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The economic impacts of low-carbon transition in Asia: NDC and Net Zero Transition with International Carbon Market in Asia

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지속가능 발전에 기여
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* The research is a part of the background paper "Costs and Benefits of Low Carbon Transition in Asia" in ADB's ADO Theme Chapter

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PART I

Introduction

Background and Research Objective

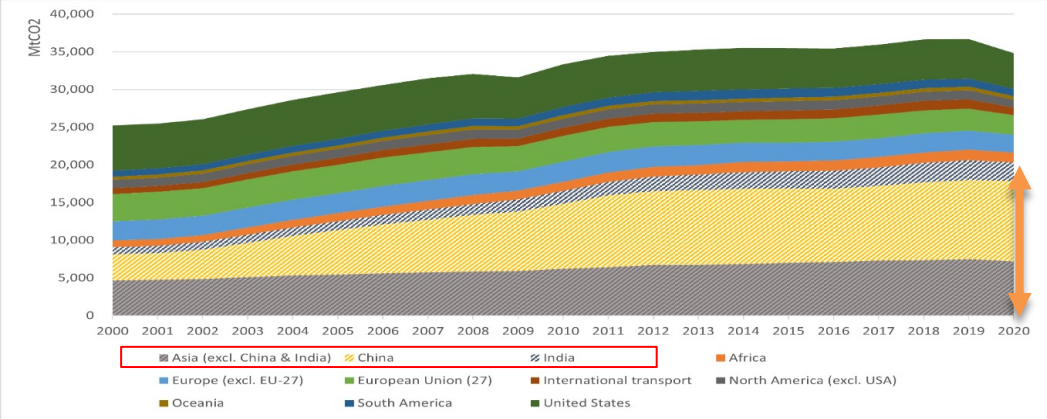
Research Objective:

- Analyzing the economic impacts of the Net Zero transition in developing Asian countries by applying a global CGE model

Background

- Developing Asian countries are among the fastest emerging economies, and their greenhouse gas emissions have been increasing rapidly
- Net Zero Transition (i) for decoupling economic growth and GHG emissions and (ii) for achieving the global 1.5-degree target and reaching Net Zero

Annual CO_2 emissions from Fossil Fuel



Source: Our World in Data, 2022

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PART II

Methodology: Global CGE Model

Methodology

Global Computable General Equilibrium (CGE) model

- Global Dynamic Recursive CGE model with GTAP 10 Power DB + other data and information
  - ➢ GTAP 10 Power DB: 121 countries, 20 aggregated regions, 76 products and services with 12 power technologies (Aguiar et al, 2019)
- Sector Aggregation: Aggregation of industries in 19 sectors

Sector	GTAP Sector Code	Sector	GTAP Sector Code
AGR (agriculture)	PDR, WHT, GRO, V_F, OSD, C_B, PFB, OCR, CTL, OAP, RMK, WOL, FRS, FSH	Food	CMT, OMT, VOL, MIL, PCR, SGR, OFD, B_T
COA (coal)	COA	Mineral	OXT
OIL and GAS	OIL. GAS, GDT	Cloth	TEX, WAP, LEA
Chemical	CHM, BPH, RPP, NMM	Paper	LUM, PPP
ELY (electricity)	ELY, TnD, NuclearBL, CoalBL, GasBL, OilBL, OtherBL. GasP, OilP	P_C (petroleum and coal products)	P_C
REN (renewable)	WindBL, HydroBL, HydroP, SolarP	ICT & Computer	ELE, EEQ
Metal	I_S, NFM, FMP	Construction	CNS
Vehicle	MVH, OTN	Dwell (Dwelling)	DWE
Machinery, Furniture	OME, OMF	Service	OSG, EDU, HHT, WTR, AFS, TRD, WHS, CMN, OFI, INS, RSA, OBS, ROS
Transport	OTP, WTP, ATP		

Methodology

Global Computable General Equilibrium (CGE) model

- Regional Aggregation: 7 aggregated regions reflecting ADB sub-regions

Label	Description	GTAP regions code
OECD	OECD (except the Republic of Korea): Europe Region (EU member countries, Rest of Europe, Rest of European Free Trade Association, and United Kingdom) + Australia, New Zealand, Japan, Canada, and United States	ALB, AUS, AUT, BEL, BGR, CAN, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ITA, JPN, LTU, LUX, LVA, MLT, NLD, NOR, NZL, POL, PRI, PRT, ROU, SVK, SVN, SWE, TUR, USA, XEF, XER
DC	The other developing countries: Countries not included in OECD and five Asian sub-regions	MEX, XNA, ARG, BOL, BRA, CHL, COL, ECU, PRY, PER, URY, VEN, XSM, CRI, GTM, HND, NIC, PAN, SLV, XCA, COM, JAM, TTO, XCB, BLR, RUS, UKR, XEE, BHR, IRN, ISR, JOR ,KWT, OMN, QAT, SAU, ARE, XWS, EGY, MAR, TUN, XNF, BEN, BFA, CMR, CIV, GHA, GIN, NGA, SEN, TGO, XWF, XCF, XAC, ETH, KEN, MDG, MWI, MUS, MOZ, RWA, TZA, UGA, ZMB, ZWE, XEC, BWA, NAM, ZAF, XSC, XTW
CCA	Caucasus and Central Asia	KAZ, KGZ, TJK, XSU, ARM, AZE, GEO
EAsia	East Asia: China, Korea, Hongkong China, Taipei,China, and Mongolia	CHN, HKG, KOR, MNG, TWN, XEA
SAsia	South Asia: India, Pakistan, Nepal, Bangladesh and nearby countries (Maldives, Afghanistan, Bhutan, Sri Lanka)	BGD, IND, NPL, PAK, LKA, XSA
SEAsia	Southeast Asia: 10 ASEAN member countries and Timor-Leste	BRN, KHM, IDN, LAO, MYS, PHL, SGP, THA, VNM, XSE
Pacif	The Pacific: Mostly small island countries	XOC

Asian Regions

Methodology

Global Computable General Equilibrium (CGE) model

▷ Key Assumptions:

- UN Population Projections and SSP (Shared Socioeconomic Pathways) 2 Scenario
- Total Factor Productivity (TFP) to reproduce the SSP-2 GDP Projections
- Learning rate of 15% to the productivity of renewable energy technologies

