COVID-19 underscores the urgency of just transition alongside green recovery

Yaxin Zhang
State Key Joint Laboratory of Environment Simulation and Pollution Control (SKLESPC), School of Environment, Tsinghua University https://orcid.org/0000-0002-9533-1472

Xinzhu Zheng
China University of Petroleum, Beijing

Huilin Luo
State Key Joint Laboratory of Environment Simulation and Pollution Control (SKLESPC), School of Environment, Tsinghua University

Can Wang (canwang@tsinghua.edu.cn)
Tsinghua University https://orcid.org/0000-0002-1136-792X

Article

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COVID-19 underscores the urgency of just transition alongside green recovery

Yaxin Zhang[1,#], Xinzhu Zheng[2,#], Huilin Luo[1], Can Wang[1,*]

1. State Key Joint Laboratory of Environment Simulation and Pollution Control (SKLESPC), School of Environment, Tsinghua University, Beijing 100084, China
2. School of Economics and Management, China University of Petroleum, Beijing 102249, China

# These authors contributed equally to this work
* Corresponding to C. Wang (canwang@tsinghua.edu.cn)

Abstract

Green recovery has been highly advocated as a promising strategy to balance climate actions and economic reset after COVID-19. However, the potential inequality risk associated with the green recovery hasn't been fully assessed. Here, enabled by an extended adaptive regional input-output (E-ARIO) model, we quantify the short-term impacts of COVID and various recovery packages on labor demand and income equality. The findings reveal that in the pandemic, low- and medium-income labor suffered more income decrease (by 36%) than those with high-level income (by 24%), leading to a 24% increase of income inequality at the global level (measured by the Oshima coefficient). The high-income labor benefits more from a low-carbon pathway to economic recovery, which further exacerbates the income inequality across the world by 3~5% compared to those in a traditional, carbon-intensive recovery scenario. The findings reveal the tradeoffs between income equality and green development and underscore the urgency of just transition alongside green recovery.

Main

COVID-19 adds unprecedented health and economic challenges to the existing poverty and inequality in the world. The pandemic is aggravating economic divisions, which, in turn, worsens the negative effect of the crisis. On the one hand, the poor and the vulnerable are more likely to suffer income loss from distancing measures and economic recessions. This is because these people's work is usually labor-dependent (such as planting and construction) or require face-to-face contact with others (e.g., accommodation and restaurant service), which makes it less likely to work remotely from home[1]. According to the World Bank's report[2], COVID-19 put 71 million people into extreme poverty in the baseline scenario, and the number reaches up to 100 million in a downward scenario. On the other hand, economic inequality weakens the societies' resilience to pandemics since it acts as a multiplier on the virus' spread speed and mortality rate[3]. People with lower socioeconomic status have to continue working in an environment with a higher level of exposure to the virus and have less access to preventive protection[4]. If, unfortunately, infected by the virus, they have higher rates of death due to unaffordable health care costs and the accompanying chronic diseases associated with poverty[5,6]. The self-reinforce feedback loop reveals the necessity and urgency of protecting the poor and the vulnerable after the COVID-19 pandemic[7].

Meanwhile, the pandemic knocked climate change down the agenda. COVID-19 has striking similarities with climate change because both are irreversible, spreading across country borders, exerting uneven impacts among people, and less costly to prevent than to cure[8,9]. However, huge differences exist as well: the pandemic occurs anytime with rapid expansion and direct cause-effect relationships, while climate change is a slow process with ambiguous and controversial attributes[8]. Such difference might lead to a viewpoint that the current world should prioritize battling COVID, improving health, restoring jobs, and stabilizing the economy over climate change mitigation[10,11]. However, others argue that the urgent need for economy reboot doesn't mean a delay in climate change mitigation but underscores the necessity to accelerate the process[12]. How governments spend billions of fiscal recovery money in recent years will determine the trend of climate change in the next few decades. The committed emissions of carbon-intensive investments in post-COVID-19 economic recovery might jeopardize the Paris Agreement goals because of the carbon "lock-in" effect of infrastructure[13]. Consequently, it is vital to make the right decisions to tackle the compound climate risks in the pandemic.

Green recoveries are called for as a solution to balance climate actions with economic recovery. Researchers have pointed out that green investment not only benefits the environment but also flattens the economic curves and creates job opportunities[14-16]. The multiplier effects of green recovery packages on economic reboots and job creation can be competitive, or even superior to, traditional carbon-intensive stimulus pathways[17]. The advocacy of green recovery and the focus on the possibilities of the co-benefits dominates current discussions on economic reset, leaving the potential risks overshadowed. The asymmetric information description and delivery might cause biased perception and improper decision making.

One of the potential risks associated with green recovery is its impacts on social equity[18]. It has been widely acknowledged that low-carbon transition will bring about structural changes in labor demand and possible risks of 'structural unemployment'[19,20]. The transition needs a painful period where low-skilled labor and people whose livelihoods depend on fossil fuel energy suffer wage reductions and unemployment, exacerbating social inequality at the time. Later, with the improvement of production efficiency and the continuous absorption of unemployed labor by other sectors, social inequity will be alleviated. Although social justice considerations are not novel, the pandemic fundamentally changes its nature, and the scale of the equity challenge remains unclear. The pandemic has reduced society's tolerance for the duration and extent of the challenging period. Any further deterioration can become the last straw that breaks the camel's back. Therefore, we need to rethink and comprehensively assess how green recovery packages affect social equity after the pandemic. Policymakers need to know who is most affected by the pandemic, to what extent these groups benefit from recovery policies, and how to avoid stark inequality while rebooting the economy.

This research addresses the social equity concern and reveals the severe structural weakness of green recoveries belied in the win-win potentials of economic growth and green development. Enabled by an extended adaptive regional input-output (E-ARIO) model, we quantify the short-term impacts of COVID and various recovery packages on social equity through the changes in income and labor demand. The findings demonstrate that the pandemic has an uneven impact on the labor market, with more negative impacts on lower-skilled and lower-income groups but less on high-skilled and higher-income groups. The less affected population, however, receives more assistance in green recovery plans compared to those in traditional recovery plans, leading to an increase in global income inequality. The findings highlight the importance of just transition alongside green recovery and provide new insights for developing green recovery strategies.

Who suffers the most from the pandemic recession?

Although most people's life and work have been negatively affected by the pandemic, low- and medium-skilled labors are more affected than those higher-skilled ones (Fig.1). Globally, more than 86% of the reduced labor demands are low- and medium-skilled workers, who account for 83% of the global labor market (Fig.1a). Due to the decrease in labor demand, the average income of low- and medium-skilled workers decrease by more than 32%, 6% higher than the decrease rate of the average income of high-skilled workers (Fig.1b). Assuming that the unemployment risk is proportional to the reduction of labor demand, the unemployment risks faced by low- and medium-skilled workers in the pandemic are about 1.2 times that of high-skilled workers.

