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An Investigation of Climate Change Within the Framework of a Schumpeterian Economic Growth Model

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1 Introduction

The effects of global climate changes are widely observed. These related changes are short-term events, such as changes in the precipitation trends, floods, hurricanes, and heat waves. They can also be long-term events, which include rising sea levels, droughts, and seasonal changes. These long- and short-term changes are the direct results of climate change, and the potential increase in short-term events is directly related to long-term changes. Climate change also has an indirect impact on disease, water

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resources, and food availability (Carman, 2020; Intergovernmental Panel on Climate Change, 2014).

Certain developments such as a change in the production and consumption patterns of societies, population increases, urbanization, and the rapid industrialization process that followed the Industrial Revolution have increased demand for energy. Economic growth became the primary goal of countries such as China, the US, and Japan, and especially after the Second World War, energy demand has increased. Human activity, such as an increased use of fossil fuels to meet this emerging energy demand, changes in land use, and deforestation, has destroyed the environment, causing a change in the composition of greenhouse gases (GHGs). Gases that create the GHG effect have accumulated in the atmosphere, which has caused a rapid increase in the natural greenhouse effect. An increase in the number of GHGs has increased the prevalence and effects of meteorological events, such as severe hurricanes, floods, and droughts. It has also raised sea and ocean levels and caused the melting of snow and icebergs (Başoğlu, 2014).

It is foreseen that global policies and regulation will increase GHGs, and by the end of the twenty-first century, these are expected to have caused an overall 3.0 °C increase in global climate. In the absence of appropriate policies, this rise could exceed 4.1 °C–4.8 °C. According to an optimistic policies scenario of December 2019, there is a 66% probability of an overheating of about 2.8 °C when ongoing planned programs and policies, which have yet to be implemented, are combined with the commitments and targets that governments have already made (United Nations Environment Programme, 2020).

Climate change still has serious effects on the daily lives of people by generating environmental, social, political, and economic multi-directional changes. It is crucial to know what can be done to positively respond to climate change. This research, based on the explanations above, studies climate change within the framework of economic growth. It explores the adaptation process to climate change on the basis of entrepreneurship and innovation in the axis of the Schumpeterian Economic Growth Model.

A large part of the literature on this topic evaluates issues of innovation, entrepreneurship, and environmental load separately. This study aims to combine the three elements by studying them concurrently. Specifically, the chapter contributes to the available literature by adding entrepreneurship and innovation factors to the production function in order to calculate the environmental load that reflects an economic value.

We present our research as follows. In Sect. 2, which follows the introduction, we first focus on the extent of climate change, and in Sect. 3, we explain the relationship between economic growth and climate change. We review related literature in Sect. 4, and information regarding case studies is presented in the Sect. 5. We conclude by presenting the results of our study and exploring their future implications.

2 Extent of Climate Change

The root causes of climate change within the last fifty years are human activity and fossil fuels. According to data collected in 2017, the amount of human-induced GHGs equals 50,820 million metric tons of carbon dioxide (CO_2). This is a record amount in humanity's history and has caused unprecedented concentrations of atmospheric CO_2, methane, and nitrous oxide over the past 800,000 years (United Nations Environment Programme, 2020; United States Global Change Research Program, 2017).

We are witness to the warmest period in the history of modern civilization. As can be seen in Fig. 9.1, global annual average temperatures increased by an additional 0.65 °C in the 1986–2016 period compared to 1901–1960. Global temperature increased by approximately 1.0 °C between the years 1901 and 2016. The human contribution to the increase in global average temperature of the 1951–2010 period is estimated as being 0.6 °C–0.8 °C; the central estimate of 0.65 ° C of observed global warming is at this range. The ratio of the human contribution to climate change in the 1951–2010 period is 92%–123% (IPCC, 2014; USGCRP, 2017). Data from the National Aeronautics and Space Administration (NASA) in 2020 shows that nineteen of the hottest twenty years occurred after 2001, with the exception of 1984, which preceded this period. The year 2016 was the hottest on record. Global average sea levels have risen by 7–8 inches since 1900, with almost half of

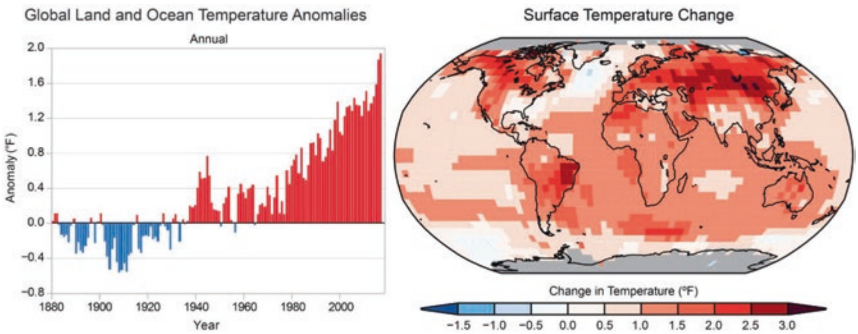

Fig. 9.1 Global average temperature anomalies and surface temperature change: 1880–2020. (Source: USGCRP, 2017)

this increase occurring after 1993. Sea levels will continue to rise by a few inches in the next fifteen years and by 1–4 inches by 2100 (NASA, 2020).