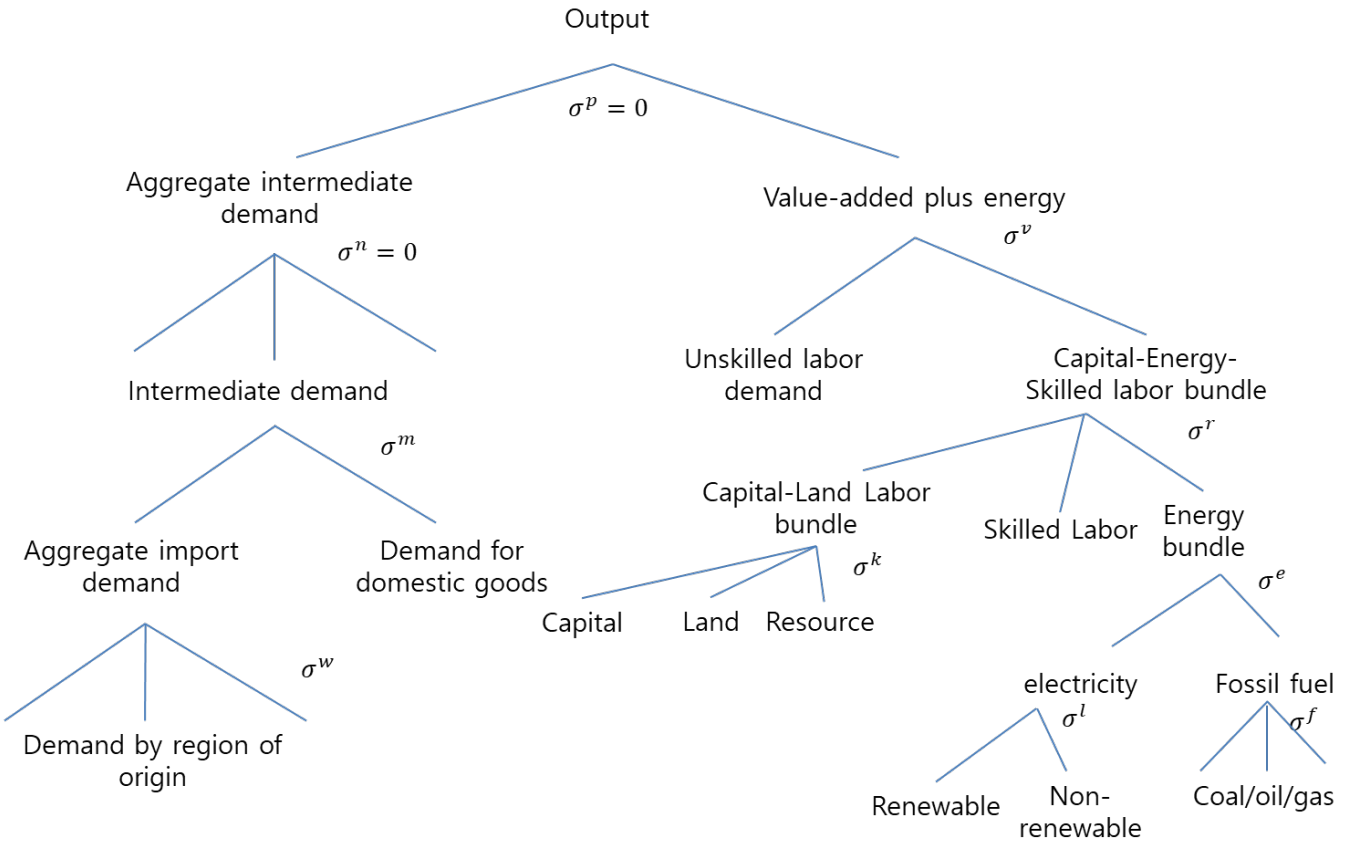
- Capital Stock Dynamics: $K_t = (1-\delta)^k K_{t-k} + \frac{(1+g_I)^k-(1-\delta)^k}{g_I+\delta} I_{t-k}$
- Current Account Balance: $\sum_{(r',i)} Pfob_{r,r',i} Qtrade_{r,r',i} + \sum_i Ptrnserv_{r,i} Qtrnserv_{r,i} + ForegnSaving_r = \sum_{(r',i)} Pcif_{r',r,i} Qtrade_{r',r,i}$
- Budget Balance (household, government, investment)
  - $(1-ti)\cdot\sum_f PF_f QF_f = \sum_i P_i\cdot(1+tc_i)\cdot QC_i + HSaving$
  - $\sum_f tf_f PF_f QF_f + ti\sum_f PF_f QF_f + \sum_i\left(tc_i P_i QC_i + tp_i PP_i QP_i + \sum_j t_{ij} P_i QAP_{ij}\right) + \sum_{(r',i)} tariff_{r',r,i} Qtrade_{r',r,i} = \sum_i P_i QG_i + GovSaving$
  - $\sum_i P_i QINV_i = HSaving + GovSaving + ForeignSaving$

k: step size for simulation (set to 2 years); K_t: Capital stock at period t; δ: Capital depreciation rate; I_t : Aggregate investment at period t; g_I: Growth rate of investment; $Pfob_{r,r',i}$: FOB price of commodity i traded from r to r' ; $Pcif_{r,r',i}$: CIF price of commodity i traded from r to r' ; $Qtrade_{r,r',i}$: Volume of commodity i traded from r to r' ; $tariff_{r,r',i}$: Import tariff rate on commodity i traded from r to r' ;$Ptrnserv_{r,i}$: Price of international transport service i provided by region r ; $Qtrnserv_{r,i}$: Quantity of international transport service i provided by region r ; PF_f: Price of factor f; QF_f: Quantity of supply of factor f; P_i: Price of commodity i ;QC_i: Household consumption of commodity i ; QP_i: Production volume of commodity i; QAP_{ij}: Intermediate consumption of commodity i in sector j; PP_i: Output price of commodity i ;QG_i: Government consumption of commodity i; $QINV_i$: Investment consumption of commodity i; ti: Income tax rate for household; tc_i: Consumption tax rate for commodity i ; tf_f: Tax rate for factor f; tp_i: Output tax rate for commodity i; t_{ij}: Intermediate consumption tax rate for commodity i in sector j; $HSaving$: Household saving; $GovSaving$: Government saving; $ForeignSaving$: Foreign saving

Methodology

Global Computable General Equilibrium (CGE) model

▷ Production Nesting Structure:



