

Coronavirus Pandemic: Opportunities or Challenges for Energy Transition?

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Abstract

The coronavirus pandemic greatly shocked the global energy market, which could be clearly demonstrated by the recent collapse in crude oil prices. Using a dynamic multi-regional computable general equilibrium model, we explored the influences of the COVID-19 pandemic on energy production and consumption. The associated impacts on the macroeconomy as well as on carbon emissions are also examined. The results of this paper indicate dramatic negative shocks of the COVID-19 pandemic to energy consumption at both global and national levels, particularly for oil and oil products. However, the energy transition to renewables will be paused, as other non-oil fossil fuels can still play significant roles in economic activity. The epidemic may also temporarily terminate the more than ten-year increasing trend of the world's total CO₂ emissions, despite its limited contribution to the mitigation of global warming. However, there are still many opportunities worthy of use to promote short- or mid-term low-carbon energy transitions.

Introduction

The outbreak of COVID-19 has become the largest crisis in the world since World War II, and there is little doubt that the world has entered a global economic recession. Currently, there are more than 5.33 million confirmed cases and 339,467 deaths worldwide, and the situation is still worsening (JHU, 2020). The impact of this pandemic is dramatic: cities and countries are on lockdown, factories and stores are shut down, and bars and schools are closed (Acuto, 2020). The astonishing shutdown of economic activity due to COVID-19 has decreased energy use, as occurred during every recession in history. The 2008 financial crisis and the great recession that followed had profound effects on the energy sectors throughout the world, decreasing the price of crude oil from approximately

\$150/bbl. to \$35/bbl. in only a few months. The economic data from the first quarter of 2020 show that COVID-19 struck the world economy more heavily than expected. For instance, China's first quarter GDP decreased by 6.8% (below the 6% consensus) when compared to the same period last year, which was the worst single quarter since comparable data began to be published in 1992. Industrial output decreased by 1.1% in March compared to a 13.5% decline over January and February. At the same time, retail sales fell by 15.8% following a 20.5% collapse in the first two months of the year. Fixed asset investments decreased by 16.1% in the first quarter compared to a 24.5% drop in January and February. The IMF projects that the global economy will sharply decrease by -3% in 2020 due to the

COVID-19 pandemic, much worse than that during the 2008 financial crisis. According to the International Energy Agency (IEA), the global oil demand will decrease for the first time in a decade during the first quarter of 2020. It can be expected that the impacts of this pandemic on the energy sector could be much worse than the 2008 financial crisis. Does this pandemic represent an opportunity or challenge for energy transition that has been promoted throughout the world? To answer this question, we quantitatively investigate what the COVID-19 pandemic implies for energy consumption, output, trades and carbon emissions across regions.

Input–output (IO) models have been widely used to examine the effects of economic crises or policies in response to crises. For instance, David et al. (1995) used a 10-sector input–output model of the UK to simulate the effects of a variety of policy issues related to energy use and environmental impacts. Using an input-out model, Bekhet and Yasmin (2014) assessed the influence of the global financial crisis on Malaysia’s trade and energy consumption and analysed the effect of the government’s stimulus plan for economic revival. However, the IO models fail to consider the optimization or adjustments that the economy can reach on its own in response to the crisis. Computable general equilibrium (CGE) models have the benefits of enabling active adjustments by consumers, producers, or policy makers, and thus, they have been used to generate insights into the impacts of economic crisis (e.g., see Anderson & Strutt, 1999; McKibbin et al., 2001; Siriwardana & Iddamalagoda, 2003).

The globalization of the world increases the dependence of the economy on trade, and thus, one of the main effects the coronavirus pandemic has would be on the supply chain and international trade. To this end, it would be valuable to include a trade module when modelling the impact of the pandemic on the global economy and energy consumption. The static version of the Global Trade Analysis Project (GTAP) model has also been previously used to model the financial/economic crisis (e.g., see Jongwanich et al., 2009; Strutt, 2009). Willenbockel and Robinson (2009) used a multi-country, multi-sector model named GLOBE to assess the impact of the financial crisis on world prices and trade in developing countries. Jonwanich et al. (2009) analysed the impacts of economic slowdown in OECD countries on developing Asia in 2009–2010 using the GTAP model. Stutt and Walmsley (2009) employed the GDyn model, which is based on the GTAP model, to explore the effects of economic slowdown, with a particular focus on trade and sectoral impacts. In this paper, we use the GDynE model, a dynamic version of the GTAP-E model, to see how the COVID–19 pandemic has affected the energy transition in different countries, where the model allows the substitution among energy, labour and capital, which is different from the GDyn model and particularly useful to simulate the substitution effect of energy and primary factors when the labour force was decreased due to the epidemic.

We find that the COVID–19 pandemic will lead to a dramatic reduction in this year’s energy consumption for all regions/countries, especially China and the US. The oil and oil product industries are the most affected energy sectors in all regions, and it is ominous that the decrease in oil in the energy consumption portfolio has not been taken over by renewable/non-fossil electricity, but instead coal and natural gas. In contrast, the pandemic plays a limited role in improving the energy structures. At the same time, this pandemic will generally lead to an observable shrinkage in global energy trade, which is a result of the substantial shrinkage of energy demand.

In summary, the COVID–19 pandemic does not provide much opportunity for the world’s clean and sustainable energy. In other words, to boost the economy, countries may loosen their efforts or standards for clean energy use. Additionally, it is unlikely that the pandemic will benefit the worsening climate change situation in the long run, and the lessons learned from the 2008 financial crisis indicate that the emissions will retaliatorily rebound after the drop.

Main Text

Impact analysis of the COVID–19 outbreak on energy transition

As the COVID–19 outbreak has become a global pandemic, the change in one country's economic loss and energy consumption not only depends on the development of the epidemic but also closely relates to the prevention policies and measures taken by other countries. And the empirical analysis was conducted with the dynamic version of the GTAP-E model (GdynE, Burniaux and Truong, 2002; Hertel, 1997). To assist our research, the 141 regions in the original database are merged into 7 categories, namely, China, USA, Japan, South Korea (SKorea), the European Union (EU), Middle East & North Africa (MES) and the rest of the world (ROW). And with uncertainties surrounding the future development of the epidemic, this study considers three policy scenarios, Base-case scenario, Optimistic scenario, and Pessimistic scenario, respectively. In addition, given that our dynamic CGE model based on GDynE is essentially an optimization model, its results can be viewed as the best way that the world economy can react to COVID–19 shocks, as well as changes in energy. The detailed methodology description is presented in the Appendix.