The extent of climate change beyond the next few decades will be based on the amount of GHGs produced (especially CO_2) and the sensitivity of climate to related emissions. The annual average global temperature increase can be limited to 2 °C or less with significant decreases in GHG emissions. However, it is foreseen that increases in annual average global warming will exceed 5 °C by the end of the twenty-first century if emissions are not greatly reduced (USGCRP, 2018).

Figure 9.2 illustrates the observed monthly global mean surface temperature change and estimated human-induced global warming. The orange dashed arrow and horizontal orange error bar, respectively, show the central estimate and possible time range when reaching 1.5 °C in the case of a continuing available warm-up speed. The gray area on the right represents the possible range of warming reactions that are computed by a simple climate model, based on stylized pathways, where CO_2 emissions reach zero by falling to a straight line in 2055 from 2020. The radiation stress (forcing) without CO_2 increases until 2030 and then decreases. We can see in the blue area that faster CO_2 emissions reductions decrease cumulative CO_2 emissions, which reach zero by 2040. The purple area shows that CO_2 emissions are at zero in 2055 and that forcing without CO_2 remains stable after 2030. Lines at the right of the figure represent the possible ranges of vertical error bars.

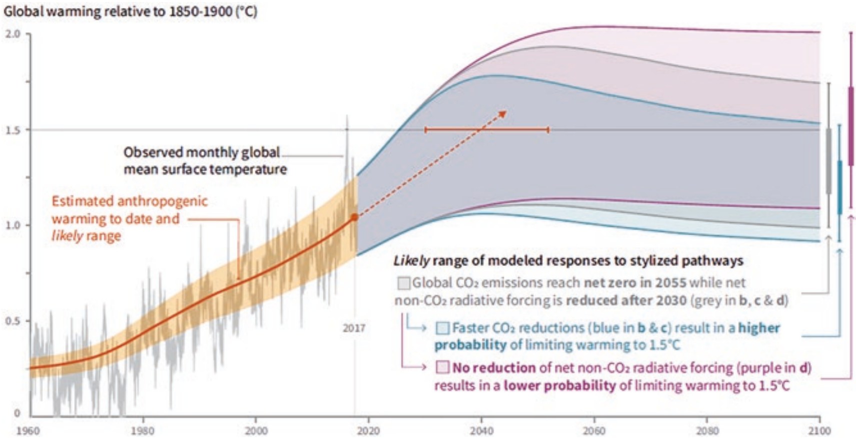

Fig. 9.2 Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways. (Source: IPCC, 2018) (Color figure online)

Climate-related risks for people and natural systems are based on the size and ratio of global warming, geographical position, development and vulnerability levels, choice of adaptation and mitigation options, and their respective implementation. The potential effects and related risks that are created by a change in the range of 1.5 °C and 1.5 °C–2 °C in global climate are as follows (IPCC, 2018):

- Remarkable differences, such as changes in average temperatures in many land and ocean regions and other regional climate characteristics, extreme temperatures in many residential areas, heavy rain in a few areas, and drought and rainfall probability in certain areas will be observed.
- The global average increase in sea level will be about 0.1 meters higher by the year 2100.
- Biological diversity will decrease as a result of the extinction of land and sea species, the effects of which will be significant to ecosystems.
- The acidity of oceans will increase, and a decrease in oxygen levels will bottom out along with temperature increases in the oceans.

- Climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth will increase.
- The adaptation capacity for people and natural systems and the losses associated with it will be greater.
- The effects of climate change on sustainable development, poverty eradication, and reduction of inequalities will be more pronounced.

According to the United Nations Intergovernmental Panel on Climate Change's (IPCC) 2018 report, green areas between one-fifth and one-twelfth of the planet will become deserts, 99% of coral will be destroyed, 450 million people will be affected by increased temperatures, and hundreds of millions of people will fall below the poverty line as a result of a 2 °C increase in global temperature. Moreover, there will be food and water shortage crises due to rising sea levels polluting agricultural land and water resources. There will also be desertification in areas where global warming is more significantly pronounced (IPCC, 2018).

3 Economic Growth and Climate Change

Environmental and economic values are evaluated as contradictory to each other in discussions regarding climate change. It is thought that there is a need to make a choice between providing economic growth and protecting nature, and that fewer emissions entail higher costs (Doganova & Karnøe, 2015). According to environmental economics, environmental degradation is caused by a market failure, while the entrepreneurship literature argues that opportunity lies in the nature of the failure (Dean & McMullen, 2007). Efforts to reconcile environmental and economic values are the result of these contradictions.

3.1 The Schumpeterian Economic Growth Model

Joseph Schumpeter (1942) examines innovation and technology based on Marx's Plus Value Hypothesis within the frame of creative destruction thesis. The creative destruction process is defined as those companies that use new products, new production structures, and new technology, and which outcompete companies that use old products, old production structures, and old technologies. This relational process emerges as innovation meets the market. The engines of economic development are research and development (R&D) and innovation. It is possible for companies to organize production activities and profit sustainably by adaptiveness (Çelik, 2020; Genç & Tandoğan, 2020; Lundvall, 2007).

Schumpeter, in his entrepreneurship theory, defines capitalism as a production flow that is completely stable and which reproduces itself within a circular flow which never changes or increases in its wealth creation. Profit emerges when this flow is interrupted and diverges from the route of a static economy. A change in technological and organizational innovation involved in the flow can cause its deviation. In other words, innovation is directed by monopoly profit expectation, and profit can be achieved by reducing the cost of producing a product or if a new product can be created. In this way, an income flow is independent of the contribution of labor and capital owners (Acemoglu, 2009; Büyükılgaz, 2020).