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PART III

Policy Scenarios

Policy Scenarios

Transition Scenarios

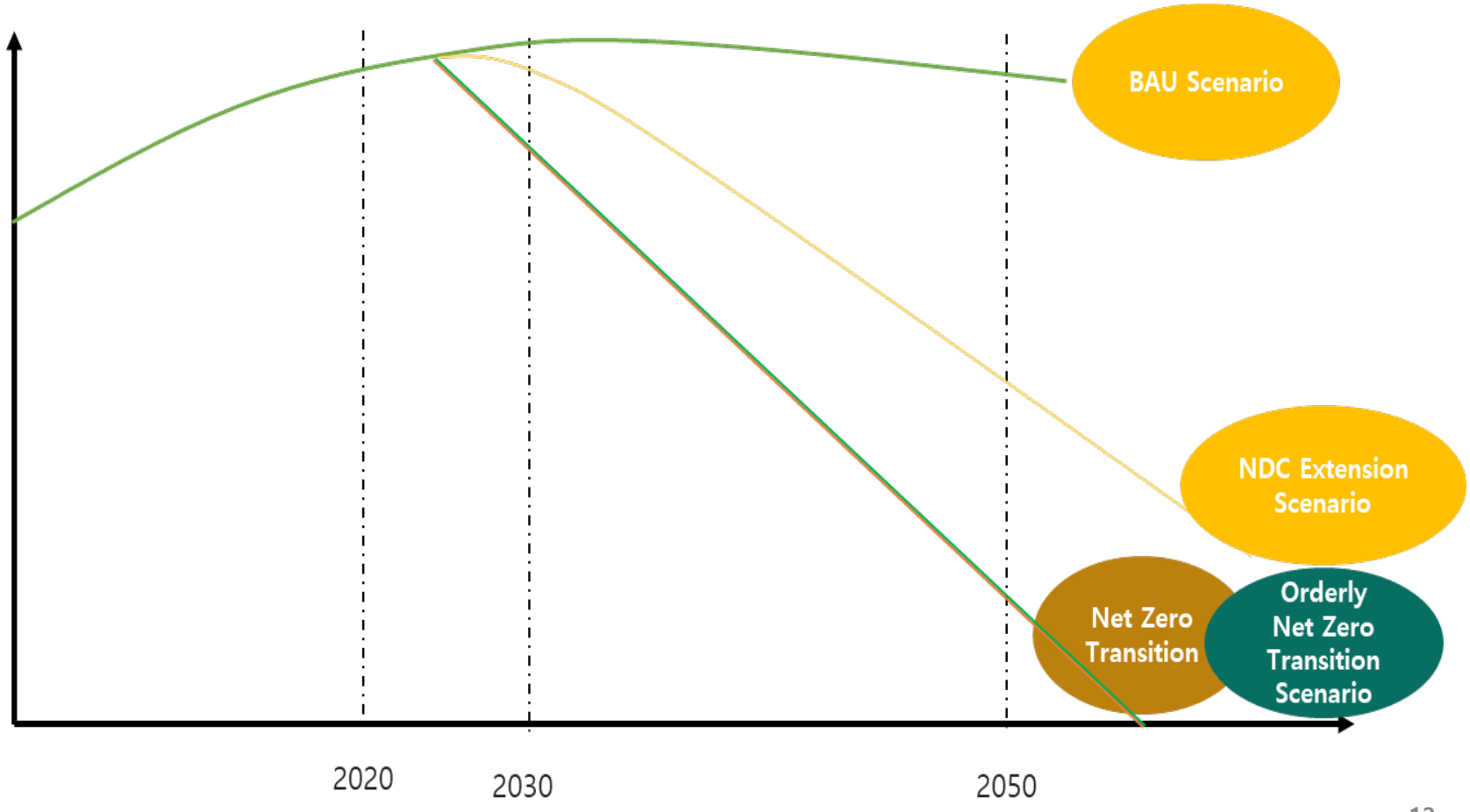
BAU	• Each country follows its own development pathways under current business models. The emissions trajectory of the BAU scenario shows that global emissions reach their peak around 2034 and gradually decrease afterward
NDC Extension	• Achieving countries' NDC targets and continuing their mitigation actions but not achieving the global Net Zero by 2050* • NDC targets of individual countries in OECD and Asia regions
Net Zero Transition	• Applying global carbon prices suggested by IEA Net Zero Emission (NZE) scenario • Economy-wide carbon pricing with revenue recycling towards distortionary taxes
Orderly Net Zero Transition	• Applying global carbon prices suggested by IEA Net Zero Emission (NZE) scenario • Economy-wide carbon pricing with revenue recycling towards distortionary taxes • Adoption of an international carbon market in Asia

Note: IPCC Special Report on Global Warming of 1.5-degree indicated the level of emissions reductions would be about 59% ~ 69% (average 62.3%) reductions relative to the 2010 emission level in 2050

* Only countries announced to achieve Net Zero by 2050 reach Net Zero by 2050. The other countries assume to achieve Net Zero after 2050 (if not specified, year 2070)

Policy Scenarios

Graphical Illustration of the Transition Scenarios



Policy Scenarios

Net Zero Transition Scenarios: Carbon Prices

Classification	2030	2050
Advanced economies	130	250
Selected emerging market and developing economies	90	200
Other emerging market and developing economies	15	55
Source: (IEA, 2021)		

- **Advanced economies**: OECD countries and European countries
- **Selected emerging economies**: Selected emerging economies classified by IEA (China, Russia, Brazil, South Africa) + Singapore, Taipei,China, Malaysia, Indonesia, Kazakhstan, Argentina, Costa Rica, Brunei Darussalam
- **Other emerging economies**: Remaining countries not classified as advanced or selected emerging economies

	2030	2050
OECD	129.11	248.48
Caucasus and Central Asia	56.22	134.69
East Asia	92.07	202.40
South Asia	15.00	55.00
Southeast Asia	56.40	135.05
Pacific	15.00	55.00
Other Developing Countries	57.83	134.90
Source: Author's calculation		

