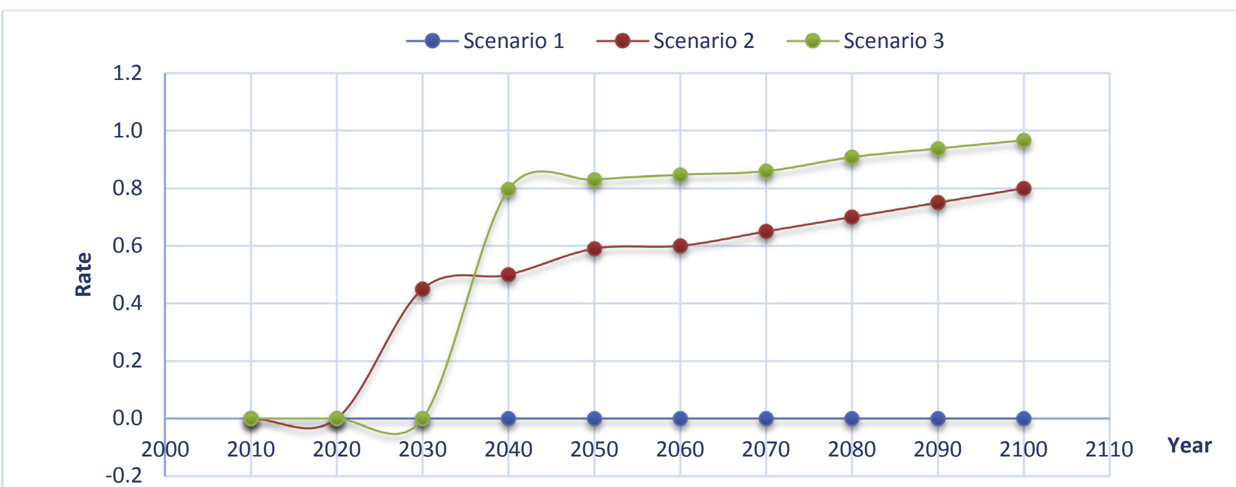
The results from the exercise show that scenarios two and three are promising as the global economy is decarbonised drastically. Scenarios two and three show declining emissions over time. However the intensity and pace of emission fluctuations, and abatement costs between the two scenarios differ. This study supports the other recent works done by Wang and Wei (2014), Wang et al. (2012) and Russell et al. (2010). Scenario 3 is the best alternative when the emphasis is on reducing emission intensity, but Scenario 2 shows lower abatement costs. Since the objective is to lower emission intensity, efforts must be taken to stimulate the development of backstop technologies, which would inevitably raise abatement costs. The colossal amount of funds required to install emission intensity controls and the stimulation of backstop technologies poses is a major challenge to implementation of INDC's in the developing countries. Donald Trump's attempt to revoke the United States' commitment to the Paris Accord has raised concerns over the mobilization of aid to support mitigation attempts among the developing countries.

Nevertheless, the developed country members at the COP22 meeting reaffirmed their commitment to support the "$100bn a



Source: Authors' simulations.

Fig. 8. Emission control rates, 2010–2100 (ppm).



Source: Authors' simulations

Fig. 9. Emission control intensity, 2010–2100 (MYR/unit control).

year by 2020" goal, and to achieve a greater balance between adaptation and mitigation by assisting the developing nations through funding as well as technology transfer (UNFCCC, 2016). Members at COP22 meeting also agreed to act with mitigation efforts within two years, i.e. by 2018. Hence, Malaysia should choose between scenarios 2 and 3 and implement a framework for bringing down carbon emission levels with the expectation that other countries will also implement similar policies to green the world.

While Malaysia has agreed in its INDC to bearing on its own the financing accounting for 35% of the reduction of carbon emissions with the remaining 10% through assistance from the developed countries, it will very much expect technology transfer from abroad as the prime source of greening technologies. There has already been an international effort in this direction, such as the UNFCCC's Technology Mechanism and the Climate Technology Centre and Network (CTC-N), but it desperately needs proactive action. The introduction of green technologies should be seen to enhance rather than undermine productivity and growth in the country. Thus, although implementation of 45% GHG mitigation will be a great challenge, collaboration between countries shall not only help reduce costs but also offer the room for adaptive learning.

Stern (2007) and Nordhaus (2008) had set the compass for checking climate change after arguing convincingly that human activity using fossil fuels as the prime cause of global warming. Significant institutional development have since taken place through the auspices of the United Nations. Especially the initiatives to follow the climate mitigation direction established at the Paris Accord and the Marrakech Proclamation will go a long way to achieving the decarbonisation of the global economy. Since lowering emission intensity is the goal of the Paris Accord, Malaysia should adopt scenario three, which offers the largest reduction in carbon emissions by 2100.

5. Conclusions

The world witnessed a major step forward following the Paris Accord of 2015 and the Marrakech Proclamation of 2016 the INDC became a promising GHG mitigation instrument to check man-made global warming. Thus, this study analysed the mitigation impact of two targeted scenarios against the business as usual scenario for Malaysia over the period from 2010 to 2100. We found that the cumulative climate damage over the period 2010–2100 will amount to 2078 mtoe under scenario 1, 1076 mtoe under scenario 2, and 632 mtoe under scenario 3. Meanwhile, cumulative carbon concentration over the period 2010–2100 will amount to 1746.64 ppm under the present climate regime, which will fall to 1005.55 ppm and 871.292 ppm respectively under scenarios 2 and 3 respectively. Although the total abatement costs for scenario 2 of MYR4,293 million is lower than scenario 3 of MYR4,8194 million, the latter should be preferred due to its superior capacity to decarbonise the economy.

Hence, the Stern (2007) and Nordhaus (2008) reports have given the broad direction for the COPs deliberate on the strategies to reduce man-made climate change. Following COP21 and COP22, individual nations have translated their INDCs accordingly to decarbonise the global economy. While constant re-estimations and recalibrations to take account of green technology substitution responses and new developments will be necessary to guide Malaysia's path to the achievement of the COP21 and COP22 goals, the results are also important to draw lessons for other countries seeking to do the same. The findings enhance our knowledge of: (a) setting up long-term national climate change mitigation policies, and (b) plugging gaps in our understanding of impact, (including costs) of the different climate control options. Although the ultimate target group considered in this study is principally Malaysian policy makers, a wide range of research communities and stakeholders related to climate change studies shall benefit from the analysis due to the robustness of the scientific outcomes.

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APPENDIX I

Mathematical statement of the study model:

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

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

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

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

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

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

$$Q(t) = C(t) + I(t) \tag{7}$$

$$C(t) = C(t)/L(t) \tag{8}$$

$$K(t) = I(t) + (1-\delta_k)K(t-1) \tag{9}$$

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

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

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

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

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

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

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

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

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

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

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 to 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)

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