Impacts on energy consumption

Energy demand has been dramatically reduced due to the COVID–19 pandemic, despite a significant increase in residential energy loads (Rajvikram et al., 2020). Oil and oil products are most affected by COVID–19 in terms of energy consumption, and this phenomenon has already been demonstrated by the recent price crash in the WTI. In the Base-case scenario, the decreases in the consumption of oil and oil products are 4.21% and 4.71% in China, 2.83% and 3.12% in the United States, 1.62% and 2.31% in Japan, 4.42% and 4.30% in South Korea, and 2.28% and 2.31% in EU_28, while the decreases in the consumption of coal and gas are 1.16% and 2.07% in China, 0.83% and 2.17% in the United States, 0.74% and 0.50% in Japan, 2.97% and 3.34% in South Korea, and 0.89% and 1.21% in EU_28 (Fig. 1). It is ominous that the decrease in oil in the energy consumption portfolio has been taken over not only by non-fossil electricity but also by coal and gas. This phenomenon is not only true in China (the share of coal and gas in the energy consumption portfolio has been increased by 0.56 percentage points compared to the 2020 projection, while the share of non-fossil electricity has been increased by 0.21 percentage points) but also in other regions (in the United States, the share of coal and gas in the energy consumption portfolio has been increased by 0.18 percentage points compared to the 2020 projection, while the share of non-fossil electricity has been increased by 0.18 percentage points; in Japan, the share of coal and gas in the energy consumption portfolio has been increased by 0.25 percentage points compared to the 2020 projection, while the share of non-fossil electricity has been increased by 0.13 percentage points; in EU_28, the share of coal and gas in the energy consumption portfolio has been increased by 0.18 percentage points compared to the 2020 projection, while the share of non-fossil electricity has been increased by 0.15 percentage points). In addition, the situation of higher share penetration of coal and gas than that of non-fossil electricity will also occur in the Pessimistic scenario. From the results, it can be seen that the shock

of COVID–19 will not only reduce the energy demands but also make non-oil fossil fuels penetrate more shares in the energy consumption portfolio, which is a setback against the efforts in the development of renewable and new energy in the past decades. Although the magnitudes of the share changes are slight, these changes greatly show that the energy consumption is still built on fossils. If the pandemic continues, the threat to renewable and new energy may increase.

The changes in output among domestic energy sectors vary across the regions. The MES region intends to increase the output of gas to fight against the shock of COVID–19 on the domestic economy (in the Base-case scenario, the gas production (in physical quantity) in the MES will be increased by 2.02% compared to the 2020 projection, and this number will be further increased to 2.34% in the Pessimistic scenario). In China and EU_28, the total decreases in fossil energy output are all larger than that in non-fossil electricity output (in the Base-case scenario, the decreases in the output of fossil energy in China and EU_28 are 1.90% and 1.91% compared to the 2020 projection, respectively, while the decreases in the output of non-fossil electricity are 1.14% and 0.66%, respectively (Fig. 2); in the Pessimistic scenario, the decreases in the output of fossil energy in China and EU_28 are 2.29% and 1.90% compared to the 2020 projection, respectively, while the output decreases of non-fossil electricity are 1.61% and 0.75%, respectively). However, if we look into the total decrease in coal and gas and exclude oil and oil products, the numbers are 0.90% and 0.42% for China and EU_28 in the Base-case scenario and 1.29% and 0.01% (a positive increase) in the Pessimistic scenario compared to the 2020 projection, respectively. From the results, it can be found that the decreases in coal and gas are all smaller than the decreases in non-fossil electricity in China and EU_28. In addition, one exception is the United States. Due to the decrease in gas output, the decrease in the output of non-fossil electricity is smaller than that of coal and gas in both the Base and Pessimistic scenarios (the decrease in coal and gas output in the United States is 3.00% and 4.15% in the Base-case and Pessimistic scenarios compared to the 2020 projection, while the decreases in non-fossil electricity output are 0.74% and 1.05%, respectively).

The large decrease in non-fossil electricity output makes it seem that renewable and new energy has been left behind with the shock of the pandemic. On the one hand, new and renewable energy is capital intensive, and the costs of such energy are higher than those of fossil fuels worldwide if externalities are not taken into consideration. The government needs to provide a given number of fiscal budgets to integrate such energy into the energy system. With the spreading of COVID–19, such a budget can be easily moved to support other sectors that are labour intensive to maintain social stability. On the other hand, to recover the economy, energy and energy-intensive sectors can play significant roles with consideration of their scale and employment. If the government has to choose, it will drop the emission control or renewable development targets but rebound fossil energy production after the shock of COVID–19, which also makes the development of new and renewable energy vulnerable during the economic crisis.

Impacts on global energy trade

COVID-19 will almost certainly cause a great shrinkage in global energy trade (Fig. 3a-3c). The total energy trade will be reduced by 2.20% in the Base-case scenario compared to the 2020 projection (in which the total trade of coal, oil, gas, and oil products are reduced by 1.62%, 2.70%, 1.62%, and 2.16%, respectively, compared to the 2020 projection in the Base-case scenario), and the numbers of energy trade reductions are 1.85% and 2.55% in the Optimistic and Pessimistic scenarios (in which the total trade of coal, oil, gas, and oil products are reduced by 1.27%, 2.36%, 1.17%, and 1.85%, respectively, compared to the 2020 projection in the Optimistic scenario, while the numbers are 1.98%, 3.03%, 2.07%, and 2.48%, respectively, in the Pessimistic scenario). The United States, China, and the EU will significantly reduce their energy imports (in the Base-case scenario, the reductions in energy imports compared to the 2020 projection are -2.47%, -4.06%, and -1.99% in the United States, China, and the EU, respectively, meanwhile such numbers are -3.05%, -4.49%, and -2.23% in the Pessimistic scenario). The energy exports in the ROW region, but not the MES, will be most affected (in the Base-case scenario, the reductions in energy exports compared to the 2020 projection are -0.57% and -2.64% in the MES and ROW regions, respectively, while such numbers are -0.60% and -3.07% in the Pessimistic scenario). Several scholars have discussed the “secondary impacts” associated with the pandemic, which mainly refers to employment and polarization of wealth within a country or region. Globally, COVID-19 has reduced the demands by major countries (also the major energy consumers) on energy, and this has caused a decrease in energy production in the ROW region. This decrease is not only a concern on trade, but also can be viewed as an “energy secondary impact” to the ROW region. In addition, the MES is also affected by COVID-19, but its energy exports to the EU and Japan have slightly increased, and this would also occur in the Pessimistic scenario (in the Base-case scenario, the MES’s energy exports to EU_28 and Japan have increased by 0.18% and 1.63% compared to the 2020 projection, respectively, while such numbers are 0.17% and 1.97% in the Pessimistic scenario). As a major energy exporter, the endowment of oil and gas in this region has provided a cost advantage in oil and gas production, which helped such regions fight against the impacts resulting from COVID-19.