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PART

Ⅳ

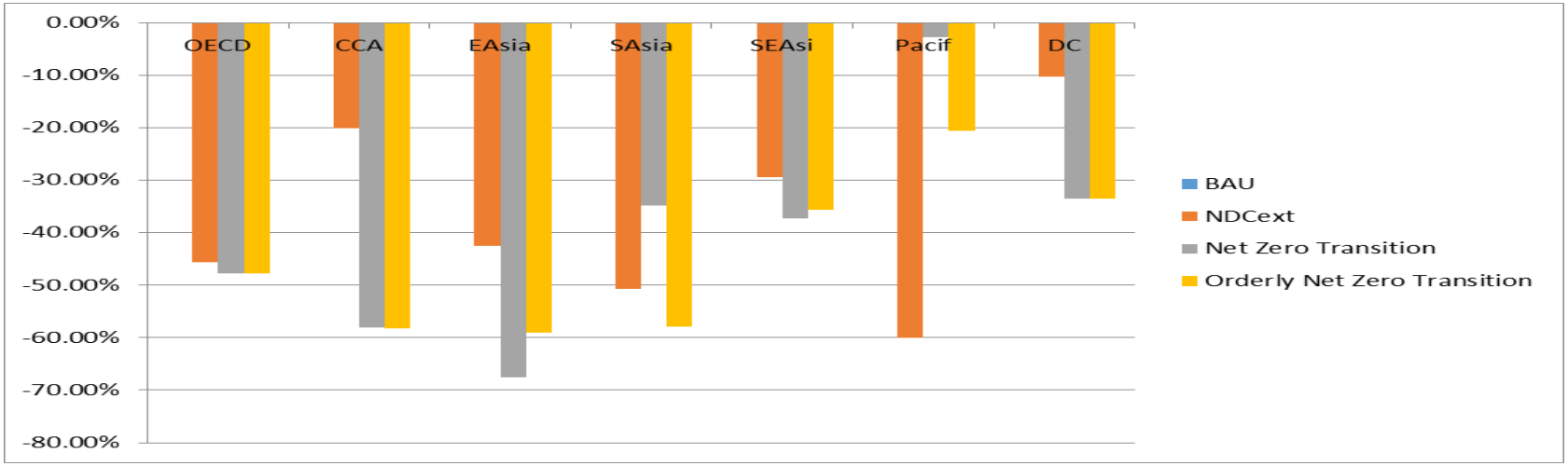
Results

Changes in GHG emissions (2022–2050)

- A significant emission reduction in the OECD region (~50% relative to BAU)
- Carbon Prices for Net Zero Transition: Further decrease in CCA, East Asia, and Developing Countries (Compared to NDC Extension Scenario)
- With carbon pricing only, relatively less emissions reductions in South Asia

  ➔ With both carbon pricing and the international carbon market in Asia, a noticeable emission reduction in South Asia

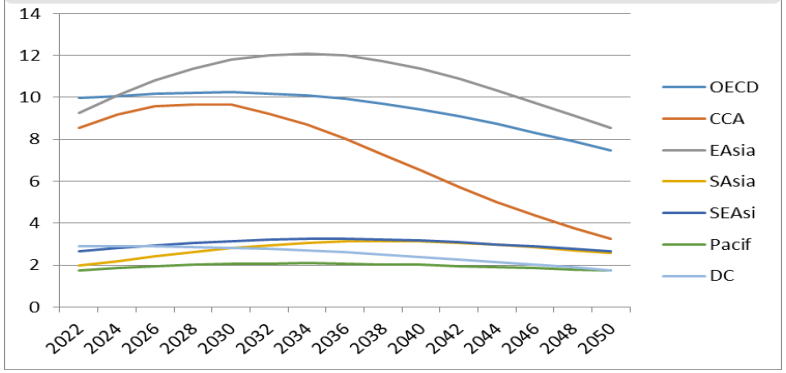
Changes in GHG Emissions (2022–2050) (% difference from BAU level)



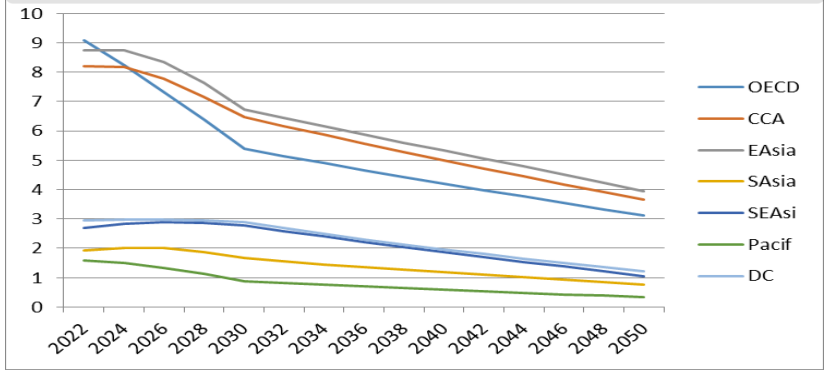
Orange (NDC Extension), Grey (Net Zero Transition), Yellow (Orderly Net Zero Transition)

GHG Emissions per capita by region (unit: tCO_2eq)

