Climate change, biodiversity, and pollution: Modelling the interlinkages in drivers, impacts, and policies

Preliminary scenarios for climate and clean air in Korea

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Abstract

Climate change, biodiversity loss, and pollution are closely interlinked, as they share common drivers and affect each other in various ways at the local, national, and supra-national scale. Policy design should take these interlinkages into account to leverage synergies and carefully navigate potential trade-offs. Here, we present quantitative scenarios that illustrate interactions between climate and clean air policies in Korea as a case study. We then reflect on the development of an integrated methodological approach to assess current trends and policy responses to the triple planetary crisis of climate change, biodiversity loss, and pollution.

JEL Codes: C68, D58, H23, Q53, Q54

Introduction

Climate change, biodiversity loss, and pollution are closely interlinked, as they share common drivers and affect each other in various ways at the local, national, and supra-national scale. The corresponding consequences can exacerbate each other, representing compound risks that may affect future health and economic prosperity. At the same time, scientific evidence suggests there are large synergies in tackling climate change, biodiversity loss, and pollution. For instance, climate change affects (the economic value of) ecosystems by shifting biomes (Bastien-Olvera et al., 2023); investing in nature (e.g. through payments for ecosystem services) can contribute to economic growth (Johnson et al., 2023); and the costs of policies to bring down greenhouse gas emissions can be offset by co-benefits for air pollution and the associated health outcomes (Vandyck et al., 2018). To leverage synergies and carefully navigate potential trade-offs, research calls for an integrated approach to assess and tackle multiple, interlinked environmental pressures (Leclère et al., 2020; Van Vuuren et al., 2019).

Here, we first present a case study for climate and clean air policies in Korea. Given the synergies between climate and air pollution, air quality policies have the potential to contribute to the climate transition. Indeed, some air pollutants such as black carbon (BC) and methane (CH_4) are also short-lived climate pollutants, therefore contributing to climate change. Further, several emission sources, such as the combustion of fossil fuels or the use of nitrogen fertilizers, lead to the emission of both air pollutants and greenhouse gases. Finally, many sectors are large contributors to both environmental pressures. For instance, road transport leads to emissions of carbon dioxide (CO_2) but also nitrogen oxides (NO_x) and BC; the iron & steel industry emits CO_2 as well as fine particulate matter ($PM_{2.5}$); and agriculture causes emissions of CH_4, nitrous oxide (N_2O) and ammonia (NH_3). Leveraging these synergies in policy design provides opportunities for ratcheting up climate ambition.

The model-based assessment aims at evaluating the contribution of air quality policies to the net-zero emission transition, focusing on the specific example of Korea. It highlights potential interactions between climate and air quality policies, relying on a model-based scenario analysis. Compared to previous work on the consequences of climate (PCCNGG, 2021) and air quality (Lanzi et al., 2022) policies, the contribution of this paper is to highlight the interactions between policies in the two domains.

Next, we present an analytical framework that enables consistent global modeling of environment-economy interactions across climate change, biodiversity loss, and pollution by coupling computable general equilibrium and integrated assessment models. The modelling toolbox will serve to derive an outlook of selected environmental pressures under a current-policy trajectory, revealing socio-economic and sectoral drivers of environmental pressures across world regions up to 2050. This current-policy baseline will then form the basis for an assessment of policy responses to meet international targets of climate change (Paris Agreement), biodiversity loss (Kunming-Montreal Global Biodiversity Framework), and pollution (WHO air quality guidelines and towards zero plastics pollution). Results will show spill-overs of thematic (i.e. separate) policies, and will illustrate how integrated action can outperform uncoordinated policy responses.