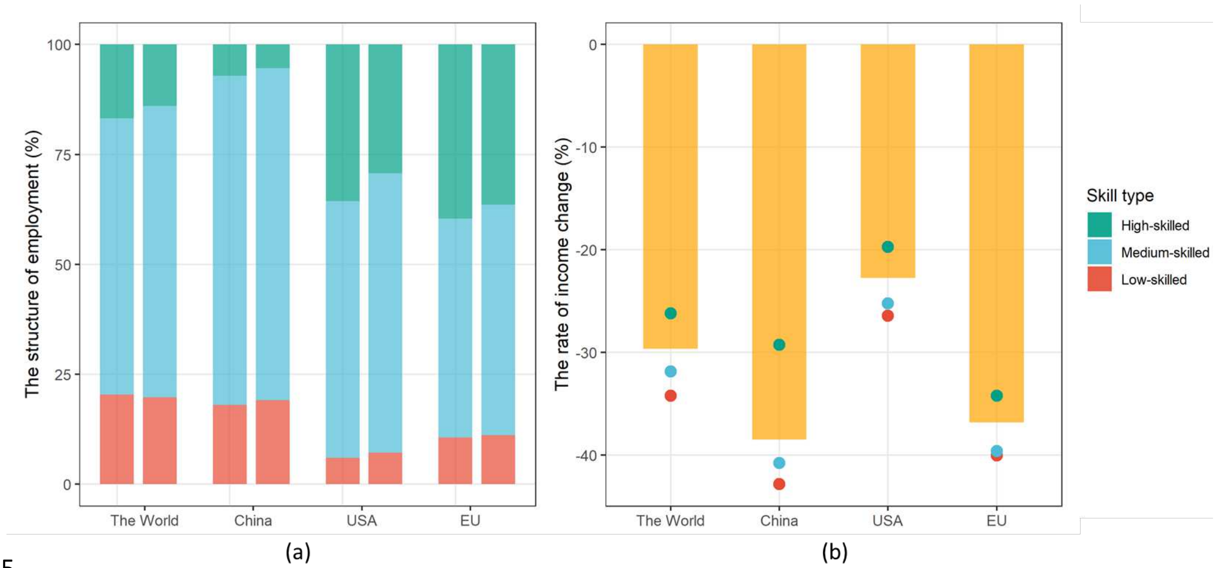

Fig.1 The impacts of COVID-19 on labor demand and average income. Graph (a) shows the structure of the labor force in each region in the initial situation (left bars) and the structure of the labor force affected by the COVID-19 lockdown (right bars). Graph (b) describes the income change of different skill groups (displayed as points) and the average level (displayed as bars) in each region in the lockdown period.

At the national scale, the uneven impacts of the pandemic on the labor market are also evident, albeit with a different extent across countries. In China, the average income of low- and medium-skilled workers, who account for 95% of the labor demand reduction, decrease by more than 41%. In contrast, the average income of high-skilled workers only decreases by about 29%. The unemployment risks that low- and medium-skilled workers faced is 1.3 times those of high-skilled ones. In the United States (USA), 71% of the reduced labor demand is low- and medium-skilled, who account for 6% and 58% of the labor market, respectively. The average income of the low- and medium-skilled workers decrease by about 26% in the pandemic while the figure for high-skilled workers is less than 20%. As for the EU, low- and medium-skilled workers account for 64% of the reduced labor demand, of whom the average income loss is about 40%, 16% higher than high-skilled workers.

The most affected industries at the global level are low- and medium-income ones, whose employees have limited ability to resist the impacts (Fig.2). Before the COVID, 26% and 38% of the global industries are low- and medium-income industries, and 36% are high-income (see more details of the sector classification by income level). Among the industries with a substantial decline in average income (the decline rate is more than the sectorial average), 36% are low-income industries, 46% are middle-income industries, and 18% are high-income industries. The average wage of the low- and medium-income industries decreased by 36%. In particular, low-income agriculture industries, including fruit and vegetable planting, cereal grains planting and farming, suffer particularly heavy losses due to the shutdown of the transportation industry and downstream processing industry. The average income of this industry decreased by 41%, from 117 Euros per month to 69 Euros per month. On the contrary, high-income industries, including the healthcare industry and medical, precision and optical instruments manufacturing industry, are less affected, with a 3.4~6.2% decrease in the average income.

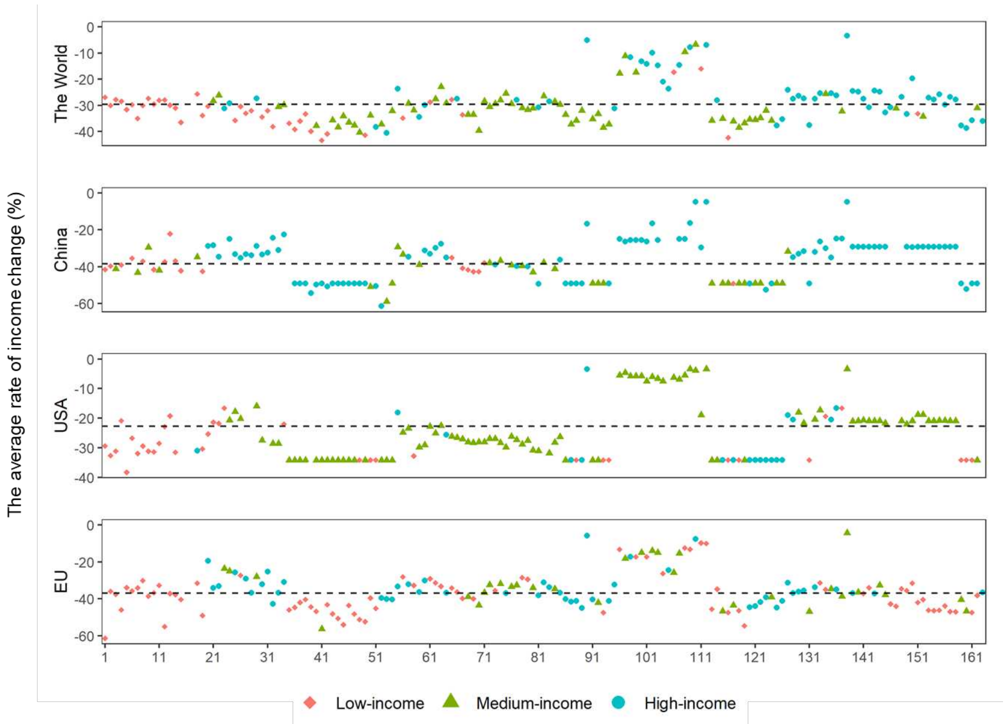

Fig.2 The impacts of COVID-19 on income by sectors. The list of the sectors (indicated by the numbers on the horizontal axis) is provided in the Supplementary Information (SI) Table S2.

At the national level, the situations distinct across counties (Fig.2). In China, 61% of the low-income industries suffer substantial income decrease (higher than the average level of income decrease) while the proportion is only 34% for high-income industries. In the EU, the average wage of low- and medium-income industries decrease by 40% while that of high-income industries decrease by 34%. The situation is slightly different in the USA, where high-income industries suffer as many negative impacts as low- and medium-income industries. About 77% of the low-income industries, 54% of the middle-income industries, and 68% of the high-income industries in the USA went through substantial income decrease.

Such results imply that the pandemic has an uneven impact on the labor market, with more negative impacts on low- and medium-income groups. The finding implies that the pandemic may exacerbate income inequality. After calculating the Oshima coefficients (a measurement of income equality) in countries, we find that this implication is supported at the global scale, but the situations vary across countries. For example, the Oshima coefficients increase by 24% at the global level, increase by 16% and 29% in China and the EU, but decreases by 4% in the USA. The decrease in the USA, which implies slight elimination in income equality, is more or less out of expectation[4]. The contradictory result might be explained that our estimation only captures the impacts of COVID on income equality through lockdown measures on labor supply and consumer demand. Other influencing channels on inequality, including unaffordable economic burden brought by the access to healthcare, healthcare spending and overcrowded housing conditions[4], are not included in our estimation, which might underestimate the income inequality in the pandemic.

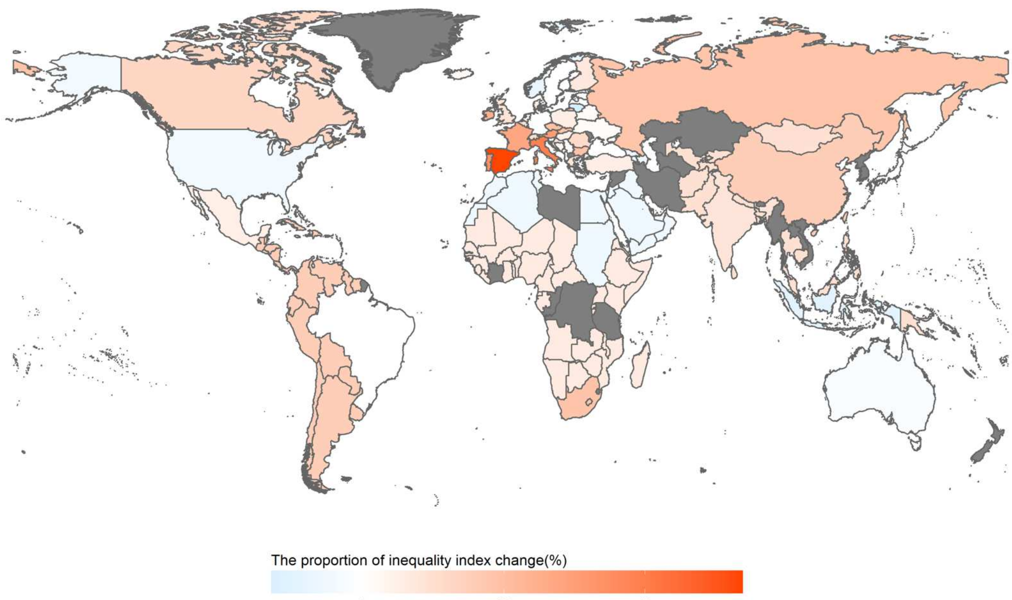

Fig.3 The impacts of COVID-19 on income equality

Who will benefit more from a green recovery?