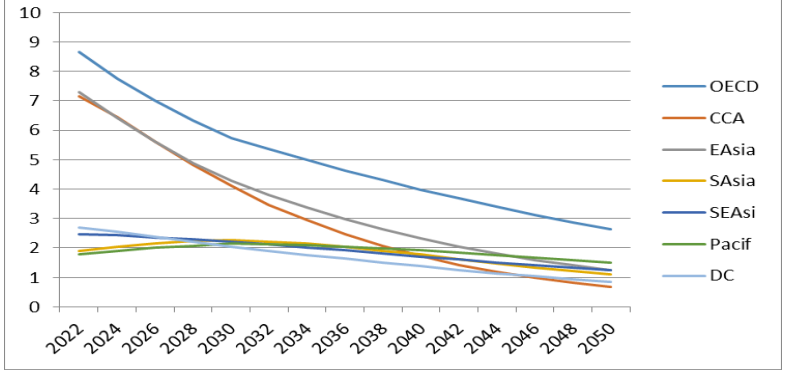
BAU



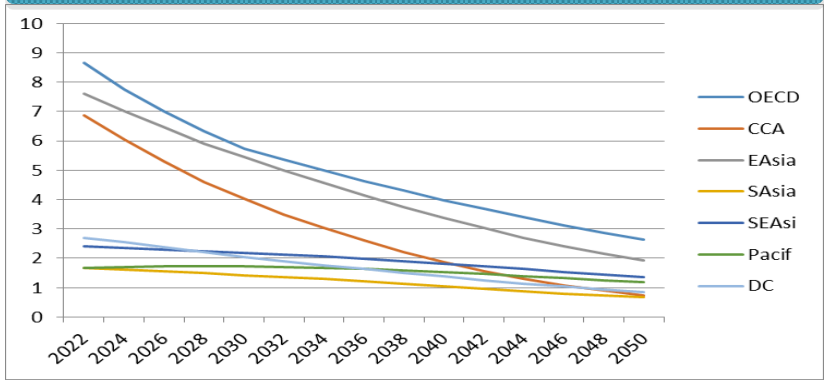
NDC Extension



Net Zero Transition

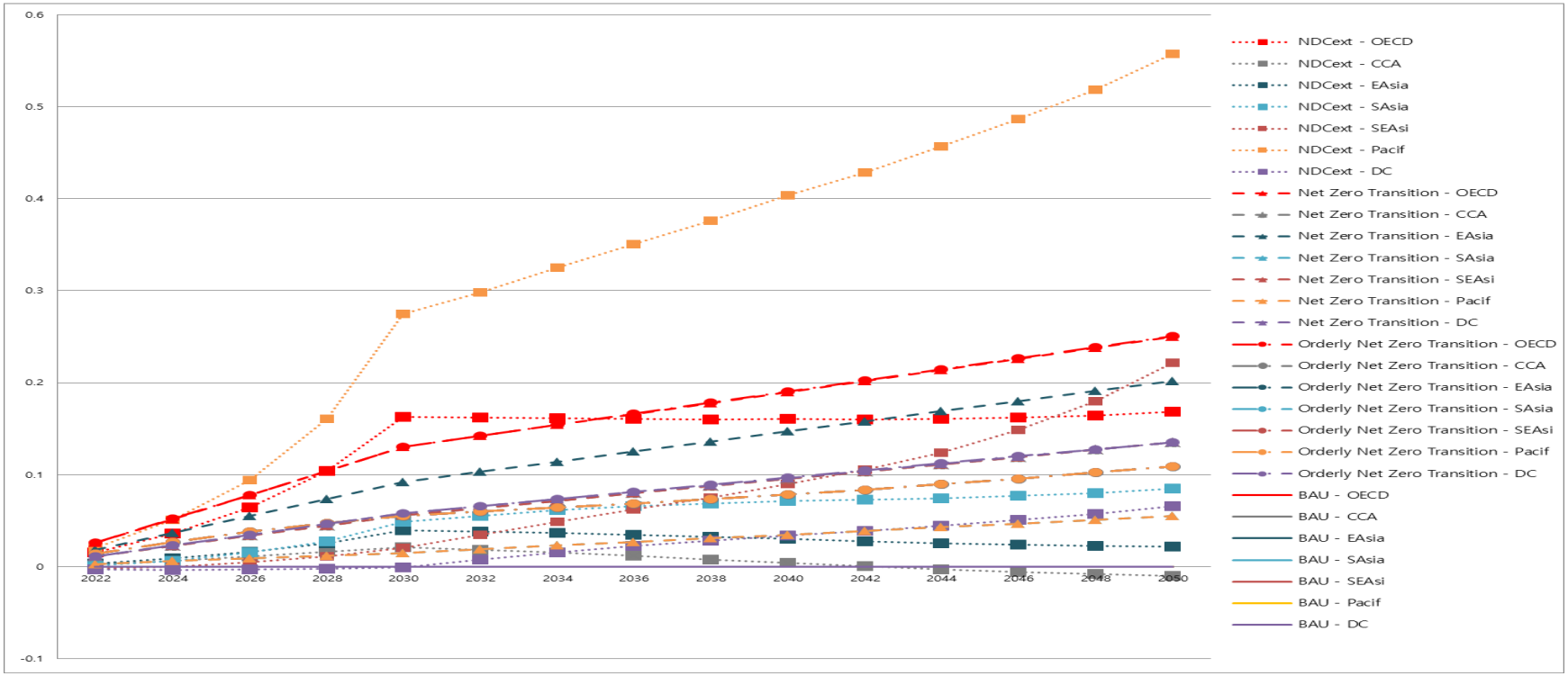


Orderly Net Zero Transition



Trajectories of Regional Carbon Prices by Scenario

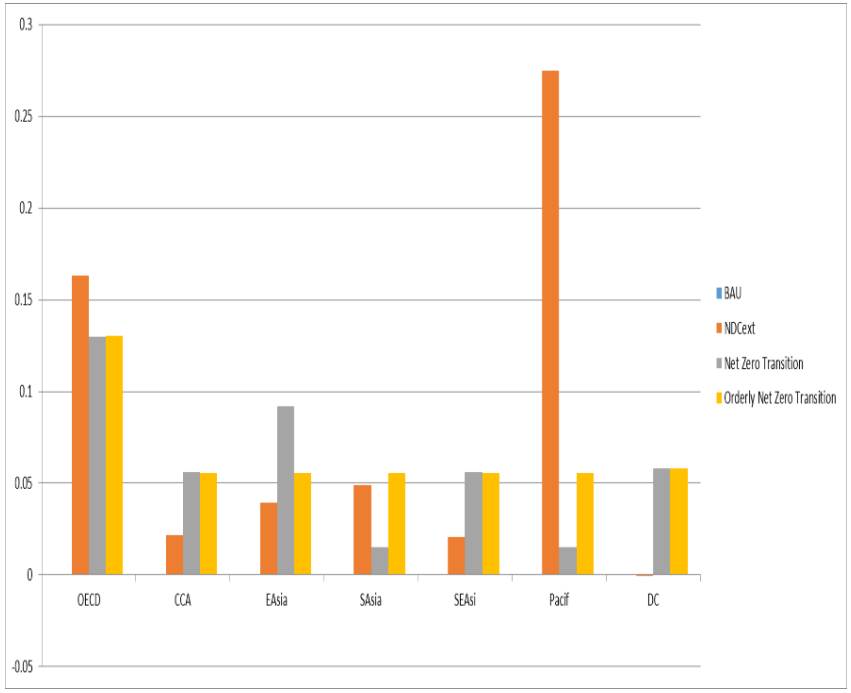
(Unit: $1,000 per tCO2eq)



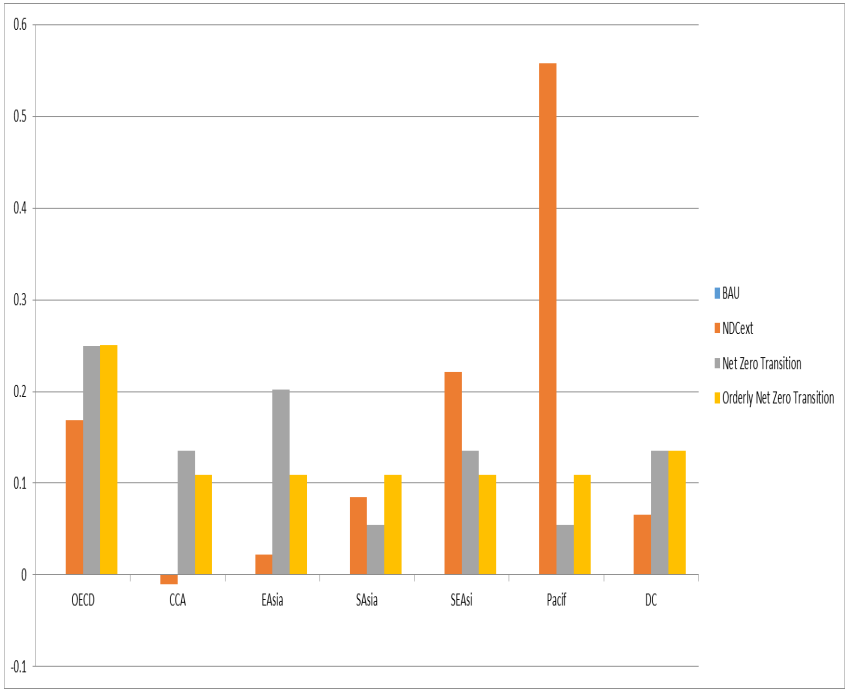
(Region) OECD (Red), East Asia (Dark Green), South Asia (Light Blue), Southeast Asia (Brown) Caucasus and Central Asia (Grey), Pacific (Orange), Developing Countries (Purple)
(Scenario) BAU (Dash), NDC Extension (Square), Net Zero Transition (Triangle), Orderly Net Zero Transition (Circle)