Climate and clean air policies in Korea

As a pilot study for the more comprehensive work to come, we present preliminary results on a subset of interactions with a narrower geographical scope: climate and clean air policies in Korea. The analysis relies on the OECD's global multi-region multi-sector model ENV-Linkages (Château et al., 2014). ENV-Linkages is a recursive-dynamic computable general equilibrium (CGE) model that describes economic activities in different sectors and regions and how they interact. It is based on the GTAP 10 database (Aguiar et al., 2019) and GTAP-Power satellite account (Chepeliev, 2020). In the model, Korea is isolated as a single country but linked through international trade to other countries and regions in the world. The model links economic activity to environmental pressures, including greenhouse gas emissions, air pollutants and materials.

To ensure a realistic representation of policy efforts, the analysis will exploit the ENV-Linkages modelling framework, which is able to represent both pricing and non-pricing policies to mitigate environmental externalities, e.g. carbon prices, changes in taxes and subsidies, regulations, emission standards, or green investment policies (Fouré et al., 2023). Using this range of policy instruments, this paper compares four scenarios at the 2050 horizon: a *Baseline* scenario reflecting currently enacted climate and air quality policies in Korea and the rest of the world, a *Net-zero emission (NZE)* scenario where Korea achieves carbon neutrality in 2050, an *Air quality* scenario with ambitious policies to improve air quality, and an *Integrated policies* scenario where ambitious air quality and climate change mitigation policies are implemented simultaneously. This set of scenarios will highlight interactions between air quality and climate mitigation policies. The scenarios assume that countries and regions other than Korea also implement ambitious climate and air quality policies in each scenario.

Net-zero emission (NZE) scenario. Governments have a wide array of policy instruments they can use to achieve emission reductions. This paper builds on previous OECD work on a global Net-Zero Emission scenario (Fouré et al., 2023) by focusing on six key policies to decarbonise the economy, which were chosen because (i) they cover all key sources of CO_2 emissions, and (ii) they contain some of the most widely used instruments by governments. The instruments considered are:

- Carbon pricing
- Fossil fuel support removal (FFSR)
- Regulations in the power sector to enforce a switch away from fossil fuels
- Regulations to stimulate investments to decarbonise building and transport emissions
- Policies to stimulate firms’ energy efficiency improvement
- Subsidies to reduce and decarbonise energy consumption by households.

This policy package is used to meet the climate goals as stated by the Korean government. The Korean climate mitigation policy is defined by two distinct milestones. First, Korea has submitted its Nationally Determined Contribution (NDC) to the UNFCCC registry for year 2030, and updated its content in 2021 (GOK, 2021). The 2030 milestone corresponds to a reduction in domestic greenhouse gas (GHG) emissions by 40% from the 2018 level, and to a decrease from 727.6 Mt CO_2eq in 2018 to 436.6 Mt CO_2eq. This target covers all main GHGs: carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbon (PFCs) and sulphur hexafluoride (SF_6). Korea is also part of the Global Methane Pledge and plans to reduce CH_4 emissions by at least 30% in 2030 compared to 2020 level.

Air quality scenario. A range of air quality policies are considered and reflected in the wide adoption of best available techniques (BATs) to control air pollution, with time horizon to 2050. Beyond introduction of the most stringent (achievable) emission limits for large scale stationary processes and combustion, road and non-road vehicles, medium and small-scale residential boilers, additional incentives (subsidies and emissions pricing) and regulations are assumed to assure steady improvement of energy and nutrient efficiency; the latter requiring more efficient application of organic and mineral nitrogen fertilizers resulting in reduction of ammonia and soil NOx emissions. Evaporative Non-Methane VOC (NMVOC) losses from storage and distribution of liquid fuels are reduced as well as emissions from solvent use, including wide application of low solvent or water-based products. For methane, key additional policies address venting emissions from fossil fuel (coal, oil, gas) production and distribution, development of efficient waste management system for industrial and municipal water and solid waste, reduction of emissions from rice production, and incentives to increase farm-based biogas production capacity. Introduction of these policies assures that the maximum technical mitigation potential is achieved in all sectors by 2050. Estimates of sector- and country-specific investments necessary to deploy BATs are obtained from IIASA's GAINS model (Amann et al., 2011), which was used to develop mid-term mitigation scenarios (Xing et al., 2011; Zhao et al., 2013; Rao et al., 2016; Amann et al., 2020). Furthermore, measures aim to reduce PM2.5emissions by -80% compared to 2019.