3.2 Economic Effects of Climate Change

There are two risks in determining the cost of natural disasters in climate change analysis models. The first is underestimating the immediate effects of losing assets from disasters on the economic output flow in the aggregate production function. The other is that the capital stock in the production function causes the rebuilding capacity of output impact of natural disasters (as a critical determinant of welfare losses) to be ignored, which also causes a decrease in the estimation of the output impact of natural disasters (Hallegatte & Vogt-Schilb, 2016).

As can be seen in Fig. 9.3, the repercussions of climate change include fluctuating temperature increases and precipitation regimes. This situation causes huge economic losses by increasing the frequency and severity of climate-related natural disasters, such as extreme droughts, floods, and storms. Almost 87% of recorded natural disasters in the 1980–2012 period are climate related. Of these disasters 44% were storm, 41% were floods, and 15% were droughts. The economic losses associated with

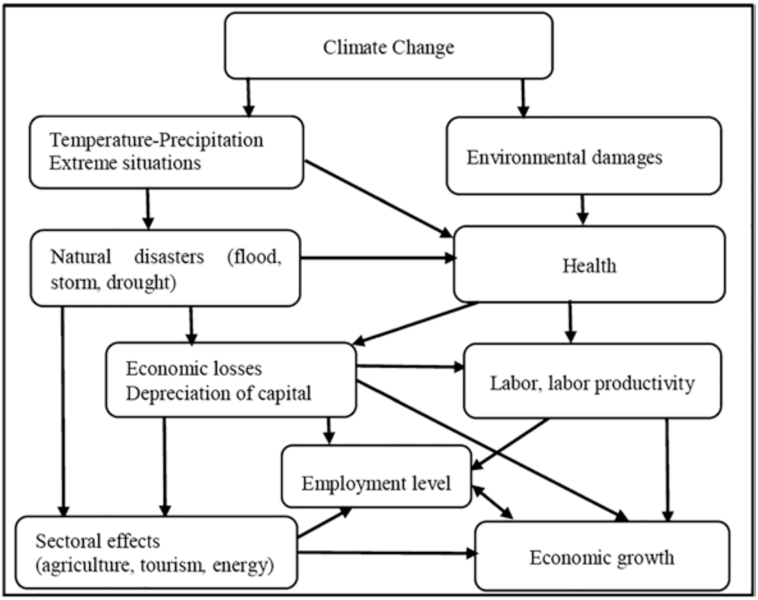

Fig. 9.3 Economic effects of climate change. (Note. The original version of the text in the figure is in Turkish. Source: Başoğlu, 2014)

these disasters, in the related period, reached 2.8 trillion US$ (Başoğlu, 2014). The average estimated global flood losses in 2005 were approximately 6 billion US$. This estimation increases to 52 billion US$ when socio-economic change is considered. This number, along with other damages caused by climate change, is assumed to be the 1 trillion US$ or more per year (Hallegatte et al., 2013).

Climate change is expected to be the stochastic shock that trickles into the productivity of labor, energy efficiency, and company inventories. Accordingly, the Dystopian Schumpeter meeting Keynes (DSK) model shows comprehensive micro- and macroempirical regularities regarding both economic and climatic dynamics (see Fig. 9.4). The model explains frequent and mild climate shocks with low probability, but with extreme climatic events. There are technical changes in both the manufacturing and energy sectors. Innovation determines the cost of the energy that is generated by dirty and clean technologies, the status of which impacts

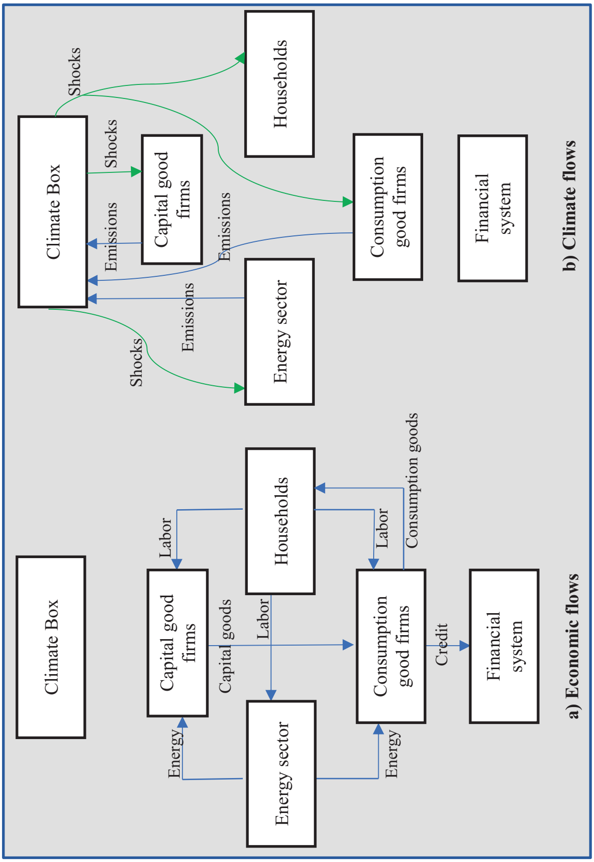

Fig. 9.4 A stylized representation of the DSK model. (Source: Lamperti et al., 2018)

the energy technology production mix and the amount of CO_2 emissions. Structural changes in the economy are closely associated to climatic dynamics. Moreover, climatic shocks affect economic growth, duty cycles, technical change trajectories, GHGs, and global temperatures (Lamperti et al., 2018, 2020). There is an observable cyclical relationship between economic growth and climate.