The regions with resource endowments will increase their exports under the shock of COVID-19. China will increase the export of coal, and MES will increase its export of natural gas (in the Base-case scenario, China will increase its export of coal by 2.00% compared to the 2020 projection, and the number will be 1.75% in the Pessimistic scenario (Fig. 4); meanwhile, the MES region will increase its export of gas by 4.77% and 5.74% in the Base-case and Pessimistic scenarios, respectively). As we discussed above, both regions have cost advantages in terms of coal and gas. The shrinking coal demand in China’s domestic market will also push the export of coal. All of the exports of energy sources (coal, oil, and gas) in the United States have been reduced, especially natural gas exports (in the Base-case scenario, the reductions in the exports of coal, oil, gas, and oil products are -5.75%, -2.73%, -12.44% and -1.73% compared to the 2020 projection, respectively, while such numbers are -8.44%, -3.11%, -17.96%, and -2.32% for coal, oil, gas, and oil products, respectively). Although the United States has the largest shale gas capacity in the world, the production cost is much higher than that of natural gas in the MES region. The abroad demand for shale gas exists only when the natural gas price is high and the supply is somewhat limited.

When the demand falls, the price of natural gas can be easily cut, while this is not possible for shale gas. The United States has lost its energy abroad market under the shock of COVID-19.

Impacts on CO2 Emissions

It seems that COVID-19 can reduce CO2 emissions given that the shock decreased the emissions among the regions. In the Base-case scenario, the CO2 emissions among regions decreased from 1.42% to 2.31% (Fig. 5), in which the United States will be most affected (compared to the 2020 projections). However, the magnitudes of the changes in CO2 emissions are smaller than those of GDP (e.g., the decreases in GDP and CO2 emissions are 2.39% and 2.31% in the United States, while the numbers are 2.61% and 1.69% in China), except in the MES region (the decreases in GDP and CO2 emissions are 1.30% and 1.77%, respectively). And the results of macro-economic shocks are presented in Appendix A3. As depicted in Fig. 6, such decoupling of GDP and CO2 emissions will be even worse in the Pessimistic scenario; the decreases in GDP and CO2 emissions are 4.32% and 2.83% in the United States, while the numbers are 3.54% and 2.10% in China, even the decrease in GDP in the MES region will be higher than the decrease in CO2 emissions (2.13% compared to 1.93%). It can be inferred that the spreading of the pandemic is slowing global actions related to CO2 emissions reduction. Aside from the MES region, to implement isolation measures, governments need to ensure that residents have a stable energy supply, and energy suppliers would prefer fossil fuels instead of intermittent renewables. On the one hand, fossil fuels will become less expensive as demand decreases; on the other hand, emissions pressure can also be eased due to the shutdown of factories and commercial facilities.

The decoupling of GDP and CO2 emissions will result in an increase in energy and carbon intensities among most of the regions compared to that in 2019 in all scenarios except the Optimistic scenario, under which the small impacts of COVID-19 set by the model resulted in the decrease in the energy and carbon intensities, except for the energy intensity in South Korea (a 0.28% increase compared to the 2020 projection) and the carbon intensity in China (a 0.41% increase compared to the 2020 projection). Actually, the Optimistic scenario is to a great extent in accordance with the situation in early March, when the epidemic had not spread to the EU_28 and the United States. However, such a situation may not be realistic given the unexpected rapid spread of COVID-19. Despite the increases in both the Base-case and Pessimistic scenarios, the changes in energy intensities are not in accordance with the changes in carbon intensities. In China, the change in carbon intensity is larger than that of energy intensity (0.94% versus 0.19% in the Base-case scenario and 1.49% versus 0.72% in the Pessimistic scenario), while it is smaller in Japan (0.57% versus 0.93% in the Base-case scenario and 1.59% versus 1.95% in the Pessimistic scenario), as shown in Fig. 7. It is interesting that the MES region will show trends of decreases in energy and carbon intensities in both the Base-case and Optimistic scenarios (-0.18% and -0.48% in the Base-case scenario, and -0.83% and -1.14% in the Optimistic scenario), and it increases slightly in the Pessimistic scenario (0.49% and 0.20% in the Pessimistic scenario). Given that the MES region is highly reliant on the oil and gas industry, the decreases in energy and carbon intensities in the Base-case and Optimistic scenarios have already been discussed above.

Conclusions

In this paper, we investigated the impact of the COVID–19 pandemic on the global energy system by employing the GTAP model, and the differences in shocks across regions are also explored. The shocks to the energy system due to the pandemic are closely related to its shocks to the world economy, which are direct results of the spread of the novel virus, city lockdowns and strict social-distancing measures. We find a significant impact of the outbreak on the economy, and this effect is especially severe for developed countries; as for the whole globe, the outbreak may decrease the economy by 2.1% under the Base-case scenario, and this decrease could be further increased to 3.4% if a more serious epidemic situation appears.

The COVID–19 pandemic will lead to a dramatic reduction in this year’s energy consumption for all regions/countries, especially China and the US. The oil and oil product industries are the most affected energy sectors in all regions, and it is ominous that the decrease in oil in the energy consumption portfolio has not been taken over by non-fossil electricity, but instead coal and gas. In contrast, the pandemic plays a limited role in energy structures, which implies that the influence of the epidemic on the energy system should be short term. At the same time, we can observe a relatively weak impact of the COVID–19 outbreak on renewables, and such negative effects in China and the US are only approximately 1%. However, it is still difficult to determine whether the epidemic is an opportunity or challenge for future energy transitions from fossil fuels to renewable fuels. The large blows to the global oil market seem to provide an opportunity for energy restructuring and the potential large-scale substitution of renewables for conventional energy, but our results show only the relatively weak impacts of the pandemic on renewables, which may be due to their minor roles in the current energy structure, and this could not lead to the conclusion that the epidemic is beneficial to the development of renewables.

COVID–19 will lead to an observable shrinkage in the global energy trade, especially for the ROW regions, which could be well understood from the substantial shrinkage of energy demand. In fact, this is not a pure trade issue but should be viewed as an “energy secondary impact” to the ROW regions. Furthermore, the outbreak also shocked the energy trades in the MES, despite its exports to the EU and Japan encountering a slight increase. As a major energy exporter, the endowment of oil and gas in this region has made it competitive in terms of oil and gas production, which helps to hedge against the potential risks associated with COVID–19.