<u>Preliminary results</u>. While consequences on the climate system and air quality are derived by linking with the MAGICC climate model and the TM5-FASST air quality model, respectively, results displayed in Figure 1 focus on the change in emissions from two policy scenarios compared to the baseline. The current-policy Baseline reflects currently enacted climate and air pollution policies in Korea and the rest of the world. The net-zero emissions (NZE) climate scenario represents a future where Korea and the world achieve carbon neutrality in 2050 using a broad set of policy instruments. The air quality scenario implements ambitious policies to improve air quality through the adoption of best available techniques.

Preliminary results (Figure 1) show that the transition towards net-zero, using a broad range of policy instruments, significantly contributes to the abatement of air pollutant emissions in Korea. Most impacted pollutants are NO_x (-68% compared to Baseline), CO (-53%) and BC (-48%), and the two most important channels are the phasing out of the use of fossil fuels in road transport, as well as the reduction in power generation from fossil sources. This global NZE scenario also reduces air pollutant emissions worldwide in a similar manner, leading to strong co-benefits: premature deaths due to PM2.5 and ground-level ozone are reduced by 28% and 17% compared to Baseline, respectively.

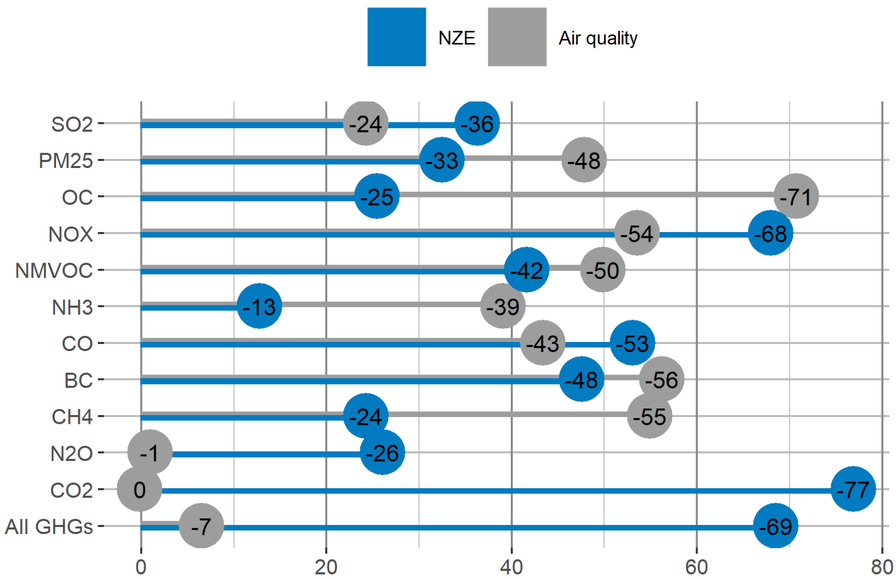

Figure 1. Changes in greenhouse gas and air pollutant emissions in 2050 in Korea, deviation from Baseline (%). Source: OECD ENV-Linkages model.

Similarly, the Air quality scenario exhibits co-benefits for the mitigation of greenhouse gas emissions. The adoption of best available reduces CH_4 emissions (-55%), and as such contributes to the mitigation of climate change (-7% GHG emissions in 2050). This contribution remains limited if the instruments used are restricted to end-of-pipe measures: alternative policy design, incentivizing a shift away from fossil fuels through pricing, also reduce CO_2 emissions and thus could help maximize the synergies across policy domains (Figure 2). As such, the contribution of air quality policies to climate change mitigation depends on the policy mix.