The annual economic value of world terrestrial ecosystem services equals the annual amount of global GDP. According to World Bank estimations, air pollution causes 5 trillion US$ of lost revenue in health and 225 billion US$ in welfare costs per year. It is foreseen that climate change will decelerate economic growth, complicate the reduction of poverty, further erode food security, prolong current poverty traps, and create new traps in hunger zones, especially in urban areas (UNEP, 2020).

4 Literature Review

The roles of innovation and international information dissemination during economic growth and development processes are inclusively analyzed in Schumpeterian research. Another comprehensive research area is one that scrutinizes the Schumpeterian Innovation and Growth Models. This research focuses considerably on the comparative dimension of the economic growth process across countries in the Schumpeterian literature (Castellacci & Natera, 2016). Studies on climate change are less common in the literature.

There has been a growing interest (e.g., Cohen & Winn, 2007; Dean & McMullen 2007; Riti et al., 2015) in environmental entrepreneurship that pursues profit opportunities that deliver environmental benefits besides the ability (e.g., Dean & McMullen, 2007; Riti et al., 2015) for entrepreneurs to take advantage of opportunities inherent in environmentally relevant market failures. Studies that analyze the effects of entrepreneurial activities on the environment need to consider that related effects vary according to the economic growth levels of the countries in question. Acs et al. (1994) consider entrepreneurship levels, which are generally explained by economic development stages, in situations particular to different countries and periods. Omri (2018) explains that results are responsive to different income groups and sectoral analyses.

A vast majority of studies focusing on the relationship between governmental regulations and strict environmental policies notice a positive correlation between variables. Albrecht (2002) emphasizes that the environmental policy area that strongly increases governmental regulation aims to correct market failure and, accordingly, affects market forces. Albrizio et al. (2017) survey the effects of changes in the frequency of environmental policy in Organisation for Economic Co-operation and Development (OECD) countries on productivity growth at the industrial and company level. They conclude that pressures on environmental policy are associated with a short-term increase in productivity growth in most technologically advanced countries at the industrial level. Chen and Wang (2017) analyze the effect of consumer demand preferences and environmental policies on the environmental investment decision-making processes of companies and the development of environmentally friendly technologies. Their results show that consumers prefer the product price. Indeed, a market-based tool combined with an information-driven tool can promote the development of environmentally friendly technologies, while a market-based tool implemented alone decreases environmental investment. Cohen and Winn (2007) claim that market failure causes environmental degradation and that it also provides significant opportunities to create radical technology and innovative business models. According to Doganova and Karnøe (2015), policymakers and entrepreneurs rely on a combination of technological innovation and market mechanisms to reconcile environmental and economic value on the agricultural sector; they have, however, already attempted various methods of reconciliation. Filatova (2020) summarizes the developmental aspects of legislation governing environmental and entrepreneurial relations in Russia. In this case, there is no legal regulation of environmental entrepreneurship for the regulator. There is a need to consider the priority of environmental organization of economic activities. Low-level development of legislation acts as an external factor which constrains environmental entrepreneurship. Kasim and Mohd Nor (2015) emphasize that company executives and entrepreneurs should apply environmental management practices, such as recycling, water-saving, and energy efficiency management systems to solve environmental problems. Meireles et al. (2016) develop a dynamic general balance growth model by establishing technological change based on inner skills to review the contributions of environmental policies for ecological goods. In the model, the dynamics of the transition are analyzed and it is shown that when green firms and green research are supported by policy and/or dirty activities are taxed, technological progress leads to more ecological product production and improvements in environmental quality.

We see in the existing literature that the majority of studies emphasize a positive relationship between entrepreneurship and environmental quality. In this context, Dean and McMullen (2007) focus on the issue of how entrepreneurial activities can be a solution for environmental problems in global socio-economic systems, and they find that entrepreneurial activities lighten market failures. Demir Uslu et al. (2015) claim that more profit targets and industrialization cause climate change in the developing global economy and that green entrepreneurship provides opportunities for economic agents that are affected by this change. Kimmel and Hull (2012) analyze ecological entrepreneurship as an integrated conservation strategy in terms of both environmental and economic targets. According to them, ecological entrepreneurship supports local economies as much as the environment; in other words, this type of entrepreneurship promotes sustainable development. Lenox and York (2011) pose that environmental entrepreneurship theory has gone beyond the business/environment dilemma and reuses market forces as a solution for environmental degradation. Nakamura and Managi (2020) conclude that there is a U-shaped relationship between entrepreneurship and the marginal cost of CO_2 emissions in economic development; a so-called developed country such as Japan has median marginal CO_2 cost, while countries such as China, with low CO_2 reduction levels, have higher entrepreneurship ratios. They also emphasize the entrepreneurship process, which discusses the central issues of environmental concerns. Shepherd and Patzelt (2011) conclude that increasing entrepreneurial activity does not always increase environmental degradation, as it can also protect ecosystems and be a solution for climate change. York and Venkataraman (2010) offer entrepreneurship as a solution to environmental degradation. According to their research, entrepreneurs contribute to the solution of environmental problems by establishing new products, firms, markets, information resources, and institutions that are more environmentally sustainable.