The pandemic has paused the key increases in carbon emissions. According to the chair of the Global Carbon Project, the world may welcome its first dip in carbon emissions since the 2008 financial crisis, with the expected fall to be 4–7% (Le Quéré et al., 2020). In fact, we are not optimistic about the decrease, despite the dramatic decreases in the observable carbon emissions in China and the whole world in the first quarter, and this situation should be changed in the coming quarters. In fact, the magnitude of the decline in carbon emissions is smaller than that of GDP, implying an increase in carbon intensities among these regions, i.e., the spreading of the pandemic is slowing down the global efforts for CO₂ emission reductions, and fossil energy plays a more formidable role in tackling this public health emergency event.

It is of low probability that the COVID–19 pandemic will benefit the worsening climate change situation, since the short-term decrease in CO₂ emissions plays a negligible role in the cumulative carbon contents and atmospheric CO₂ concentration; most importantly, the lessons from the 2008 financial crisis show that the emissions will retaliatorily rebound after the crisis. However, the carbon fall associated with the outbreak enhances the causality between human activities and carbon emissions, and most importantly, we should take effective measures to hedge against the risk of future coronavirus shocks and make use of opportunities for short- or mid-term energy restructuring (Steffen et al., 2020) and changes in energy consumption modes and lifestyles that benefit long-term low-carbon energy transitions.

Declarations

Competing interests: The authors declare no competing interests.

References

1. Acuto, M., 2020. COVID-19: Lessons for an urban(izing) world. *One Earth*, 2(4): 317-319.
2. Anderson, K., & Strutt, A. (1999). Impact of Easter Aisa's Growth Interruption and Policy Responses: The Case of Indonesia. *Asian Economic Journal*, 13(2), 204-218.
3. Bekhet, H. A., & Yasmin, T. (2014). Assessment of the global financial crisis effects on energy consumption and economic growth in Malaysia_ An input–output analysis. *International Economics*, 140(C), 49–70.
4. Burniaux, J.M., & Truong T. (2002). GTAP-E: An Energy-Environmental Version of the GTAP Model. GTAP Technical Paper No. 16. Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.
5. Duan, H. B., Wang, S. Y., & Yang, C. H. (2020). Coronavirus: Limit the short-term economic damages. *Nature*, 578(7796): 512.
6. Golub, A., 2013. Analysis of Climate Policies with GDyn-E, GTAP Technical Papers No. 32. Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.
7. Hertel, T.W., 1997. *Global Trade Analysis: modeling and applications*. Cambridge University Press.
8. Ianchovichina, E., McDougall R., 2000. Theoretical Structure of Dynamic GTAP. GTAP Technical Paper No. 17, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.
9. Jongwanich, J., James, W.E., Minor, P.J., & Greenbaum, A., (2009). Trade Structure and The Transmission of Economic Distress in the High-Income OECD countries to Developing Asia.
10. JHU. Coronavirus COVID-19 Global Cases by the Center for Systems Science and Engineering at Johns Hopkins University (JHU), 2020. Access at: <https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html?from=singlemessage&isappinstalled=0#/bda7594740fd40299423467b48e9ecf6>.

11. Klemes, J. J., Fan, Y. V., Tan, R. R., & Jiang, P. (2020). Minimising the present and future plastic waste, energy and environmental footprints to COVID-19. *Renewable and Sustainable Energy Reviews*, 127: 109883.
12. McDougall R., Golub A., 2007. GTAP-E: A Revised Energy-Environmental Version of the GTAP Model. GTAP Research Memorandum No. 15, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.
13. McKibbin, W. J., Wang, Z., & Coyle, W. (2001). The Asian Financial Crisis and Global Adjustments: Implications for US Agriculture. *The Japanese Economic Review*, 52(4), 471-490.
14. McKibbin, W., Fernando, R. The Global Macroeconomic Impacts of COVID-19: Seven Scenarios. CAMA Working Paper 19, 2020.
15. Le Quéré, C., Jackson, R. B., Jones, M. W., Smith, A. J. P., Avernethy, S., et al., 2020. Temporary reduction in daily global CO₂ emissions during the COVID-19 forced confinement. *Nature Climate Change*, <https://doi.org/10.1038/s41558-020-0797-x>.
16. Rajvikram, M., Shafiullah, G. M., Kannadasan, R., Vijay, R., et al. (2020). COVID-19: Impact analysis and recommendations for power and energy sector operation. *Energy Xiv: Sustainability of Energy Systems*.
17. Siriwardana, M., & Iddamalgotda, A. (2003). Effects of the Asian Economic Crisis on Singapore and Its Policy Responses: A General Equilibrium Analysis. *UNEAC Asia Papers*, 6 2003.
18. Steffen, B., Egli, F., Pahle, M & Schmidt, T. S. (2020). Navigating the clean energy transition in the COVID-19 crisis.
19. Joule, <https://doi.org/10.1016/j.joule.2020.04.011>.
20. Strutt, A. (2009). Some Impacts of a Global Slowdown: A Comparative Static CGE Analysis.
21. Strutt, A., & Walmsley, T. (2009). Trade and Sectoral Impacts of the Global Financial Crisis: A Dynamic CGE Analysis.
22. Verikios, G., Sullivan, M., Stojanovski, P., Giesecke, J., Woo, G. Assessing regional risks from pandemic influenza: A scenario analysis. *The World Economy*, 2015, 39(8): 1225-1255.
23. Willenbockel, D., & Robinson, S. (2009). The global financial crisis, LDC exports and welfare: Analysis with a World Trade Model.