Carbon Prices in 2030/2050, by region (Unit: $1,000)

Carbon Price in 2030



Carbon Price in 2050

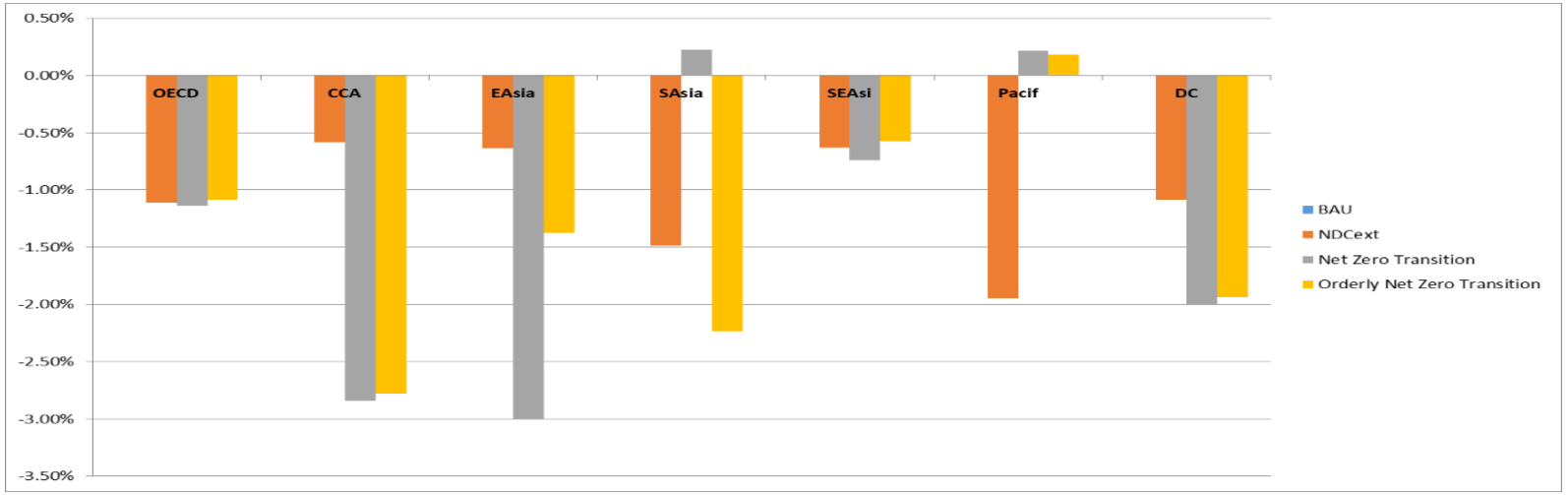


Orange (NDC Extension), Grey (Net Zero Transition), Yellow (Orderly Net Zero Transition)

Changes in Real GDP (2022–2050)

- Mild decrease in real GDP relative to the BAU level under all three transition scenarios
- Net Zero Transition Scenario relative to BAU level: More GDP losses in CCA, East Asia, Southeast Asia, and other Developing Country region ⇔ Positive GDP impacts in South Asia and the Pacific
- Orderly Net Zero Transition with International Asian carbon market: Positive impacts of carbon trading on all regions except South Asia and the Pacific

Changes in Real GDP (2022–2050) by Scenario (% difference from BAU)

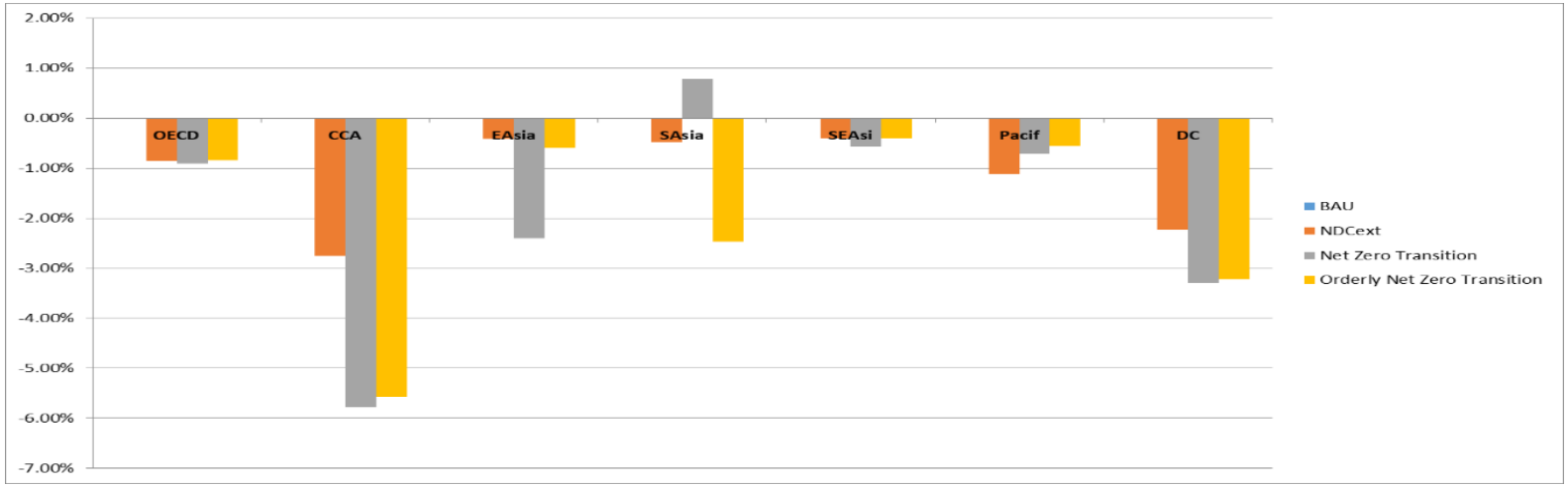


Orange (NDC Extension), Grey (Net Zero Transition), Yellow (Orderly Net Zero Transition)

Changes in Real GDI (2022–2050)

- Necessity of understanding real GDI to reflect the terms of trade better
- A similar result to changes in real GDP
- Positive effects of the international carbon market in reducing the real GDI losses in Asia in all regions, except South Asia
- Despite slightly lower real GDI relative to BAU level, much larger emissions reductions can be achieved

Changes in Real GDI (2022–2050) by Scenario (% difference from BAU)