Offering an example of entrepreneurial activities that increase environmental degradation, Koe et al. (2014) conclude that, since entrepreneurial activities are an accepted reason for environmental degradation, entrepreneurs need to play a part in the management of sustainability issues. Riti et al. (2015) research the causal relationship between entrepreneurship and the environment. Their results show the presence of an environmental Kuznets curve and a long-term relationship between CO_2 emissions per person and entrepreneurship. They observe that entrepreneurship has a negative impact on environmental sustainability. Omri (2018) explains that the contribution of entrepreneurial activities to environmental degradation in the long term is low for high-income countries. Entrepreneurial activities in these countries increase environmental pollution to begin with; however, related activities reduce environmental pollution after a certain period of time. Omri and Afi (2020) explain that types of entrepreneurship increase carbon emissions. Mandatory and informal entrepreneurship, compared to opportunity and formal entrepreneurship, create the biggest contribution to carbon emissions, where government expenditure reduces carbon emissions in models concerned with opportunity and mandatory entrepreneurship. Vivarelli (2013) argues that increasing entrepreneurship can create a perverse effect in both the environment and the economy. Youssef et al. (2018) highlight that formal and informal entrepreneurship decrease the environmental quality in seventeen African countries; however, informal entrepreneurship increases environmental degradation more than formal entrepreneurship. The conclusion to draw from these studies is the significant role of innovation in reaching sustainability.

Ang (2009), who focuses on the innovation factor in environmental degradation, explains that CO_2 emissions in China are negatively associated with technology transfer, research intensity, and the economy's capacity to absorb foreign technology. According to Busch et al. (2018), there is a need for the promotion of innovation in low-carbon technologies, business models, and applications in order to create a low-carbon industrial strategy. There is also a need for activities to manage energy supply as well as energy demand. They offer a strategic target to provide elasticity for systematic change. Corradini et al. (2014) review investment decisions regarding innovation and emissions reduction. Their results reveal that innovative efforts are positively associated with several dissemination effects, which include a reduction of emissions in the sector. They also explain different reactivity powers as well as the special role of technological and economic complementarity. Deleidi et al. (2019) focus on the effects of government expenditure on innovation, innovation on economic growth and the ecosystem, ecological feedback on economic growth, and the expenditure efficiency of government. They observe that the government can succeed in supporting innovation and growth while simultaneously decelerating depletion rates of material and energy reserves, and also by struggling with climate change. Hickel and Kallis (2019) state that despite major technological changes and their increasing impact, revenue growth is not separated from resource demands or emissions generation at a global level.

In their study on environmental degradation's role as an economic output, Althouse et al. (2020) suggest green growth strategies that promote more productive types of economic growth, proposing that there is a need for pricing mechanisms and a demand for Keynesian management applications to solve environmental problems. Hornborg (2009) highlights that, as climate change and environmental degradation worsen, the possibility of additional calls for sustainable investment and green growth to create a zero-sum game is higher, rather than a progressive march toward sustainability and development. Lamperti et al. (2018) report much greater climate damage compared to estimates in computable general equilibrium integrated assessment models. In a recent study, they use a mediator-based integrated assessment model to review the possibility of transitioning to green and sustainable growth in the case of climatic damage (Lamperti et al., 2020). Results show that the economy has a sustainable growth path balance characterized by better macroeconomic performance with a carbon-intensive lock-in. Monasterolo et al. (2019) not only explain climate effects on socio-economic systems, but also explain the need for a new model that includes uncertainty and complexity arising from their reaction. Pollin (2019) confirms that economic growth is an acceptable and desired method of increasing environmental sustainability.

5 Case Study

The model in this study is established within Equation (9.1), by discussing the climate change problem within the framework of the Schumpeterian Economic Growth Model.

5.1 Data and Model

The sample set is composed of countries which emit the most CO_2[1] since it is the dominant factor of the climate change, based on data from 2018 (see Appendix) relating to GHGs. We analyze the output of entrepreneurship and innovation parameters regarding emissions by panel statistics for the 2002–2018 period, in the sample of the US, Germany, Russia, China, India, Japan, and South Korea. We review the model from a perspective that highlights the role of innovation and entrepreneurial activities based on the Schumpeterian type of growth model.

The model below is formulated with reference to studies from Costantini and Monni (2008), Deleidi et al. (2019), Nakamura and Managi (2020), Omri and Afi (2020), Prieger et al. (2016), Youssef et al. (2018):

$$\begin{aligned} CO_{2it} &= \partial_0 + \partial_1 GDP_{it} + \partial_2 FCI_{it} + \partial_3 GE_{it} + \partial_4 GS_{it} \\ &\quad + \partial_5 TEA_{it} + \partial_6 RD_{it} + \partial_7 PA_{it} + \mu_{it} \end{aligned} \tag{9.1}$$

CO_2, GDP, FCI, GE, GS, TEA, RD, and PA in the model represent the following, respectively: carbon dioxide emissions (million tons), gross domestic product (per capita, PPP, current international \$), fixed capital investment (gross, current US\$), government expenditure (current US\$), genuine savings (GS; adjusted, including particulate emission

[1] The main reason for taking CO_2 data in this research, which focuses on the climate change adaptation process, is that CO_2 emissions are responsible for approximately three quarters of global warming. Atmospheric CO_2 concentration, which is the largest contributor to human-induced global warming, has increased by about 40% during the industrial age. This change has caused increases in global surface temperatures by intensifying the natural GHG effect of the atmosphere and has also caused other widespread changes in the world's climate unprecedented in the history of modern civilization (UNEP, 2020).

damage, current US$), entrepreneurial activities (total early-stage entrepreneurial activity), research-development (transfer), and patent applications (residents). The *RD and PA* variables represent innovation. All the variables are included in the model by logarithmic (*ln*) structure. ∂_0 is the constant parameter, $\partial_1 \ldots\ldots \partial_7$ is the slope parameter, and μ is the error term. The sub-symbol *i* shows the units, and *t* is the time interval of 2002–2018. The CO_2, *GDP*, *FCI*, *GE*, *GS*, *and PA* data is from the World Bank's World Development Indicators (World Bank, 2020), and the *TEA and RD* data is accessed from the Global Entrepreneurship Monitor (2020a, b).