We designed four scenarios to simulate the impacts of economic recovery policy packages on economic growth and labor demand (see more details in the Methods). The four scenarios are the business as usual scenario (BAU), traditional scenario (TES), low-carbon scenario (LCS), and low-carbon and digital scenario (LDS). The results reveal some common implications across the world.

First, green recovery plans show comparable or even better multiplying effects on economic growth and labor demand compared to the traditional scenarios (Fig.4). A stimulus package equal to 10% of national GDP drives a 10%~14% increase of GDP under the three stimulating scenarios. The differences in economic stimulus between traditional recovery and green recovery are less than 0.2%. Regarding the impacts on employment, differences are minor too. The LCS scenario creates 164 million jobs, and the LDS scenario creates 179 million jobs, which are respectively 7% lower and 2% higher than the TES scenario. At the national scale, we receive similar findings but to a different extent. For example, in the USA and EU, green recovery plans in LDS show substantial advantages over the TES scenario with regard to job creation while such advantages are moderate in China. In the USA and EU, additional jobs created in the LDS scenario is about 1.3 times than those in the TES scenario. Nevertheless, in China, additional jobs created in the LDS scenario is only 3% higher than the TES scenario.

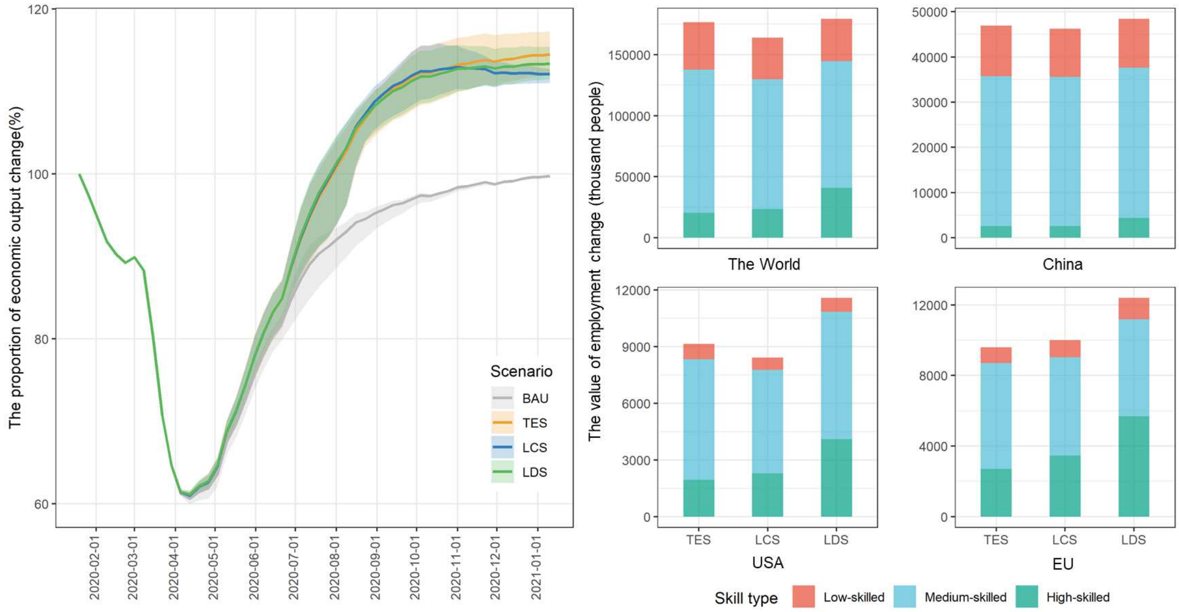

Fig.4 Impacts of recovery scenarios on economic growth and employment demand. BAU represents business-as-usual scenario. TES represents traditional recovery plan. LCS represents low-carbon recovery plan. LDS represents low-carbon and digital recovery plan.

The second similarity shared by most of the countries is that high-skilled workers benefit more from green recovery compared to traditional recovery plans. On the global scale, high-skilled workers account for 23% of the additional job creation in the LDS scenario, which is 11% higher than that in the TES scenario. At the national level, the proportion of high-skilled jobs in total job demand increase in the LDS scenario is 4%, 14%, and 18% higher than that in the TES scenario in China, the USA, and the EU, respectively. The benefits of green recovery on high-skilled workers are also apparent from the perspective of income change. In the LDS scenario, the income of high-skilled works is 5% higher than that in the TES scenario, while the difference between these two scenarios for low- and medium-skilled workers are imperceptible.

At the sectoral level, the TES scenario favors three sectors whose job demands are most affected by the pandemic: the construction industry, mining of copper ores and concentrates industry, and the land transport industry. In this scenario, the average revenues in these three sectors decrease by 37%, 46%, and 26%, respectively. The LCS and LDS scenarios favor the sector of telecommunication and education, which are affected less in the pandemic. These two sectors account for an increase of 14~16 million new jobs in the green recovery scenario. However, the most affected sectors, including the industries of fruit and vegetable planting and hotels and catering, only create 5~8 million new jobs. As the nature of job changes, about 120 million people worldwide (4% of the initial state employment) may need a career transition.

In general, economic recovery offset some adverse effects of the pandemic on income inequality. However, compared with the TES scenarios, the LCS and LDS scenarios generally increase income equality. On the global level, the Oshima coefficients in LCS and LDS scenarios increase by 3~5% compared to the TES scenario. This is consistent with the observation that LCS and LDS scenarios provide more benefits for high-skilled workers and high-income sectors compared to TES scenarios. At the country level, this finding is also valid, albeit with some exceptions. For example, in the EU and the USA, the TES brings more inequality than LCS and LDS, which can be explained by the limited pulling effect of TES scenarios on job creation.