Figures

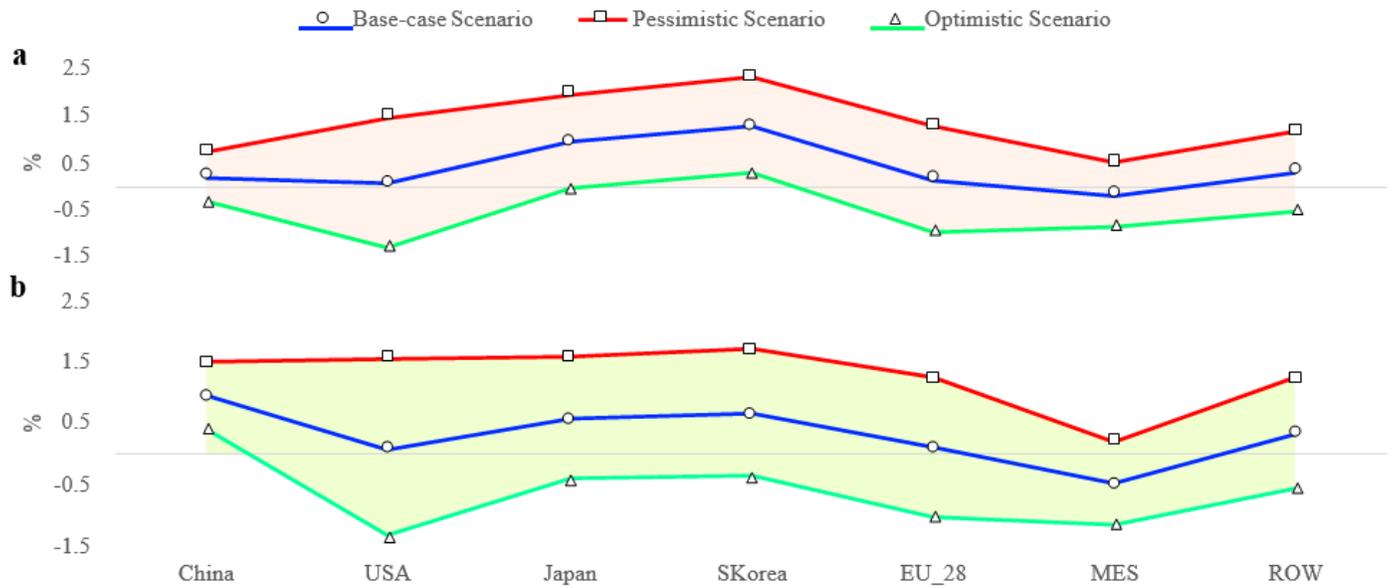


Figure 1

Cross-regional decreases of energy intensity (a) and carbon intensity (b) given the shocks of COVID-19 pandemic (banded with light pink and blue, respectively). Note: The vertical axis gives the percentage change in energy intensity and carbon intensity relative to the 2020 projections.

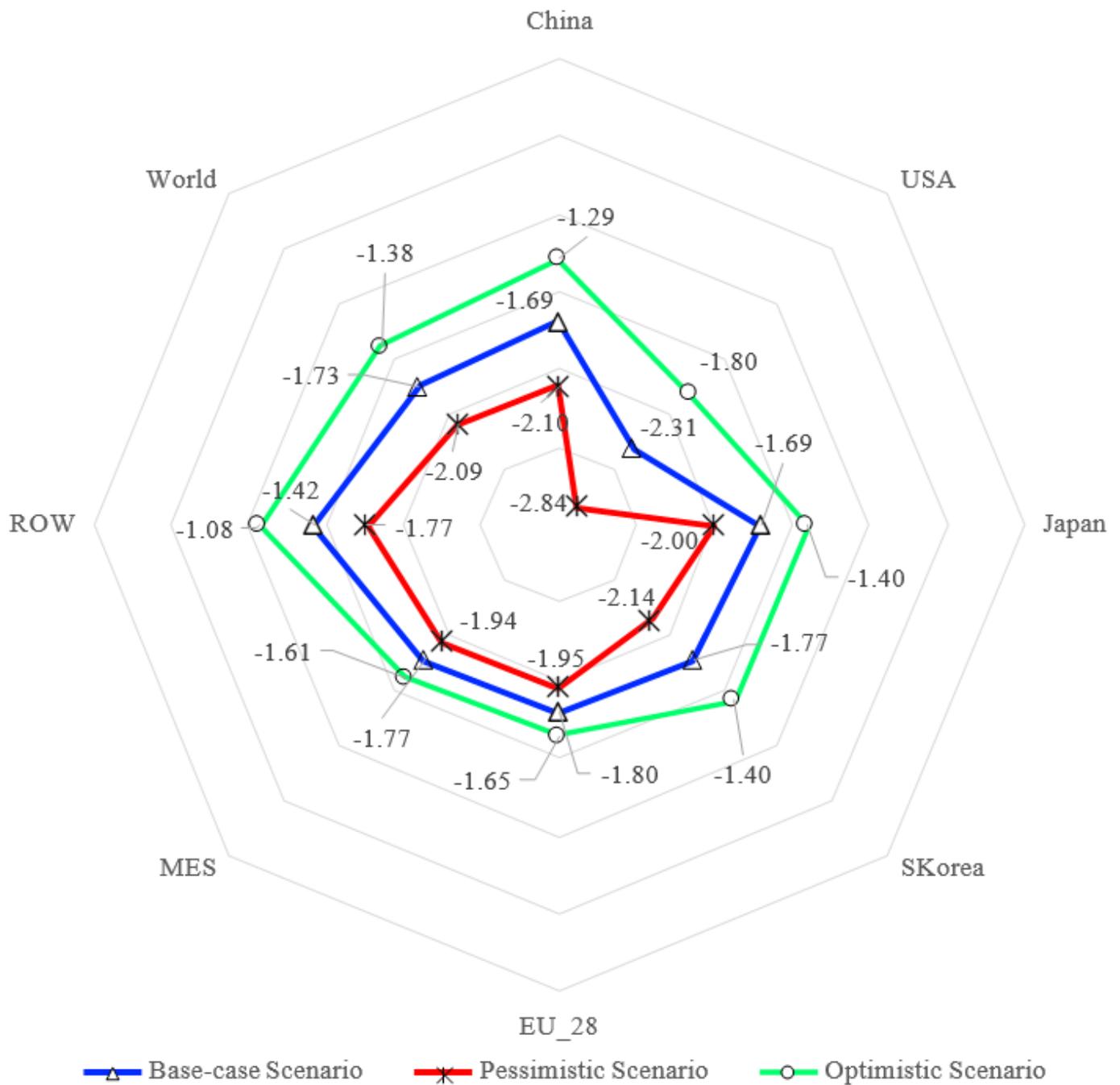


Figure 2

The impact of the COVID-19 outbreak on carbon emissions across regions under different scenarios. Note: These impacts are measured by percentage changes in carbon emissions relative to the 2020 projections