The research hypotheses within the scope of available literature are as follows:

- Hypothesis 1: We expect, within the Schumpeterian Growth Model, that entrepreneurial activity and innovation will improve environmental quality by reducing CO_2 emissions in the long term. Studies conducted by Dean and McMullen (2007), Demir Uslu et al. (2015), Kimmel and Hull (2012), Lenox and York (2011), Nakamura and Managi (2020), Shepherd and Patzelt (2011), and York and Venkataraman (2010) support this hypothesis.
- Hypothesis 2: We estimate that economic growth, fixed capital investment, and public expenditure will decrease environmental degradation by reducing CO_2 emissions in the long term. Studies by Albrecht (2002), Albrizio et al. (2017), Althouse et al. (2020), Busch et al. (2018), Chen and Wang (2017), Cohen and Winn (2007), Corradini et al. (2014), Deleidi et al. (2019), Doganova and Karnøe (2015), Filatova (2020), Hickel and Kallis (2019), Kasim and Mohd Nor (2015), Meireles et al. (2016), and Pollin (2019) provide support for this hypothesis.
- Hypothesis 3: We posit that for estimates, genuine savings have a direct negative impact on CO_2 emissions. Costantini and Monni's methodology (2008) for the GS variable explains that GS is the only macroeconomic sustainability indicator that is computed for a wide range of countries and for a consistent time series.
- Hypothesis 4: We assume that there is a causality relationship that confirms the feedback hypothesis between dependent and independent variables. The study by Riti et al. (2015) produces similar results.

5.2 Empirical Strategy

Estimation procedures of the model within Equation (9.1) are conducted for co-integration and causality analyses in a panel time series. We then perform a two-step empirical methodology toward statistical reliability of the tests in analyses. We then conduct a correlation test between the units in the first stage and apply unit root tests in the second stage.

5.2.1 Cross-sectional Dependence and Panel Unit Root Tests

We use the CD Lagrange multiplier (LM) test, which was developed by Breusch and Pagan (1980), in a matrix with 119 observations ($N = T \times n$) when the time dimension is greater than the number of cross sections ($T > n$). Breusch-Pagan CD_{LM} test findings in Table 9.1 in Appendix show a correlation between units by denying the H_0 hypothesis. There is therefore a need to choose the second-generation panel unit root tests that are used in the case of correlation between units.

The Harris and Tzavalis (1999) and Breitung (2000) panel unit root tests were applied to series with differences from cross-section means to reduce the correlation effect between units. According to stationarity findings in Table 9.1, the CO_2, *GDP*, *FCI*, *GE*, *and PA* variables are taken into the first difference and the *GS*, *TEA*, *and RD* variables are taken into the co-integration model at level values.

5.2.2 Panel Co-integration Test and Long-Term Estimates

We then perform a co-integration analysis for the presence of possible long-term equilibrium relationships between variables after cross-sectional dependence and apply unit root tests. The Westerlund (2007) panel co-integration analysis findings in Table 9.2 in Appendix show that there is a long-term co-integration relationship between variables, based on group (Gt-Ga) and panel (Pt-Pa) average statistics by denying the H_0 hypothesis. In this context, we observe that there is a long-term relationship between CO_2, growth, fixed capital investment, government expenditure, genuine savings, entrepreneurship, R&D, and patent applications.

The Panel Fully Modified Least Squares (FMOLS) heterogeneous parameter findings, in a long-term relationship within a co-integration model (see Table 9.3 in Appendix), confirm that growth, fixed capital investment, R&D, and patent applications increase emissions under statistical significance, which means genuine savings reduce emissions. Entrepreneurial activities are statistically insignificant.

Equation (9.2) is obtained by rearranging the model in Equation (9.1) based on long-term slope parameters:

$$\begin{aligned} CO_{2it} &= 0.44GDP_{it} + 0.11FCI_{it} - 0.16GE_{it} \\ &\quad - 0.01GS_{it} + 0.03RD_{it} + 0.05PA_{it} \end{aligned} \tag{9.2}$$

According to the estimation findings, while a 1% increase in GDP increases emissions by 0.44%, a 1% increase in fixed capital investment increases emissions by 0.11% and a 1% increase in innovation (R&D and patent applications) increases emissions by 0.08%. A 1% increase in government expenditure reduces emissions by 0.16% and a 1% increase in genuine savings reduces emissions by 0.01%. Within this context, GDP (%0.44) is the variable with greatest impact on emissions, while the variable with least impact is the genuine savings (%0.01). Therefore, for the purpose of adapting to climate change by reducing the CO_2 emissions level, it is thought that it is necessary to focus especially on economic growth in the long term.