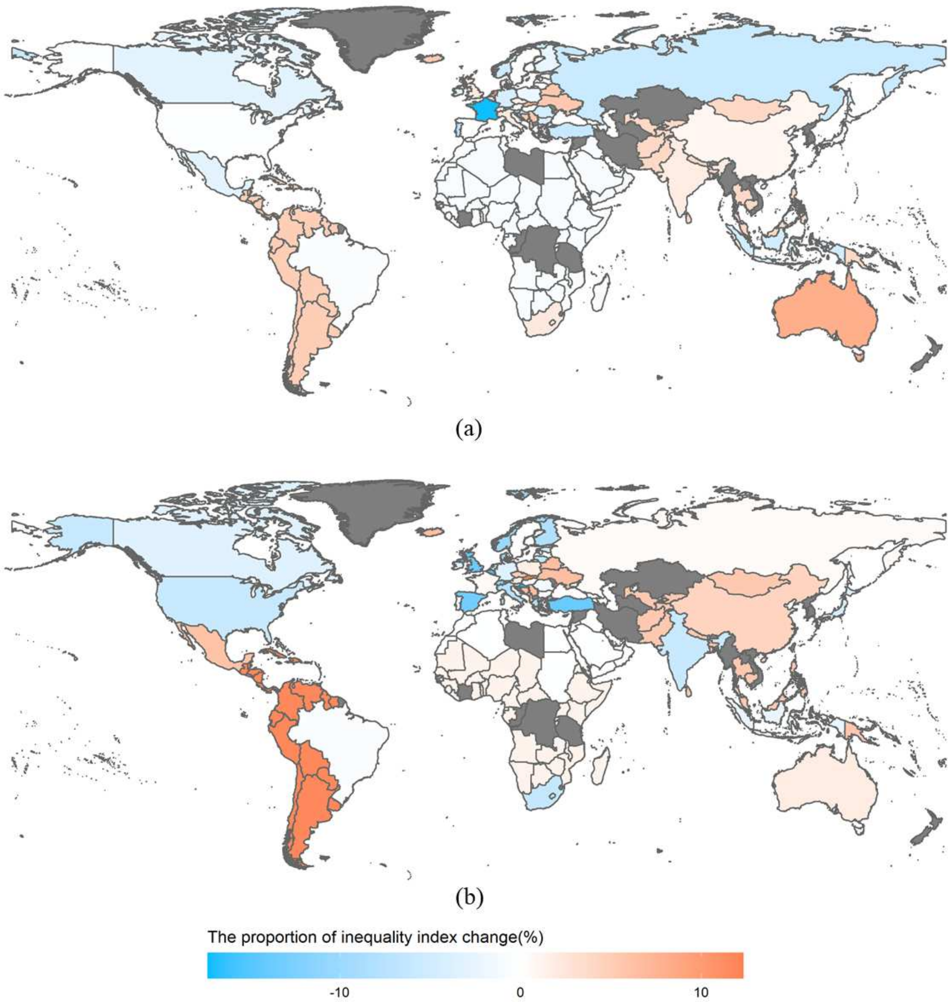

Fig.5 Oshima coefficient of green recovery scenarios compared to TES scenario

What actions are needed to fill up the mismatch?

Beyond existing concerns that COVID-19 might hinder the progress of climate change mitigation and green recovery shall be considered in the post-COVID, our analysis exerts further concerns on the low-income and the vulnerable who might be ignored in the green recovery. Although the potential impacts of low-carbon transition on income equality is not a new thing, it is vital to address this issue at the moment as the pandemic magnifies the tradeoffs and lowers societies' tolerance for further inequality. Since the low-income and the vulnerable have been most adversely affected in the pandemic, their resistance and resilience to further negative impacts are meager. Furthermore, strong advocacy on balancing the tradeoffs between economic recovery and climate change mitigation might distract people's attention to the potential harms of green recovery on the poor and the vulnerable. In this sense, we address the role of COVID-19 in the tradeoffs between climate change and income inequality and provide implications on the solutions as follows.

First, it is essential to reassess the synergies and tradeoffs between various Sustainable Development Goals (SDGs) after COVID-19 and select an optimal economic recovery pathway that reboots the economy with the least harm to other sustainable goals. The pandemic might alter the priority of the SDG achievement and the tradeoffs among SDGs. Our study provides a template for the assessment, which considers not only economic growth and job creation but also the impacts on income inequality. The primary purpose of the assessment is to answer two questions: 1) who is most affected by the pandemic? and 2) could those who suffer the most in the pandemic receive timely and effective assistance during the recovery process? For more comprehensive pathway selection, future research can include other dimensions in the analysis to best balance the tradeoffs among the SDG targets according to local situations.

The second implication is that just transition should be addressed as much as green recovery. Just transition can be designed from both short-run and long-run perspectives. In the short-run term, it has been widely acknowledged that determining a detailed plan of decarbonization at the national and sectoral levels is the premise of just transition policy design. For example, a detailed schedule of the early decommissioning pathway of the coal-fired power industry informs policymaking when and in which regions workers will be affected. Based on such information, policymakers could establish precise transitional assistance mechanisms for the affected. Transitional assistance in the short term includes three sections: financial assistance, social protection, and employment training. The first and the most direct way is to provide financial assistance to the low-skilled and low-income workers directly affected by the green recovery. Forms of financial assistance include compensation fees, relocation cost, wage subsidies, etc., and should adapt to the actual development needs of specific areas with local characteristics. Funding sources can be fiscal support for economic recovery or can be a sound green financial system with a payment transfer mechanism. The second way of just transition is to strengthen social protection networks and labor market policy. A just transition requires improvement of social welfare systems, including minimum living standards, unemployment insurance, and early retirement benefits. It is also essential to promote labor migration by reducing relocation costs and breaking down the policy barriers for cross-regional labor mobility. Moreover, training and skill development is another essential measure to assist the unemployed with career transfer. Based on identified skill needs, restarting the apprenticeship program, fostering entrepreneurship, and promoting the cross-sector flow of human resources are vital steps to improve the overall adaptive ability or workers. Apart from short-term aid measures, just transition also needs a long-term plan to enhance the flexibility of the human resource market and economic resilience. Energy transition puts forward a higher demand for cross-disciplinary talents. In the long term, cultivating innovative talents and preparing innovation curricula are fundamental ways to solve the structural contradiction between labor supply and demand. In addition to the just transition measures mentioned above, it is also vital to pay attention to the immediate basic needs of the poor and the vulnerable during and after the COVID-19. Policymakers shall take efficient measures to reduce further negative impacts of green recovery on the poor's access to housing, water, energy, sanitation, and healthcare services due to income decrease or unemployment.

Third, it is worth noting that our estimation only focuses on income equality through employment changes, while neglecting other influencing pathways on social inequality. Future research would further enhance the understanding of just transition in the green recovery from multiple perspectives. For example, although green recovery might cause structural unemployment and aggravate income inequality, the co-benefits of air quality improvement brought by climate change mitigation might alleviate the unequal harms to the poor. This is because the low-income and the vulnerable have been identified as exposed more to severe air pollution, and they may gain the most from the reduction of air pollution in the green recovery[21,22]. Moreover, research could explore the impact on the job quality of disadvantaged groups, such as ethnic minorities and women, as they usually benefit less from job creation[23]. Thus, an integrated assessment with more factors is essential to provide more comprehensive social support for achieving just transition when implementating green recovery policies.

In sum, our analysis quantitatively reveals that the low- and medium-income groups are the primary victim in the COVID-19, while the high-income is the main beneficiary of green recovery. Such mismatch alerts that COVID-19 stresses the tradeoffs among SDGs (between climate change mitigation and income equality) and highlights the necessity of performing just transition alongside green recovery. We recommend that policymakers pay attention to the immediate needs of the poor and the vulnerable during and after the pandemic and take transition assistance measures to facilitate a smooth transition in the green recovery.

Methods

Modelling of short-term economic impact. We adopt and develop an improved Adaptive Regional Input–Output (ARIO) model[24,25] to simulate the economic mechanisms during the COVID-19 and its recovery process. ARIO model can describe how the impact of the pandemic is transmitted through supply chains and further enable the estimation of future economic and social impact of recovery stimulation in the post-COVID-19 era. Guan et al.[26] have used similar model to construct a disaster footprint model to simulate how supply chains are affected by COVID-19 lockdown measures. Our model differs from Guan et al.'s model[26] from the following perspectives: a) In terms of model structure, our model specifies the economic recovery process, and provides an interface to input economic recovery packages for individual countries. b) Modules of environment and employment are integrated to systematically simulate impacts of economy, society, and environment. c) Parameters are set and calibrated according to latest available data, including big data on travelling, lockdown measures, etc., to reflect the realistic impact of the pandemic. The model after such adjustments (namely the Extended Adaptive Regional Input–Output, the E-ARIO model) is proper to explore the impacts of diverse economic recovery packages in the post-COVID-19 era. A detailed description of the model structure, calculation equations and parameter setting are provided in the Supplementary Information.