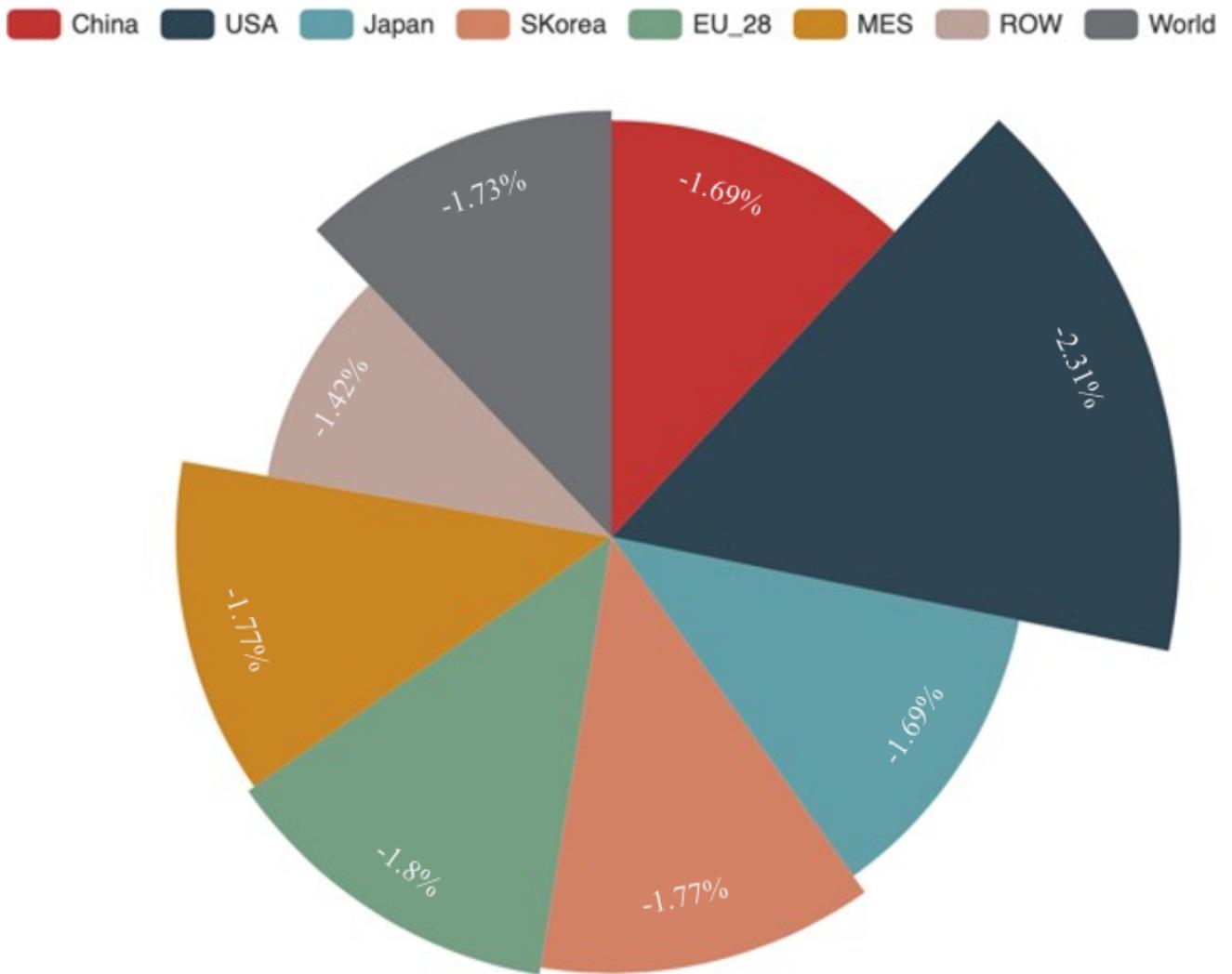


Figure 3

The impact of the COVID-19 outbreak on carbon emissions across regions under the Base-case scenario. Note: These impacts are represented by percentage changes in carbon emissions relative to the 2020 projections

		Base-case Scenario						Pessimistic Scenario						Optimistic Scenario								
		China	USA	Japan	SKorea	EU_28	MES	ROW	China	USA	Japan	SKorea	EU_28	MES	ROW	China	USA	Japan	SKorea	EU_28	MES	ROW
Coal	China		0.2	2.4	1.0	0.5	0.2	0.8		0.2	2.3	0.5	0.5	0.2	0.7		0.1	2.6	1.4	0.5	0.2	0.9
	USA	-2.3		-1.9	-2.6	-23.0	-16.7	-8.4	-3.2		-2.9	-3.6	-34.1	-23.9	-12.9	-1.4		-0.9	-1.6	-12.4	-9.8	-4.1
	Japan																					
	SKorea																					
	EU_28					-12.0	-0.5	-0.4	-0.1				-13.7	-0.5	-0.5					-10.2	-0.4	-0.3
	MES	0.1				0.2	0.2	0.1					0.2	0.2	0.1	0.1				0.2	0.2	0.2
	ROW	-639.3	-0.7	-87.8	-262.3	-97.8	-41.5	-259.0	-735.6	7.1	-122.0	-296.8	-99.6	-42.5	-385.7	-545.3	-7.5	-53.6	-227.9	-95.1	-40.2	-133.4
Oil	China						0.1							0.1								0.2
	USA	-0.1		-0.6	-5.6	-1.8	-0.3	-39.7	-0.1		-0.7	-6.0	-1.9	-0.3	-45.7	-0.1		-0.6	-5.2	-1.8	-0.3	-35.1
	Japan																					
	SKorea																					
	EU_28	-2.8	-0.6		-6.1	-44.2	-0.1	-1.3	-2.8	-0.7		-6.2	-40.3	-0.1	-1.2	-2.7	-0.6		-6.0	-47.6	-0.1	-1.3
	MES	-854.7	-96.2	-128.6	-498.1	11.1	-10.6	52.4	-915.1	-147.1	-155.6	-534.7	16.7	-11.0	17.8	-795.8	-44.3	-102.1	-461.6	6.0	-10.2	87.7
	ROW	-998.1	-963.7	-131.6	-185.4	-1231.1	-124.7	-628.4	-1082.0	-1161.8	-148.7	-201.1	-1335.6	-135.4	-728.3	-916.9	-766.0	-115.0	-170.1	-1129.1	-114.3	-530.6
Natural gas	China		1.7	0.1	0.1	5.0	0.4	35.4		1.9	0.1	0.1	5.4	0.4	38.5		1.5	0.1	0.1	4.7	0.4	32.6
	USA	-1.3		-25.5	-6.4	-233.0	-27.7	-375.2	-1.8		-36.6	-8.6	-330.9	-37.5	-550.1	-0.8		-15.2	-4.4	-142.1	-18.4	-213.0
	Japan																					
	SKorea																					
	EU_28		-1.1	-0.1	-0.1	-51.9	-1.0	-2.9		1.8			-4.8	-0.4	2.1	-0.1	-3.6	-0.2	-0.1	-95.4	-1.6	-7.5
	MES	7.8	50.3	196.3	16.1	297.6	66.9	282.5	9.0	62.6	228.3	25.9	349.1	83.7	345.6	6.8	39.2	166.0	6.9	248.7	50.9	224.2
	ROW	-209.5	-53.2	-234.4	-168.2	-638.6	-260.8	-169.2	-261.5	-69.7	-298.6	-194.1	-773.3	-305.4	-196.5	-159.1	-30.2	-172.1	-143.2	-506.1	-217.4	-138.3
Oil products	China		-3.5	-9.9	1.2	-11.8	-15.8	-63.0		-5.1	-12.4	-2.6	-14.2	-17.2			-1.9	-7.4	5.0	-9.4	-14.2	-34.5
	USA	-9.5		-13.4	-0.4	-85.0	-44.4	-182.4	-11.7		-17.3	-2.2	-107.0	-50.5	-258.8	-7.4		-9.8	1.4	-64.8	-38.8	-112.1
	Japan	-2.7	-0.7		0.7	-0.2	-0.7	-5.3	-3.0	-1.0		0.1	-0.2	-0.7	-5.6	-2.5	-0.5		1.3	-0.2	-0.7	-4.9
	SKorea	-120.0	-43.6	-122.8		-25.2	-8.7	-381.8	-123.1	-46.3	-126.9		-25.5	-8.7	-386.4	-117.0	-40.7	-118.8		-25.0	-8.7	-376.8
	EU_28	-2.6	-35.4	-0.8	-0.1	-300.7	-84.0	-55.1	-2.8	-45.3	-1.0	-0.5	-322.6	-86.0	-62.2	-2.3	-25.5	-0.7	0.4	-278.5	-82.1	-48.0
	MES	-19.4	-5.5	-34.8	14.1	-36.2	-72.0	-15.6	-21.8	-8.1	-41.4	6.3	-37.9	-71.8	-21.8	-17.2	-2.9	-28.4	21.7	-34.4	-72.3	-9.2
	ROW	-49.1	-169.8	-33.9	-3.1	-269.3	-138.1	-249.2	-56.2	-221.7	-40.1	-9.3	-303.2	-146.7	-299.3	-42.3	-118.4	-27.9	2.9	-236.2	-129.7	-199.9