5.2.3 Panel Causality Test

The Heterogeneous Panel Causality Test, developed by Dumitrescu and Hurlin (2012), results in the findings in Table 9.4 in Appendix, which show the feedback relationship between emissions and growth, fixed capital investment, government expenditure, genuine savings, and patent applications. We also find there is a one-way causality relationship from R&D and entrepreneurial activities to CO_2 emissions. Therefore, for the purpose of adapting to climate change, considering that the growth, fixed capital investment, government expenditure, genuine savings, entrepreneurial activity, and innovation variables are the cause of CO_2 emissions, policy recommendations regarding the specified parameters should be determined.

6 Conclusion

Schumpeter's opinions on growth are explained by innovation and technological competition concepts. As the entrepreneur is a production factor, it has an important role in the development of the capitalist system. Within this context, as the most important factor in the system, the application of technical advances to production by entrepreneurs is based on the expectation of monopoly profit, so technical progress can be seen.

Promoting entrepreneurship is accepted as a solution for environmental degradation and climate change today, because entrepreneurs evaluate their environmentally friendly goods and services to create a remarkable market potential. Even if green goods and services endeavor to capture demand with high margins at the beginning, it is expected they will increase market share. This assumption is based on the innovation that the focal point of entrepreneurial activity is to take correct market opportunities. Therefore, entrepreneurs who try to develop their market share and domestic market using sustainable production methods to create a positive impact on the environmental load can offer a solution for climate change.

In this study, we analyze the climate change problem within the framework of the Schumpeterian Economic Growth Model for the US, Germany, Russia, China, India, Japan, and South Korea, for the 2002–2018 period. Based on the co-integration results, there is a long-term balance relationship between the variables. As the economic growth, fixed capital investment, and emissions of innovation increase, government expenditure and genuine savings reduce emissions. The causality test results confirm the feedback hypothesis between emissions with economic growth, fixed capital investment, government expenditure, genuine savings, and patent applications. We also find a one-way causality relationship from R&D and entrepreneurial activities to emissions.

Therefore, when we evaluate the climate change adaptation process of the countries in the sample cluster, we conclude that these countries should focus their efforts on a reduction of emissions relative to growth, fixed capital investment, and innovation. Considering that the causality results also confirm the co-integration results in terms of variables, we can see that the efforts of these countries are insufficient for adaptation to climate change in the current situation. The results obtained confirm our third and fourth hypotheses. Our results also show that fixed capital investment and government expenditure, which were included in the second hypothesis, increase environmental quality.

Regarding policy perspective, we propose that countries in the sample set implement efficient policies that support production arrangements related to innovation efforts toward growth in order to reduce CO_2 emissions. Consideration must be given to the fact that parameters regarding innovation for economic growth purposes of related countries increase environmental degradation as a response to climate change. The confirmed feedback hypothesis indicates that environmental quality and economic growth, fixed capital investment, government expenditure, genuine savings, and patent applications should be reviewed together. Since entrepreneurial activities and research and development are the principal causes of emissions, the demand for green goods and services ought to be increased. We also emphasize the importance of forming public opinion on this issue.

Conflict of Interest We have no known conflict of interest to disclose.

Appendix

Table 9.1 Cross-sectional dependence and unit root tests

Cross-sectional dependence test		Unit root tests	
Variable	Statistic	Harris-Tzavalis	Breitung
$\ln CO_2$	163.3962 (0.0000)*	1.9041 (0.8622)	4.1065 (1.000)
$\Delta \ln CO_2$		0.1299 (0.0000)*	–3.1058 (0.0009)*
lnGDP	340.2257 (0.0000)*	0.8905 (0.8109)	4.3272 (1.000)
ΔlnGDP		0.2554 (0.0000)*	–4.4293 (0.0000)*
lnFCI	219.6238 (0.0000)*	0.8739 (0.7340)	2.4826 (0.9935)

(*continued*)

Table 9.1 (continued)

Cross-sectional dependence test		Unit root tests	
Variable	Statistic	Harris-Tzavalis	Breitung
ΔlnFCI		0.2366 (0.0000)*	−5.1100 (0.0000)*
lnGE	264.4116 (0.0000)*	0.9177 (0.0931)	2.8934 (0.9981)
ΔlnGE		0.2688 (0.0000)*	−3.7708 (0.0001)*
lnGS	149.9767 (0.0000)*	0.6582 (0.0035)*	−0.6123 (0.2702)
ΔlnGS		−0.0106 (0.0000)*	−6.1273 (0.0000)*
lnTEA	43.08109 (0.0031)*	0.6204 (0.0005)*	−1.4631 (0.0717)**
ΔlnTEA		−0.1709 (0.0000)*	−6.0749 (0.0000)*
lnRD	47.75574 (0.0007)*	0.7227 (0.0442)*	−1.5500 (0.0606)**
ΔlnRD		−0.0678 (0.0000)*	−5.2865 (0.0000)*
lnPA	173.3340 (0.0000)*	0.9520 (0.9662)	5.2321 (1.000)
ΔlnPA		−0.1591 (0.0000)*	−3.5968 (0.0000)*

Note. The Δ notation is the difference processor, *p*-values are in parentheses, and * and ** are 1% and 10% statistical significance levels, respectively