Orange (NDC Extension), Grey (Net Zero Transition), Yellow (Orderly Net Zero Transition)

Changes in Real GDP and Real GDI (2022–2050)

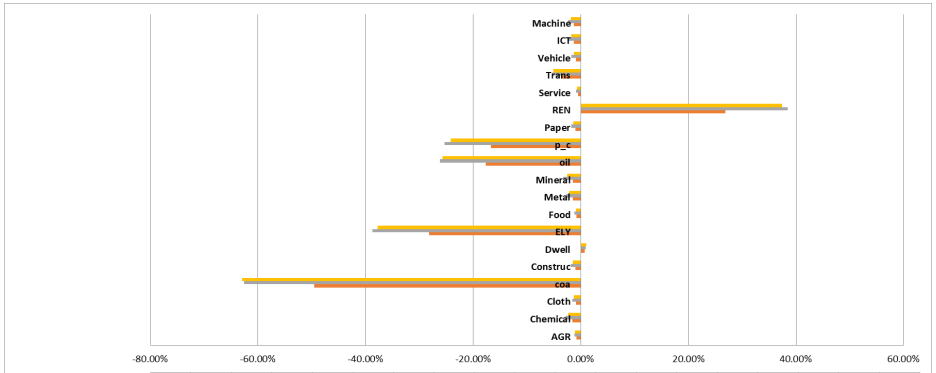
- Losses in real GDI smaller than losses in real GDP in OECD, East Asia, and Southeast Asia in all transition scenarios ⇔ losses in real GDP smaller than losses in GDI in DC and CCA (compare to BAU)
- South Asia and the Pacific: Mixed results:
  - South Asia: (Changes in real GDI 〉 changes in real GDP) under NDC Extension and Net Zero scenario
  - The Pacific: (Changes in real GDI 〉 changes in real GDP) only under the NDC Extension Scenario

Region	NDC Extension	Net Zero Transition	Orderly Net Zero Transition
OECD	−1.11% (−0.86%)	−1.14% (−0.90%)	−1.09% (−0.84%)
CCA	−0.59% (−2.75%)	−2.84% (−5.77%)	−2.78% (−5.57%)
East Asia	−0.63% (−0.42%)	−3.00% (−2.41%)	−1.38% (−0.60%)
South Asia	−1.48% (−0.49%)	0.22% (0.79%)	−2.24% (−2.46%)
Southeast Asia	−0.63% (−0.40%)	−0.74% (−0.57%)	−0.57% (−0.40%)
Pacific	−1.95% (−1.11%)	0.22% (−0.71%)	0.18% (−0.56%)
Developing Country	−1.09% (−2.23%)	−2.00% (−3.30%)	−1.94% (−3.21%)
Note: Real GDI in parenthesis ( ); % difference from BAU level			

Changes in Production and Investment (2022–2050) by sector

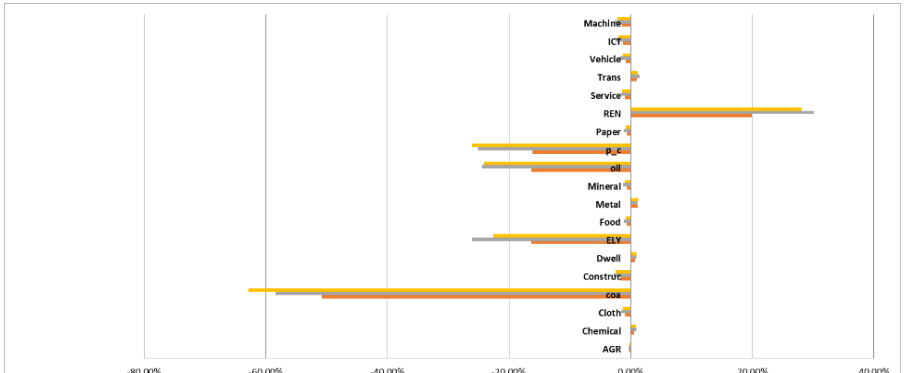
- **(Production)** Production losses relative to the BAU level in all sectors, except for the renewable and dwelling sectors
- Significant production losses, especially in fossil-fuel-related industries (coal, non-renewable electricity, oil, gas, and gas distribution) ⇔ huge increase in production in renewable energy sector
- **(Investment)** A similar trend to changes in production. Some increase in investment (though production losses) relative to the BAU level in additional sectors, such as transport, metal, and chemical

Changes in Production (2022–2050)



	AGR	Chemical	Cloth	coa	Construc	Dwell	ELY	Food	Metal	Mineral	oil	p_c	Paper	REN	Service	Trans	Vehicle	ICT	Machine
Orderly Net Zero Transition	-1.08%	-2.31%	-1.27%	-62.94%	-1.47%	0.99%	-37.82%	-0.92%	-2.16%	-2.58%	-25.74%	-24.20%	-1.42%	37.43%	-0.71%	-5.10%	-1.32%	-1.78%	-1.87%
Net Zero Transition	-1.16%	-2.85%	-1.59%	-62.54%	-1.82%	0.96%	-38.76%	-1.18%	-2.68%	-3.28%	-26.22%	-25.28%	-1.77%	38.49%	-0.93%	-5.29%	-1.77%	-2.31%	-2.32%
NDCext	-0.79%	-1.54%	-0.88%	-49.57%	-1.03%	0.77%	-28.21%	-0.78%	-1.49%	-1.51%	-17.65%	-16.74%	-1.04%	26.89%	-0.54%	-3.69%	-0.94%	-1.27%	-1.31%
BAU																			

Changes in Investment (2022–2050)