Figure 4

Energy trades across regions under the three scenarios (104 ton oil equivalent). Note: The gray blanks show that the relative impacts are zero or approximate to zero.

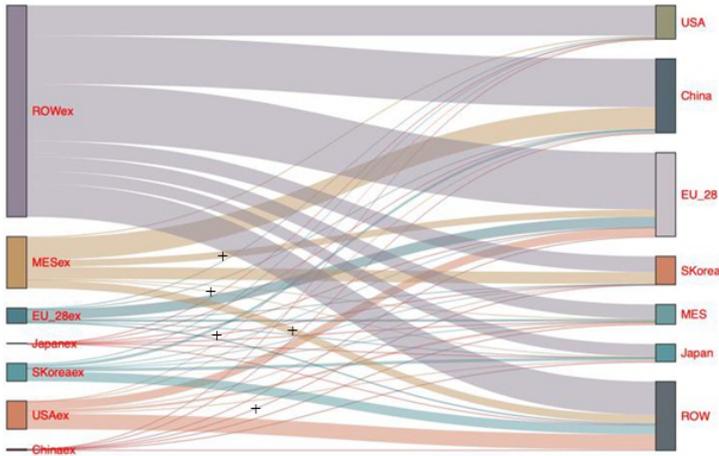


Figure 3a|Exports of total energy across regions under the Base-case scenario.

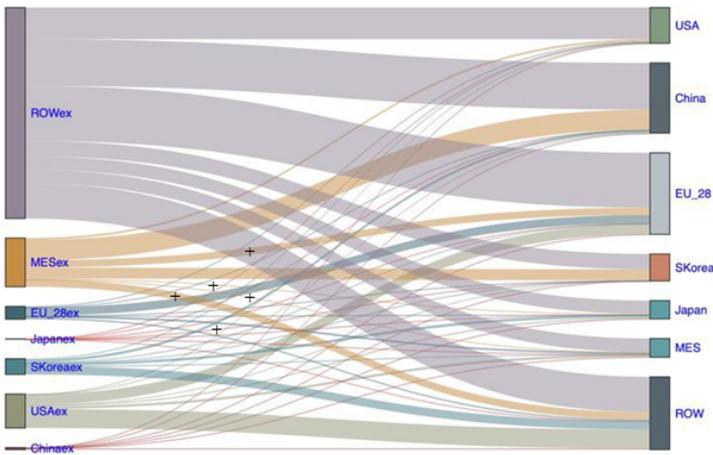


Figure 3b|Exports of total energy across regions under the Pessimistic scenario.

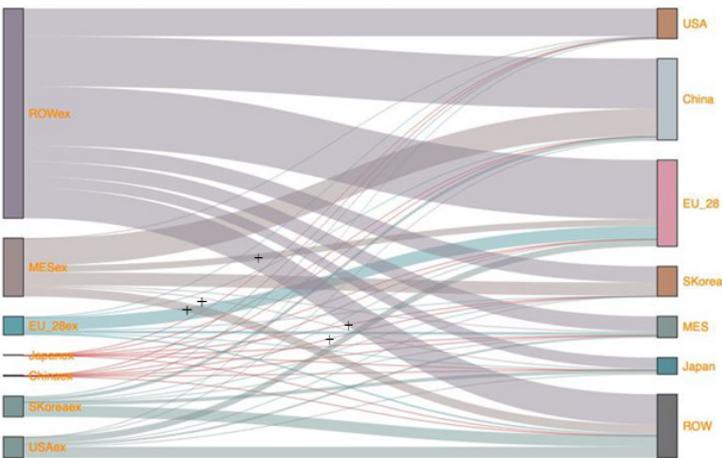


Figure 3c|Exports of total energy across regions under the Optimistic scenario.

Figure 5

a|Exports of total energy across regions under the Base-case scenario. b|Exports of total energy across regions under the Pessimistic scenario. c|Exports of total energy across regions under the Optimistic scenario. Note: The region names with 'ex' mean energy exports from those regions. The flows are negative (i.e., the exports are declining given the shock of the COVID-19), except those with sign '+'. The unit of energy trade is 104 tons of oil equivalent (toe).