Estimation of job market impacts. To explore the social impact of pandemic recovery processes, we calculate labor demand and sectoral income in each period:

$$Employment_{i,t}^{r,k} = Em_i^{r,k} \times IOX_{i,t}^r \quad (25)$$

$$Income_{i,t}^r = If_i^r \times IOX_{i,t}^r \quad (26),$$

where $Employment_{i,t}^{r,k}$ means the labor demand for kth labor type of sector i at region r at period t, and $Income_{i,t}^r$ illustrates income. $Em_i^{r,k}$ is the demand coefficient (amount of labor required for each unit of economic output) for the kth labor type, and If_i^r is the income coefficient (income provided by each unit of product). The two factors are calculated based on the initial state:

$$Em_i^{r,k} = \frac{Employment_{i,0}^{r,k}}{IOX_{i,t}^r} \quad (27)$$

$$If_i^r = \frac{Income_{i,0}^r}{IOX_{i,t}^r} \quad (28),$$

where $Employment_{i,0}^{r,k}$ is the demand for sector i to the kth type of labor at initial state, and $Income_{i,0}^r$ is the initial income provided by sector i.

Based on the sectoral average income, we categorize sectors into 3 groups according to the sectoral labor force numbers: low-income (40% of the urban labor force number), middle-income (40%), high-income (20%) group. As shown in Fig.6, the low- and medium-skilled workers account for more than 97% of low-income group, while high-skilled workers dominate the high-income group (about 40%).

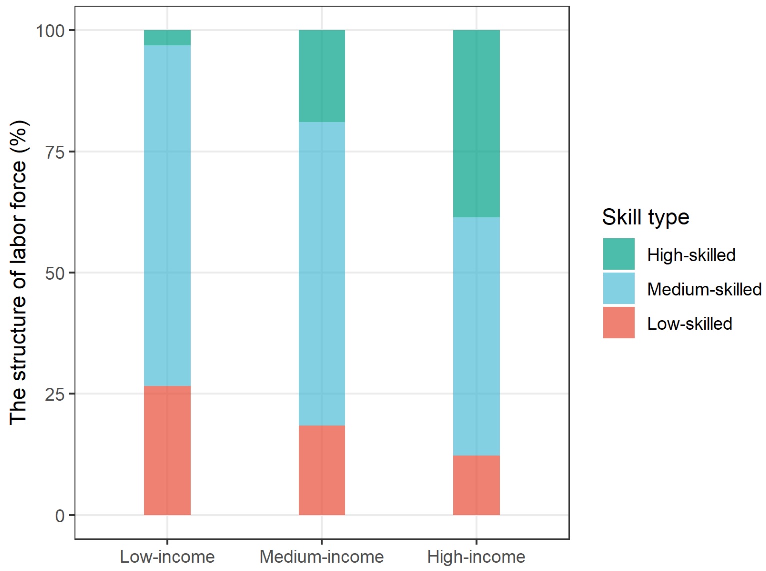

Fig.6 The relationship between the skill type and income level of labor force.

Calculation of income inequality. We calculate the Oshima index for each region to quantify the impact of the pandemic and different recovery packages on social inequality. The Oshima index is the ratio of the average income of the highest 20% of the group (AI_{max}) to the average income of the lowest 20% of the group (AI_{min}).

$$Oshima = \frac{AI_{max}}{AI_{min}} \tag{29}$$

The higher value of the Oshima index represents the greater income gap and the social inequality.

Data source. Parameters and data source are listed in Table 1. The global supply chain data in E-ARIO model uses the latest global multi-region input-output database EXIOBASE 3.7[27] which describes the currency exchange among 163 sectors in 49 countries/regions and their final demands around the world in 2015. The information on countries/regions and sectors are listed in Annex. The model sets the time step of one week considering the reaction time of companies and the pandemic development patterns. We divide the annual data by 52 and calculate the production and trading data per week, which represents the equilibrium state of production and consumption. Data on labor demand also originates from this dataset. EXIOBASE 3.7 categorizes labor demand as high-, medium-, and low-skilled labor demand. Based on this division, this research explores the impact on different policies on labor demand and income structure.

We use the actual data on the starting and ending time of every country [28] to calibrate the time and range of pandemic controlling measures to enhance reality. Google Community Mobility Report [29] is utilized to account whether residents work from home or at workplace (for example, if the 'workplace' transportation decreases by 20%, the labor force is assumed to decrease by 20%). Sensitivity factors for individual sectors are set to differentiate sectors [26]. Google Community

Mobility Report [29] also reports transportation to other destinations (retail store, grocery and pharmacy, parks, transportation hubs, and residential areas), which is used in this research to calibrate the demand data during the pandemic. Since Google data excludes China, we calculate Chinese situations as the strictest of all countries during the same period of pandemic.

Table 1. Parameters and data sources

Module	Parameter	Parameter description	Data source
Production function	$IOZ_{i,0}^{r}$	Intermediate input at initial state (t=0)	EXIOBASE 3.7 (Stadler et al., 2018)
	$IOX_{i,0}^{r}$	Total output at initial state (t=0)	
	$IOL_{i,0}^{r}$	Labor supply at initial state (t=0)	
Intermediate input	∂	Proportion of initial storage to initial intermediate input	Guan et al, 2020
Labor supply	t_1, t_2	Starting and ending time of pandemic controlling measures	Aura Vision, 2020
	γ_i	Sensitivity of labor supply for sector i to the pandemic	Guan et al, 2020
	ω_t^r	Average change in labor at region r	Google, 2020
	θ_{it}^r	Labor recovery rate after lockdown stops	Scenario setting
Demand orders	ε	Proportion of storage target to initial target	Guan et al, 2020
	$\beta_{hi,t}^s$	Change rate of final demand of sector i during lockdowns	Google, 2020
	$\upsilon_{hi,t}^s$	Rate of demand recovery of sector i after lockdown stops	Google, 2020
	μ_{hi}^s	Proportion of economic stimulation allocated to sector i	Scenario setting
	MS_{sum}^s	Total amount of economic input as economic stimulus	Scenario setting
	t_s	Starting time of economic stimulus	Scenario setting
	p	Number of periods with economic stimulus	Scenario setting
Employment	$Employment_{i,}^{r}$	Labor demand of sector i, categorized according to labor skill	EXIOBASE 3.7 (Stadler et al., 2018)
	$Income_{i,0}^{r,k}$	Income of sector i, categorized according to labor skill	

Scenario setting. Our research constructs three types of economic recovery scenarios: the Business-as-Usual, (BAU) scenario without economic recovery packages, the Traditional economy stimulation (TES) scenario with economic stimulus on fossil fuels and traditional carbon-intensive sectors, and the green recovery scenario focusing on clean energy and digital economy. The green recovery scenario has two sub-scenarios: the Low carbon stimulation (LCS) scenario focusing on clean energy transition, and the Low carbon & digital economy stimulation (LDS) scenario focusing both on clean energy and digital economy. When investing in energy systems, besides the direct generation technologies, other aspects of the projects need to be considered: planning activities, infrastructure and connecting devices. Thus, investments of energy systems are split into different products/sectors in the E-ARIO model. Ratios of investment breakdown are referred to Wiebe, et al. [30] to capture the traditional and green recovery scenario. Except for the BAU scenario, the other three scenario sets 10% of GDP economic stimulus for each region, which is put to the markets before the end of the year. Different scenarios allocate economic stimulus to different sectors based on the initial final demand. Due to the diversity of industrial situations among countries/regions, we adjust the scenario setting for each country/region to fit the scenario description. Besides recovery packages, the recovery rate of labor supply for each region is set at 4%, and economic stimulus is set to start at 4 weeks after the controlling measures are stopped. The stimulating sectors in each scenario are listed in Table 2 and the detailed setting are provided in the SI.

Table 2. Scenario setting and description

Scenario	**Sectors**		**Sector number**
Business-as-Usual (BAU)	Zero economic stimulus, economy recovers by itself		-
Traditional economy stimulation (TES)	Mining	Mining	20:34
	Manufacturing	Traditional manufacturing	56:84
		Metal product manufacturing	85:86
		Electric and electronic device manufacturing	88
	Construction		113
	Transportation	Railway and airline	121:126
	Energy	Coal power and natural gas power	96,97,101,110
		Transmission and distribution of electricity	108:109
Low carbon stimulation (LCS)	Manufacturing	Metal product manufacturing	85:86
		Transport equipment manufacturing	91:92
		Electric and electronic device manufacturing	88
	Energy	Renewable energy	98:100, 102:107
		Transmission and distribution of electricity	108:109
	Construction		113
	Transportation	Railway transportation	120
	Service Industry	Finance	128, 130, 135
		Research & Development	134
	Manufacturing	Metal product manufacturing	85:86

Low carbon & digital economy stimulation (LDS)		Transport equipment manufacturing	91:92
		Electric and electronic device manufacturing	88
		High-end manufacturing	87,89,90
	Energy	Renewable energy	98:100, 102:107
		Transmission and distribution of electricity	108:110
	Construction		113
	Service Industry	Communication and software	127,133
		Finance	128, 130, 135
		Research & Development	134
		Education, health and social work	137,138

Note: sector No. and corresponding sectors are listed in the SI.