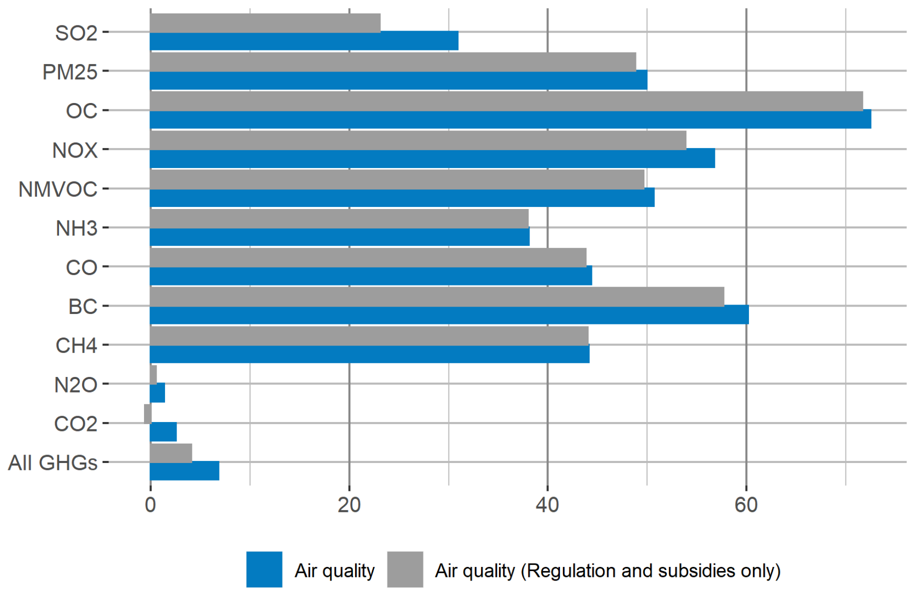

Figure 2. Changes in greenhouse gas and air pollutant emissions in 2050 in Korea under two alternative Air quality scenarios, deviation from Baseline (%). Source: OECD ENV-Linkages model.

The Integrated scenario combines air quality with climate change mitigation measures. Figure 3 illustrates that air quality measures reduce the carbon price required to meet climate objectives. Two variants of the NZE scenario are considered here: one that uses all instruments as discussed above, and one that only uses carbon pricing to reduce GHG emissions. Results indicate that carbon price reductions from clean air policies are larger when the climate policy mix has a stronger focus on non-price instruments. A further exploration of quantitative scenarios can shed more light on the role of price and non-price measures in integrated policy packages, contributing to the literature on optimal instrument choice.

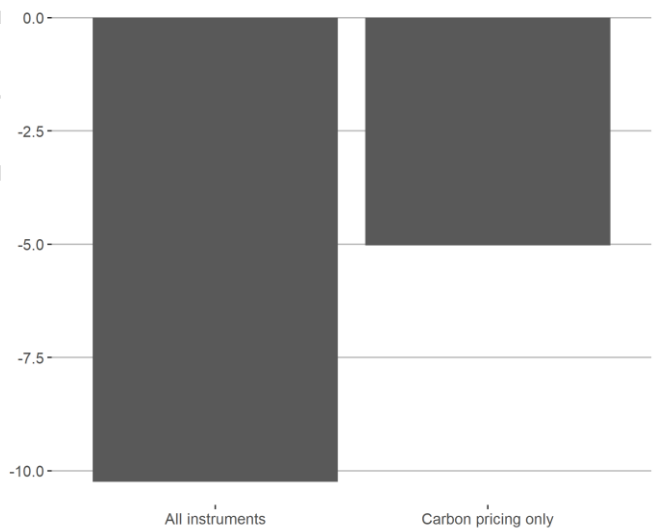

Figure 3. Change in carbon price due to air quality policies in two variants of the NZE scenario, 2050 (%). Source: OECD ENV-Linkages model.