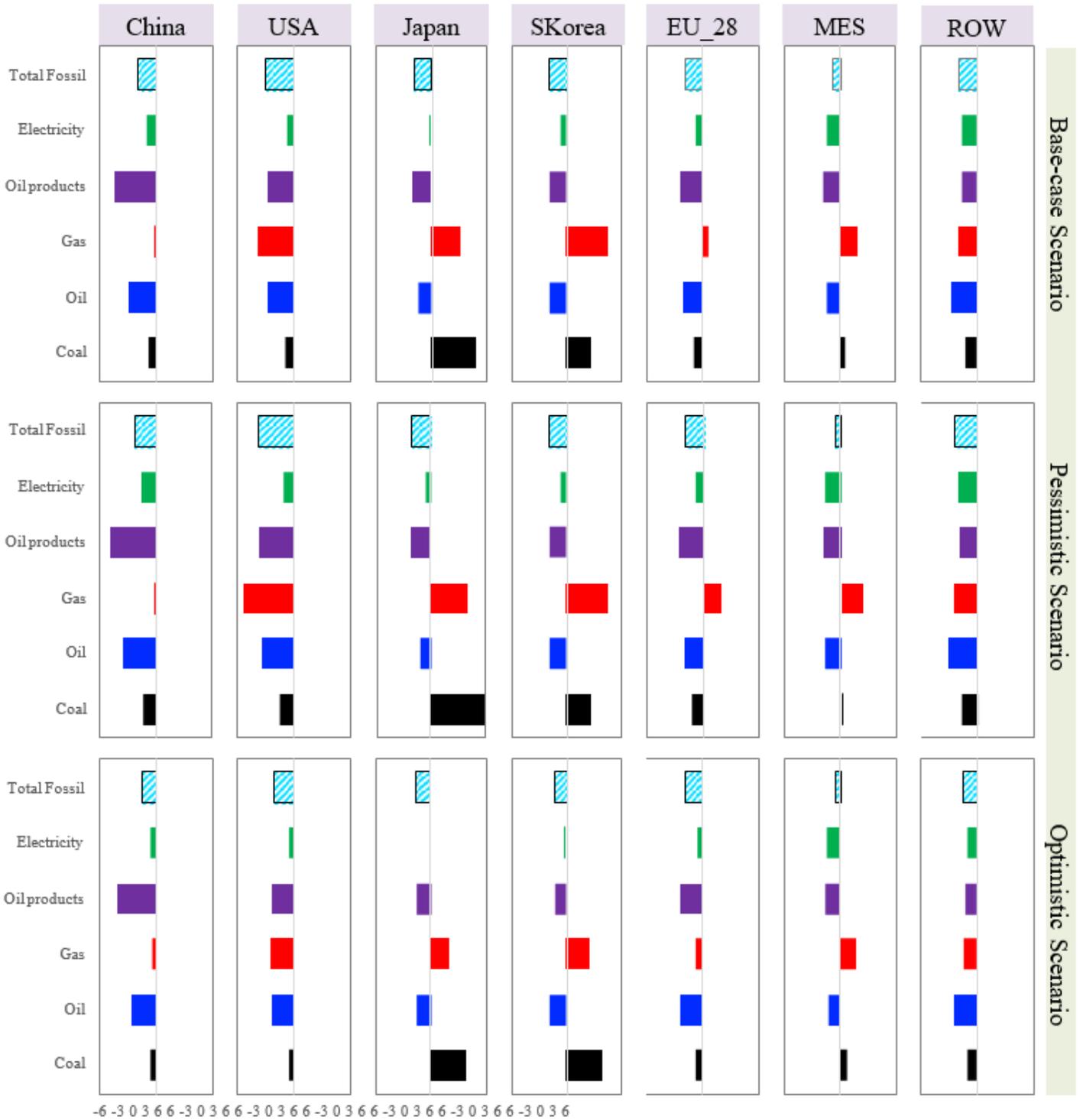


Figure 6

The impact of the novel virus outbreak on output of different energy sectors under three policy scenarios. Note: The vertical axis shows 5 energy sectors, electricity here mainly refers to non-fossil energy sector; the horizontal axis gives the percentage change in output relative to the 2020 projection.

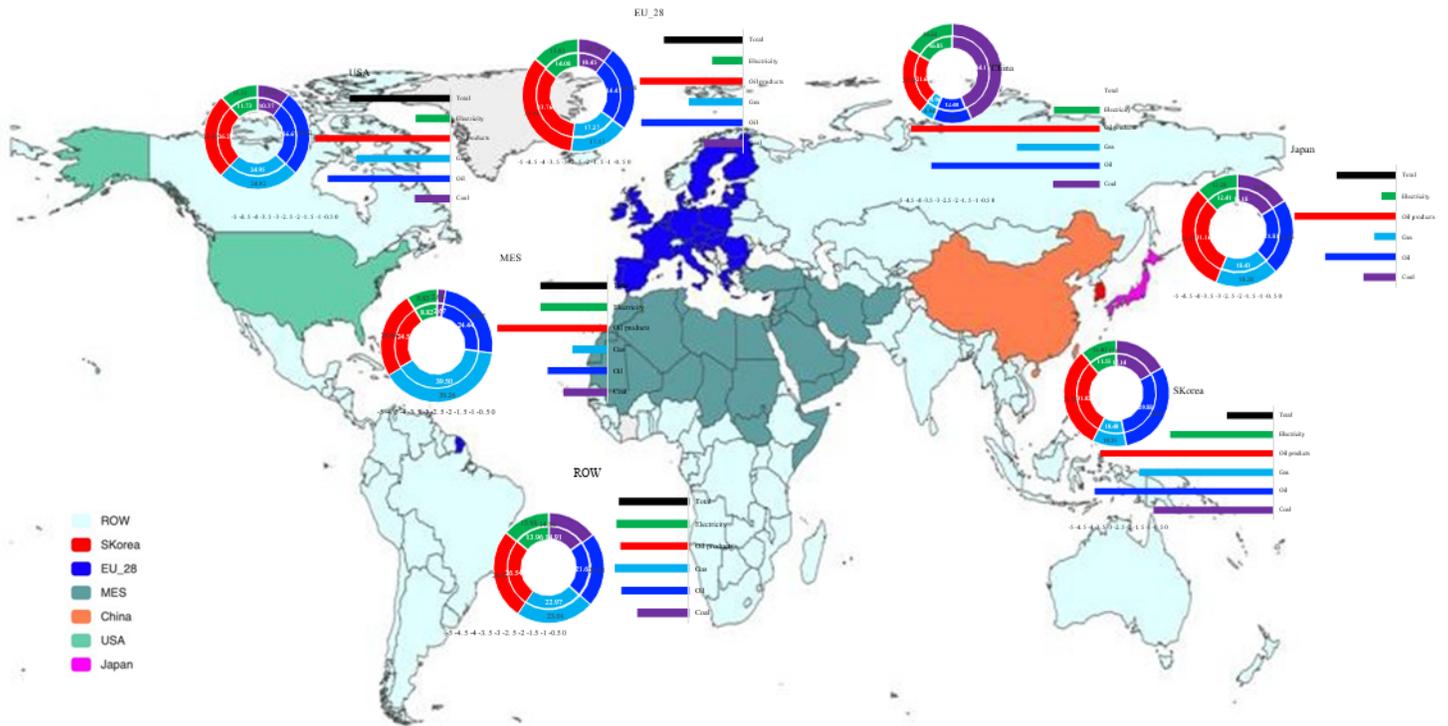


Figure 7

Cross-regional shocks of the COVID-19 outbreak on energy consumption under the Base-case scenario. Note: The world map portrays the region divisions of this work, and the bars show the impacts of the outbreak on consumption of different energy technologies and the total (percentage changes relative to no outbreak case). The doughnut charts give the changes in energy structure without (the outside doughnut) and with (the inside doughnut) the shocks of the COVID-19 outbreak. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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