Uncertainty analysis. The recovery speed of the labor market and the time of the stimulus plan may affect our estimation. To examine if the results are robust to various recovery scenarios, we set the recovery speed of the labor market at 2%, 4%, 6%, and 8% per week and the stimulus time at four points: the week of the lockdown ending, four weeks, eight weeks, and twelve weeks after the lockdown ends.

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Figures

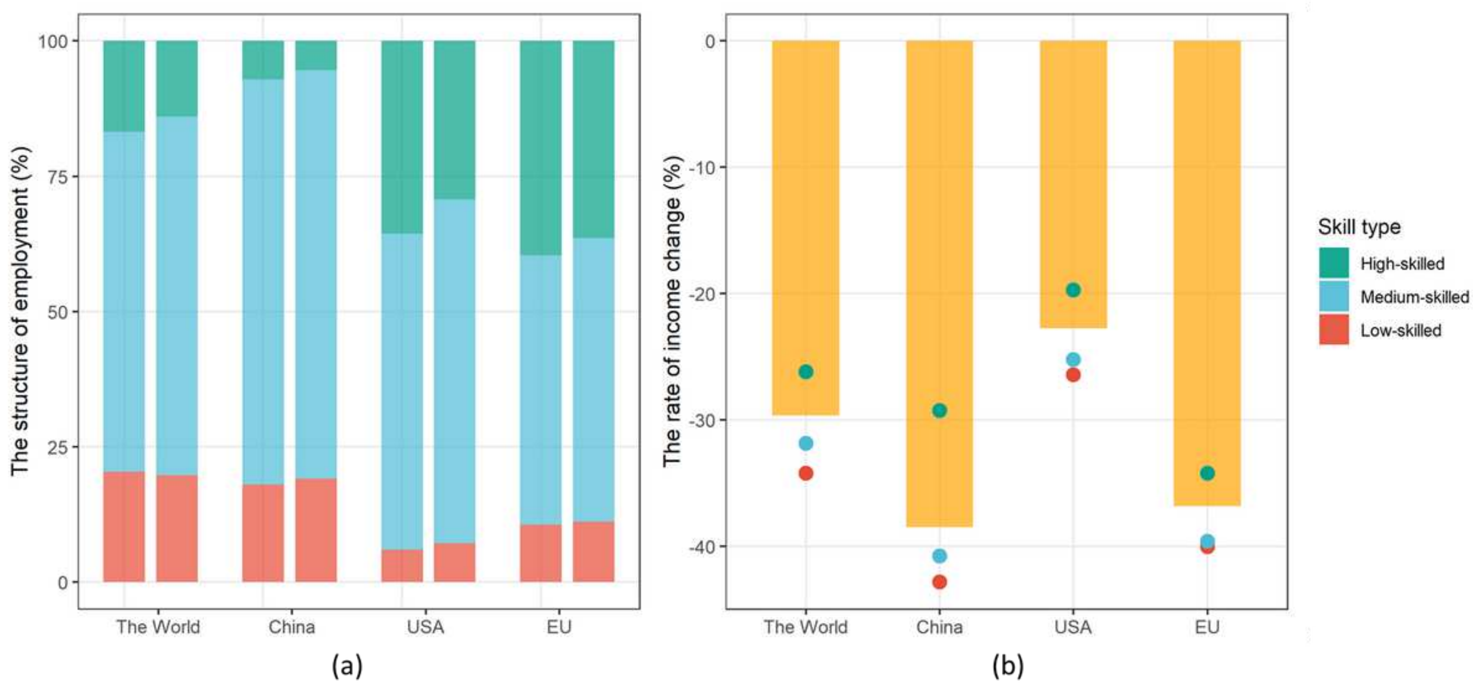

Figure 1

The impacts of COVID-19 on labor demand and average income. Graph (a) shows the structure of the labor force in each region in the initial situation (left bars) and the structure of the labor force affected by the COVID-19 lockdown (right bars). Graph (b) describes the income change of different skill groups (displayed as points) and the average level (displayed as bars) in each region in the lockdown period.

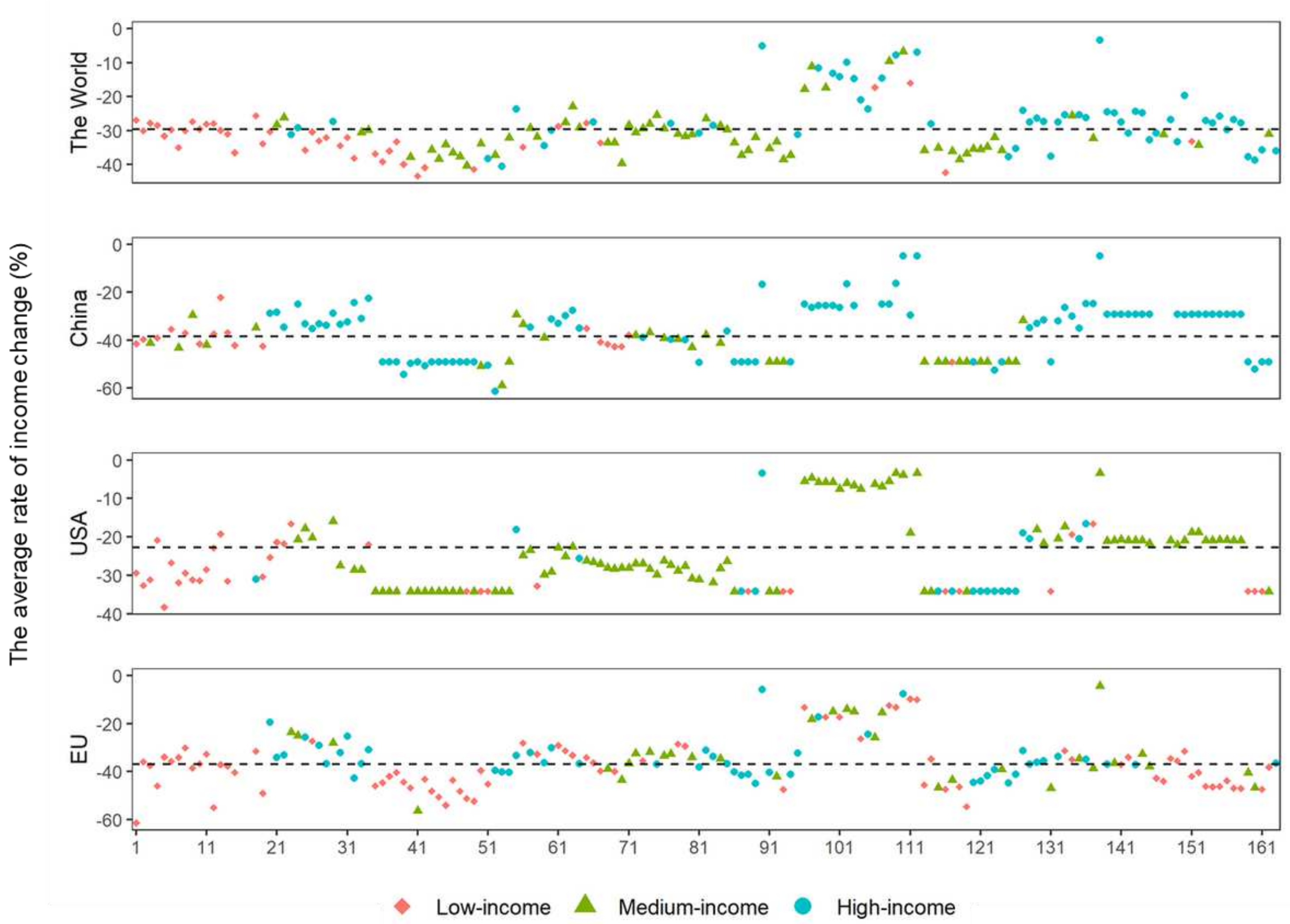

Figure 2

The impacts of COVID-19 on income by sectors. The list of the sectors (indicated by the numbers on the horizontal axis) is provided in the Supplementary Information (SI) Table S2.