Tackling the triple planetary crisis

To develop more comprehensive scenarios at the global level that look at the interactions across climate change, biodiversity loss, and pollution, we develop a modelling toolbox comprised of the OECD's ENV-Linkages model and PBL's IMAGE/GLOBIO model. Information on GDP and population growth and sectoral activity is passed on from the ENV-Linkages model to the integrated assessment model IMAGE/GLOBIO, and details on agriculture, land use and the energy system from the IMAGE/GLOBIO model serve as input into the ENV-Linkages model. Results will cover a range of environmental indicators from both models and (for a subset of these) the associated economic impacts (Dellink et al., 2019; Lanzi et al., 2018). Data updates, model developments and model linking are currently work-in-progress.

References

Aguiar, A., et al. (2019). The GTAP data base: version 10. *Journal of global economic analysis*, 4(1), 1-27.

Amann, M. et al. (2011), "Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications", Environmental Modelling & Software, Vol. 26/12, pp. 1489-1501, https://doi.org/10.1016/j.envsoft.2011.07.012.

Amann, M. et al. (2020), "Reducing global air pollution: The scope for further policy interventions: Achieving clean air worldwide", Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, Vol. 378/2183, https://doi.org/10.1098/rsta.2019.0331.

Bastien-Olvera, B. A., et al. (2023). Unequal climate impacts on global values of natural capital. *Nature*, 1-6.

Château, J., Dellink, R., & Lanzi, E. (2014). An overview of the OECD ENV-linkages model: version 3. OECD Working Paper.

Chepeliev, M. (2020), "GTAP-Power Data Base: Version 10", Journal of Global Economic Analysis, Vol. 5/2, pp. 110-137, https://doi.org/10.21642/JGEA.050203AF.

Dellink, R., Lanzi, E., & Chateau, J. (2019). The sectoral and regional economic consequences of climate change to 2060. *Environmental and resource economics*, 72, 309-363.

Fouré, J. et al. (2023), "Public finance resilience in the transition towards carbon neutrality: Modelling policy instruments in a global net-zero emissions", OECD Environment Working Papers 214, p. 76, https://doi.org/10.1787/19970900.

GOK (2021), The Republic of Korea's Update of its First Nationally Determined Contribution.

Johnson, J. A., et al. (2023). Investing in nature can improve equity and economic returns. *Proceedings of the National Academy of Sciences*, 120(27), e2220401120.

Lanzi, E., Dellink, R., & Chateau, J. (2018). The sectoral and regional economic consequences of outdoor air pollution to 2060. *Energy Economics*, 71, 89-113.

Lanzi, E. et al. (2022), The economic benefits of international co-operation to improve air quality in Northeast Asia, https://doi.org/10.1787/5c5ee1a3-en.

Leclère, D., et al. (2020). Bending the curve of terrestrial biodiversity needs an integrated strategy. *Nature*, 585(7826), 551-556.

PCCNGG (2021), Carbon Neutrality Scenarios, https://2050cnc.go.kr/eng/contents/view?contentsNo=42&menuLevel=2&menuNo=49.

Pörtner, H. O., et al. (2023). Overcoming the coupled climate and biodiversity crises and their societal impacts. *Science*, 380(6642), eabl4881.

Rao, S. et al. (2016), "A multi-model assessment of the co-benefits of climate mitigation for global air quality", Environmental Research Letters, Vol. 11/12, p. 124013, https://doi.org/10.1088/1748-9326/11/12/124013.

Van Vuuren, D. P., et al. (2019). Integrated scenarios to support analysis of the food–energy–water nexus. *Nature sustainability*, 2(12), 1132-1141.

Vandyck, T., et al. (2018). Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. *Nature Communications*, 9(1), 4939.

Xing, J. et al. (2011), "Projections of air pollutant emissions and its impacts on regional air quality in China in 2020", Atmospheric Chemistry and Physics, Vol. 11/7, pp. 3119-3136, https://doi.org/10.5194/acp-11-3119-2011.

Zhao, B. et al. (2013), "NOx emissions in China: historical trends and future perspectives", Atmospheric Chemistry and Physics, Vol. 13/19, pp. 9869-9897, https://doi.org/10.5194/acp-13-9869-2013.