Table 9.2 Panel co-integration test

Model	Test	Value of test	*z*-value	Model	Test	Value of test	*z*-value
$\Delta lnCO_2$ = f(ΔlnGDP)	Gt	−2.608	−4.150 (0.000)	$\Delta lnCO_2$ = f(lnTEA)	Gt	−3.694	−5.656 (0.000)
	Ga	−8.992	−3.019 (0.001)		Ga	−36.599	−14.352 (0.000)
	Pt	−5.854	−3.858 (0.000)		Pt	−7.407	−3.461 (0.000)
	Pa	−7.533	−5.946 (0.000)		Pa	−14.579	−5.895 (0.000)
$\Delta lnCO_2$ = f(ΔlnFCI)	Gt	−3.693	−5.654 (0.000)	$\Delta lnCO_2$ = f(lnRD)	Gt	−3.733	−5.774 (0.000)
	Ga	−25.731	−9.046 (0.000)		Ga	−22.779	−7.605 (0.000)
	Pt	−7.625	−3.675 (0.000)		Pt	−8.709	−4.745 (0.000)
	Pa	−14.651	−5.937 (0.000)		Pa	−20.227	−9.151 (0.000)
$\Delta lnCO_2$ = f(ΔlnGE)	Gt	−3.392	−4.758 (0.000)	$\Delta lnCO_2$ = f(ΔlnPA)	Gt	−3.263	−4.375 (0.000)
	Ga	−26.392	−9.369 (0.000)		Ga	−21.147	−6.808 (0.000)
	Pt	−8.071	−4.116 (0.000)		Pt	−7.514	−3.567 (0.000)
	Pa	−14.918	−6.090 (0.000)		Pa	−12.796	−4.867 (0.000)
$\Delta lnCO_2$ = f(lnGS)	Gt	−4.558	−8.229 (0.000)				
	Ga	−22.365	−7.403 (0.000)				
	Pt	−7.552	−3.604 (0.000)				
	Pa	−15.799	−6.598 (0.000)				

Notes: The *p*-values are in parentheses, the model has a constant term but no trend, according to the Akaike information criterion, and the lag length is in the range of 1–2

Table 9.3 Panel fully modified least squares (FMOLS) long-run elasticity estimates

Variables	Coefficient	*t*-Statistic	Prob.
ΔlnGDP	0.441074*	9.080713	(0.0000)
ΔlnFCI	0.107715*	4.052736	(0.0001)
ΔlnGE	-0.162775*	-6.148147	(0.0000)
lnGS	-0.007143**	-2.732500	(0.0076)
lnTEA	-0.000416	-0.087704	(0.9303)
lnRD	0.031128*	3.170660	(0.0021)
ΔlnPA	0.053047**	2.629114	(0.0100)

Note. The *p*-values are in parentheses, and * and ** are 1% and 5% statistical significance levels, respectively

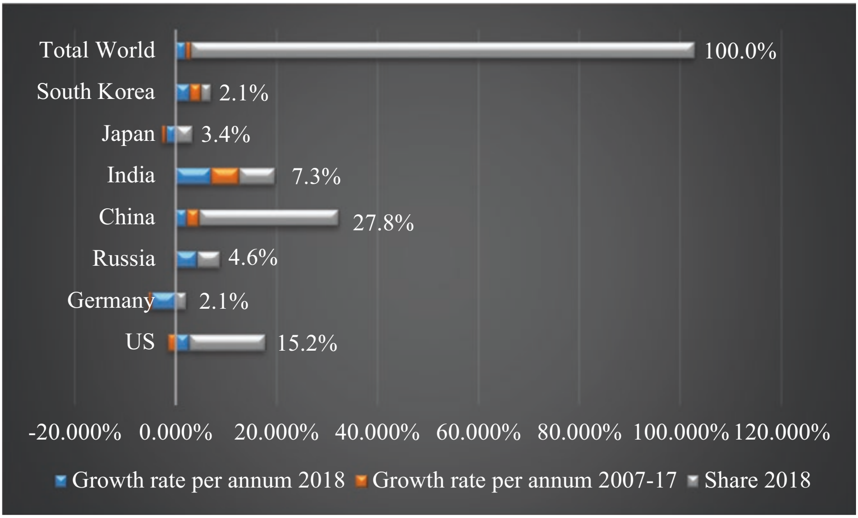

Fig. 9.5 CO_2 emissions (million tons CO_2 emissions). (Source: This was created by the researchers using data from the British Petroleum Energy Outlook Report (2019))

Table 9.4 Granger causality test

	$lnCO_2$	lnGDP	lnFCI	lnGE	lnGS	lnTEA	lnRD	lnPA
$lnCO_2$	–	6.4534 (0.0000)*	3.6715 (0.0002)*	5.8990 (0.0000)*	1.9022 (0.0571)***	0.3107 (0.7560)	–0.6172 (0.5371)	2.1876 (0.0287)**
lnGDP	2.0462 (0.0407)**	Direction of causality: $lnCO_2 \Leftrightarrow lnGDP$						
lnFCI	3.9448 (0.0001)*	Direction of causality: $lnCO_2 \Leftrightarrow lnFCI$						
lnGE	2.0575 (0.0396)**	Direction of causality: $lnCO_2 \Leftrightarrow lnGE$						
lnGS	2.1030 (0.0355)**	Direction of causality: $lnCO_2 \Leftrightarrow lnGS$						
lnTEA	5.1578 (0.0000)*	Direction of causality: $lnTEA \Rightarrow ln\ CO_2$						
lnRD	7.4611 (0.0000)*	Direction of causality: $lnRD \Rightarrow ln\ CO_2$						
lnPA	11.1947 (0.0000)*	Direction of causality: $lnCO_2 \Leftrightarrow lnPA$						

Note. The *p*-values are in parentheses, and *, ** and *** are 1%, 5% and 10% statistical significance levels, respectively

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