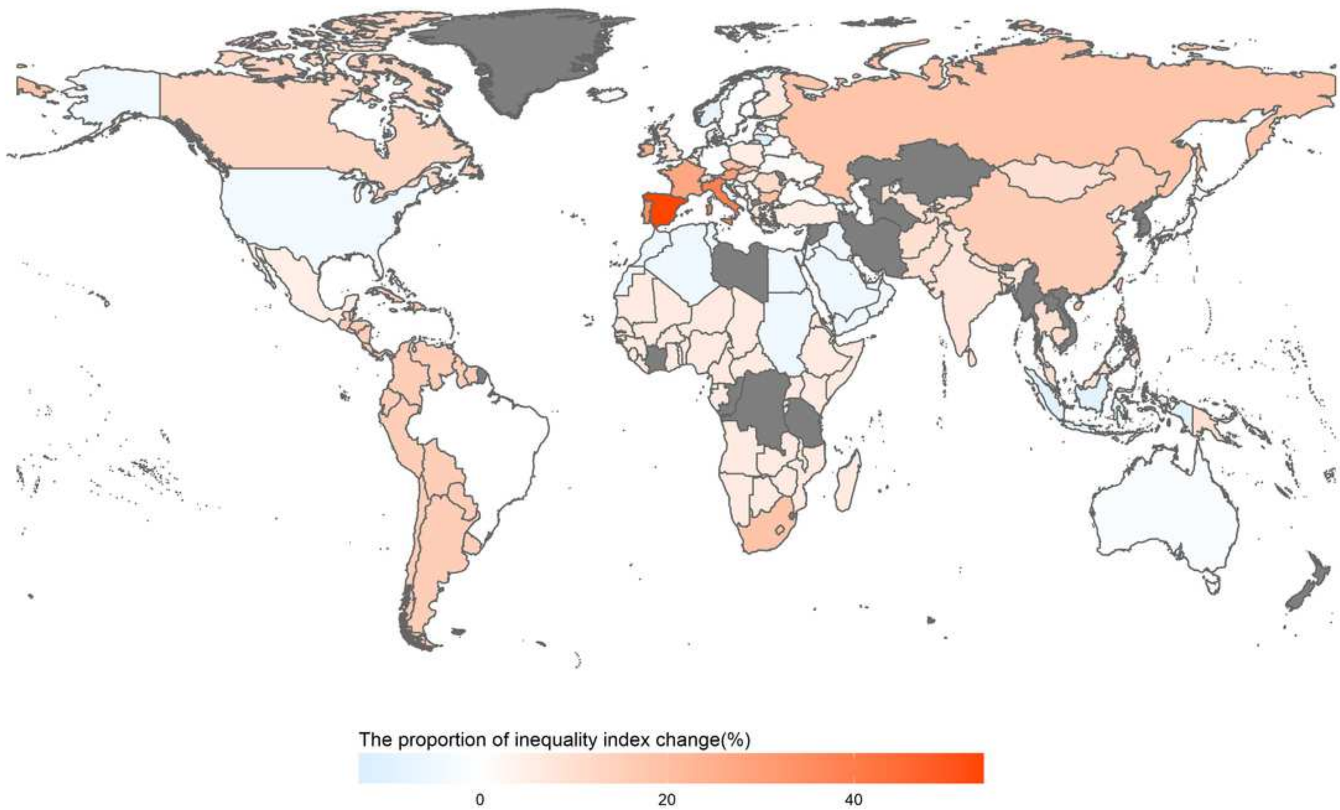

Figure 3

The impacts of COVID-19 on income equality. 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.

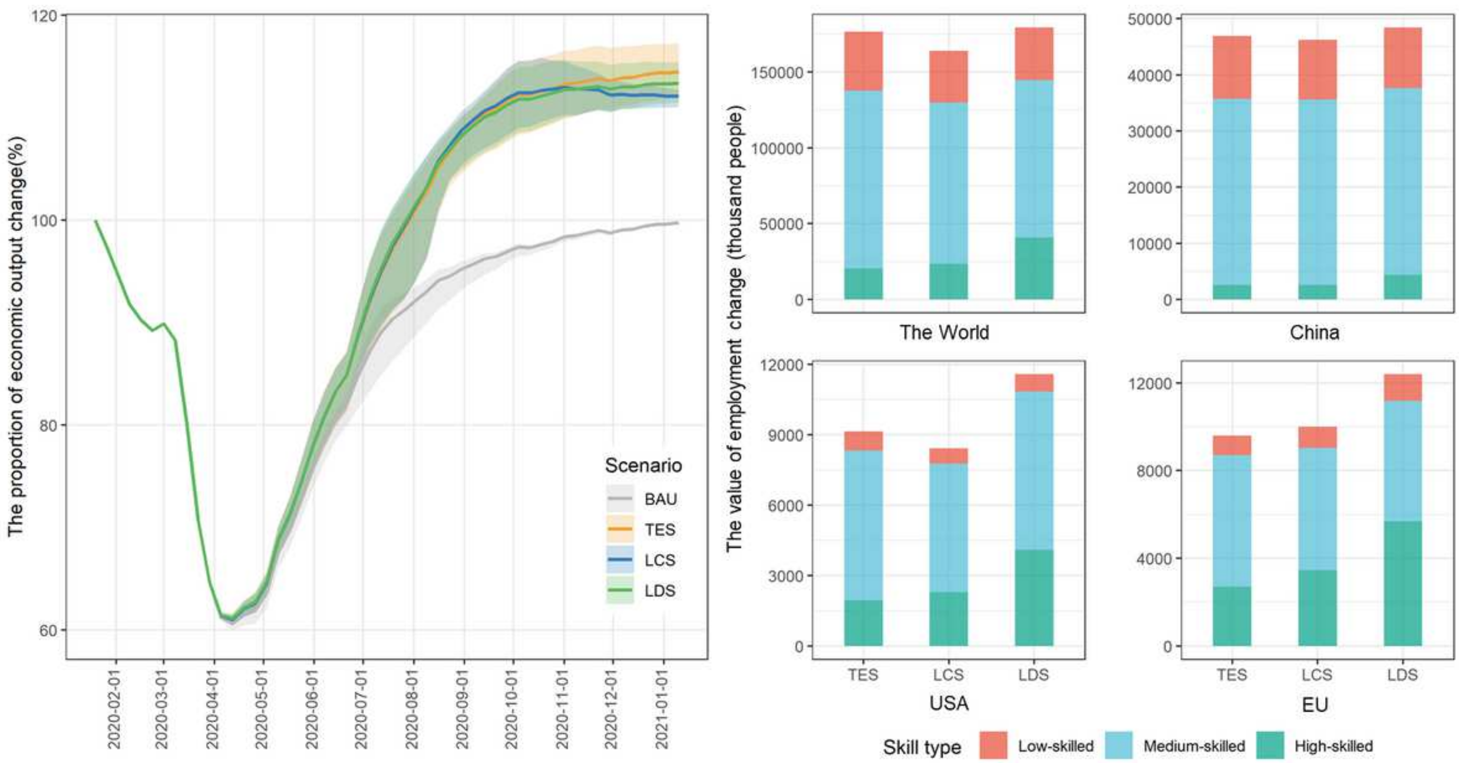

Figure 4

Impacts of recovery scenarios on economic growth and employment demand. BAU represents business-as-usual scenario. TES represents traditional recovery plan. LCS represents low-carbon recovery plan. LDS represents low-carbon and digital recovery plan.

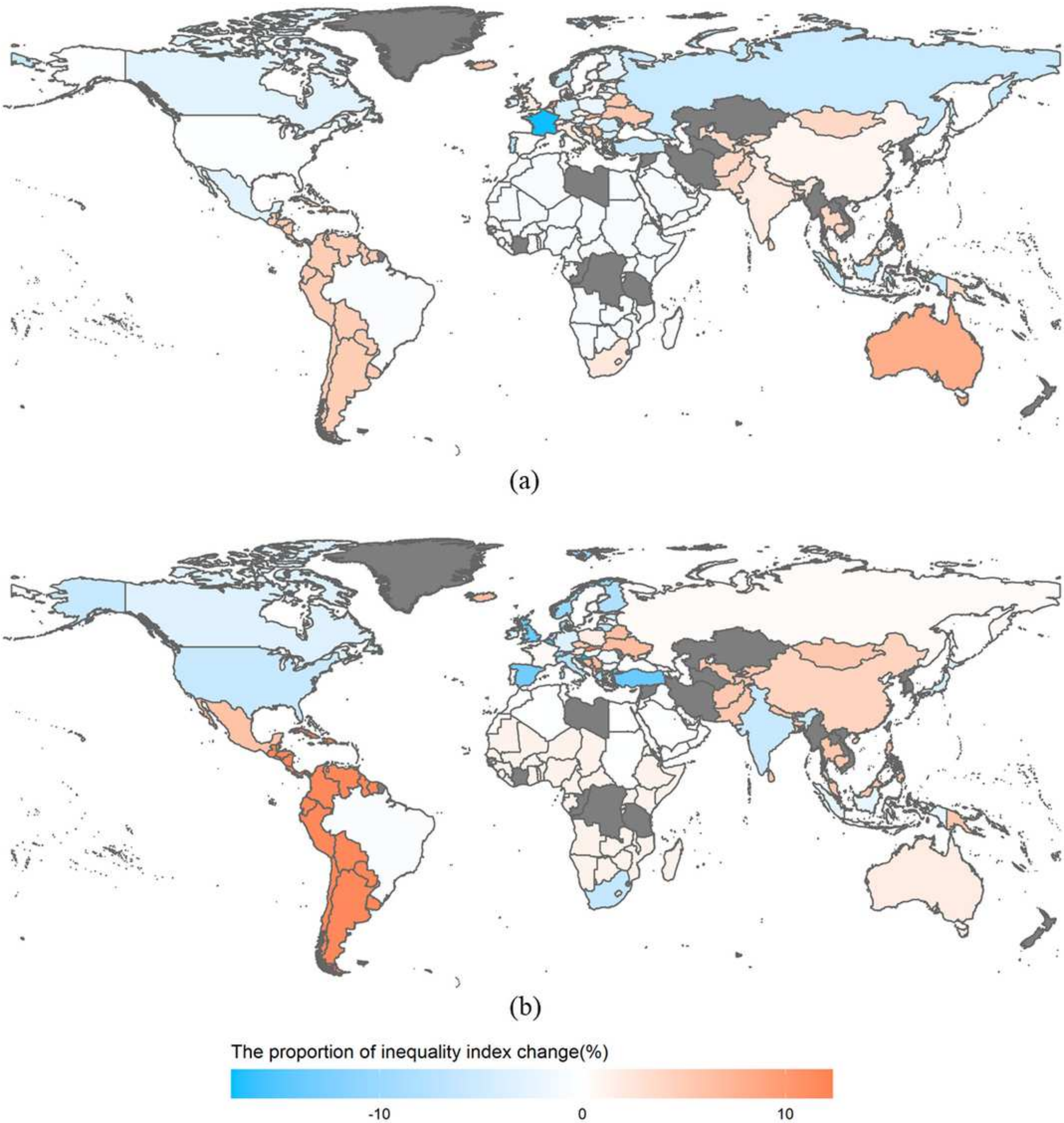

Figure 5

Oshima coefficient of green recovery scenarios compared to TES scenario. 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.

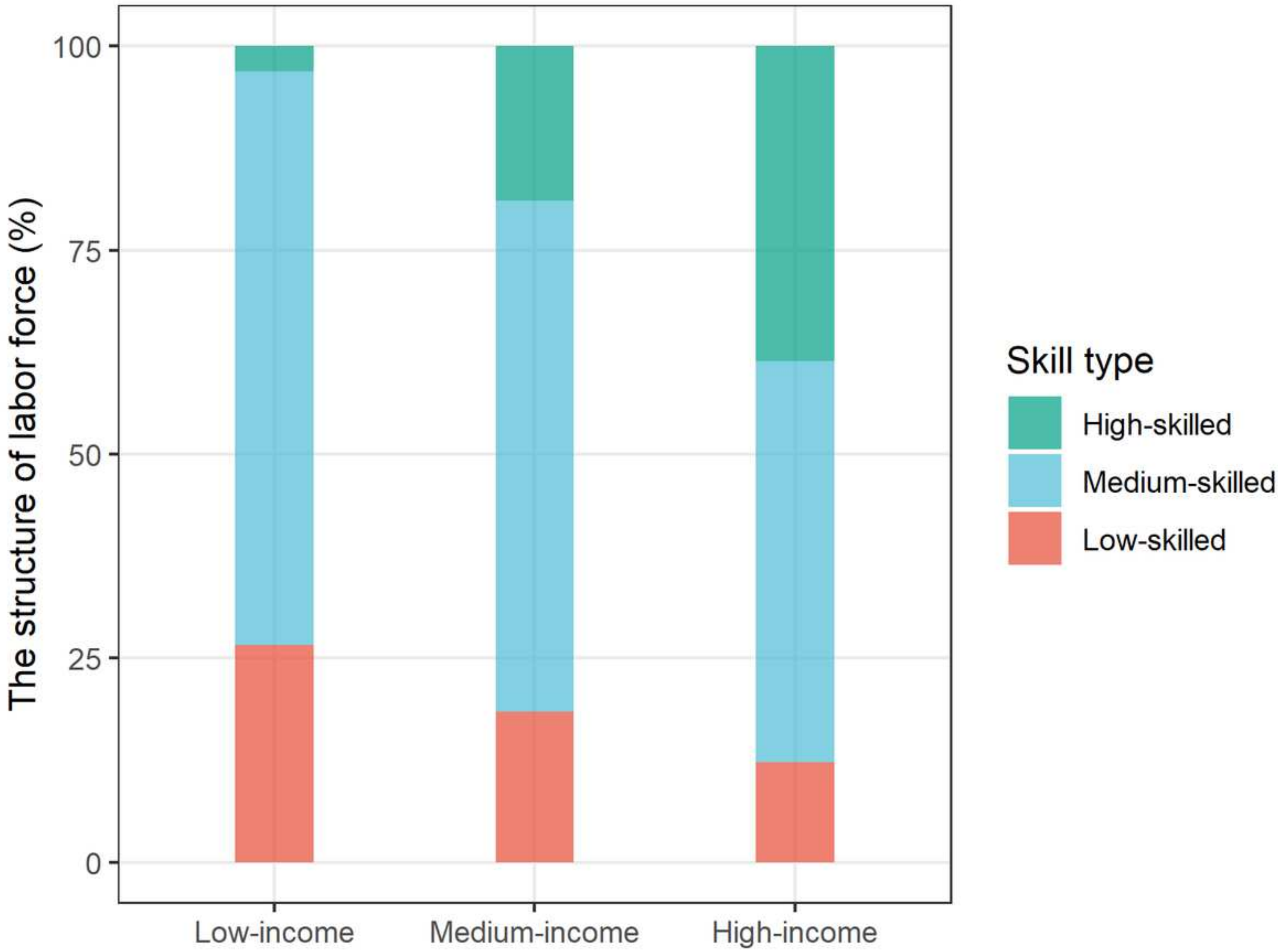

Figure 6

The relationship between the skill type and income level of labor force.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- 2.SI120200920.xlsx
- 3.SI220200920.docx