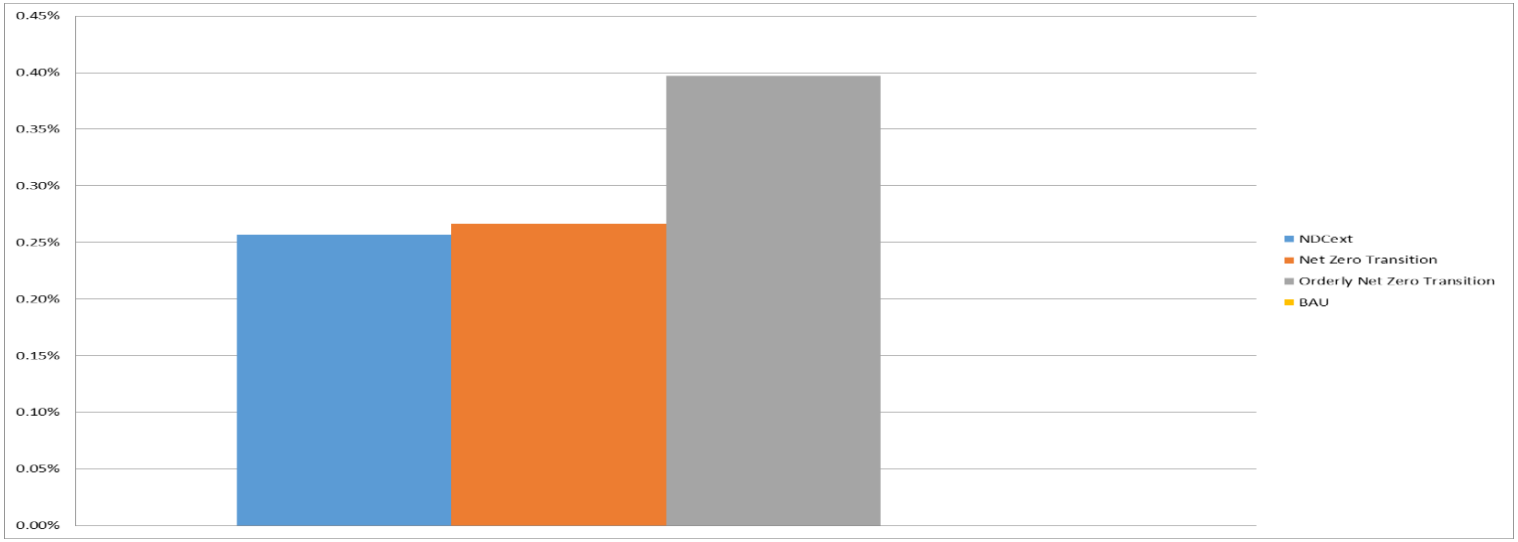


	AGR	Chemical	Cloth	coa	Construc	Dwell	ELY	Food	Metal	Mineral	oil	p_c	Paper	REN	Service	Trans	Vehicle	ICT	Machine
Orderly Net Zero Transition	-0.21%	0.86%	-1.21%	-62.82%	-2.43%	0.96%	-22.63%	-0.81%	1.26%	-0.86%	-24.16%	-26.06%	-0.84%	28.11%	-1.34%	1.22%	-1.26%	-1.91%	-2.09%
Net Zero Transition	-0.34%	0.93%	-1.52%	-58.37%	-2.78%	0.94%	-26.05%	-1.09%	1.12%	-1.20%	-24.42%	-25.08%	-1.12%	30.09%	-1.60%	1.45%	-1.77%	-2.47%	-2.56%
NDCext	-0.22%	0.54%	-0.88%	-50.77%	-1.64%	0.72%	-16.40%	-0.68%	1.18%	-0.60%	-16.30%	-16.09%	-0.58%	19.90%	-0.96%	1.08%	-0.79%	-1.23%	-1.46%
BAU																			

Changes in Employment (2022–2050)

- Positive increase in total global employment (skilled and unskilled combined) in all scenarios
- Both Net Zero Transition scenarios indicate better results compared to NDC Extension
- The largest positive changes in total global employment under the Orderly Net Zero Transition

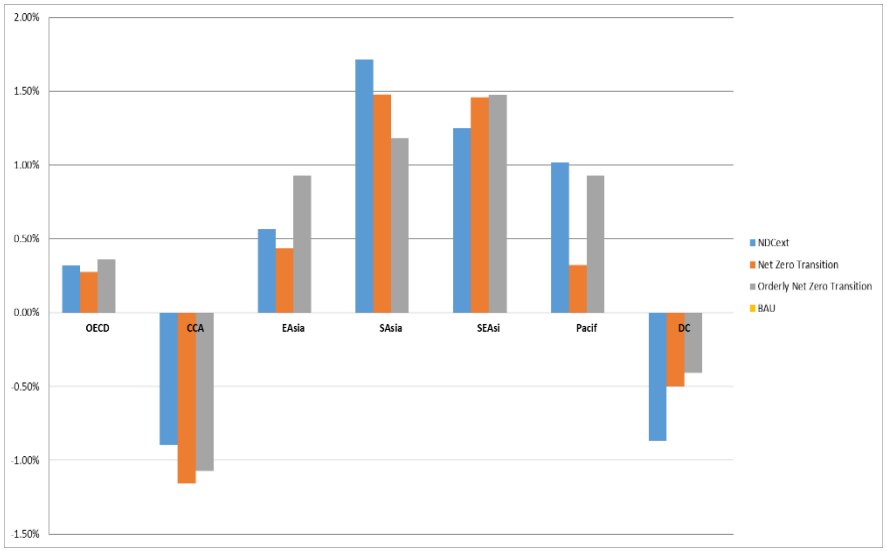
Changes in total employment (2022–2050) by Scenario (% difference from BAU level)



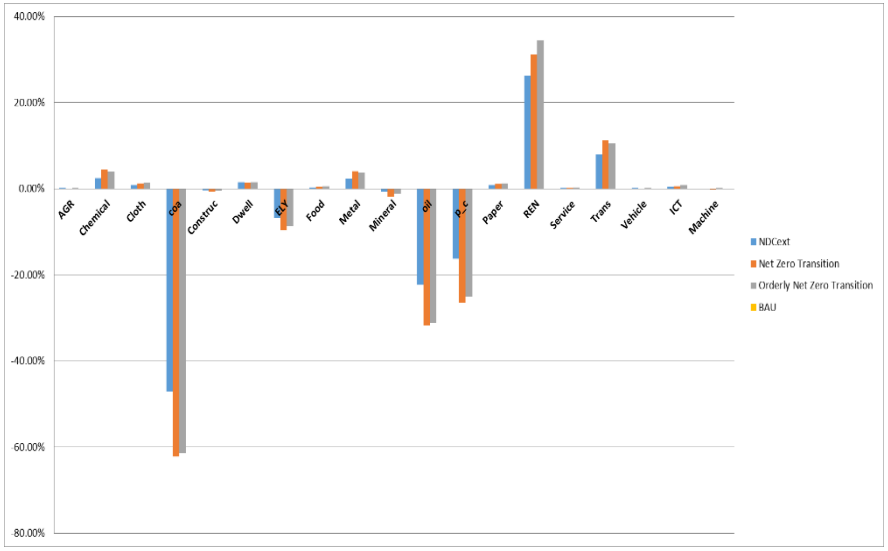
Changes in Employment (2022–2050) by region and sector

- Benefits of low-carbon transition to the developing Asian regions, except for the CCA region
- Positive impacts of an international carbon market in Asia in most developing Asian regions
- Significant decrease in the employment of fossil-fuel-related and carbon-intensive industries ⇔ significant increase in renewable electricity sector ➔ Sectoral reallocation of employment

Changes in total employment (skilled and unskilled) by region (2022–2050) (% difference from BAU level)



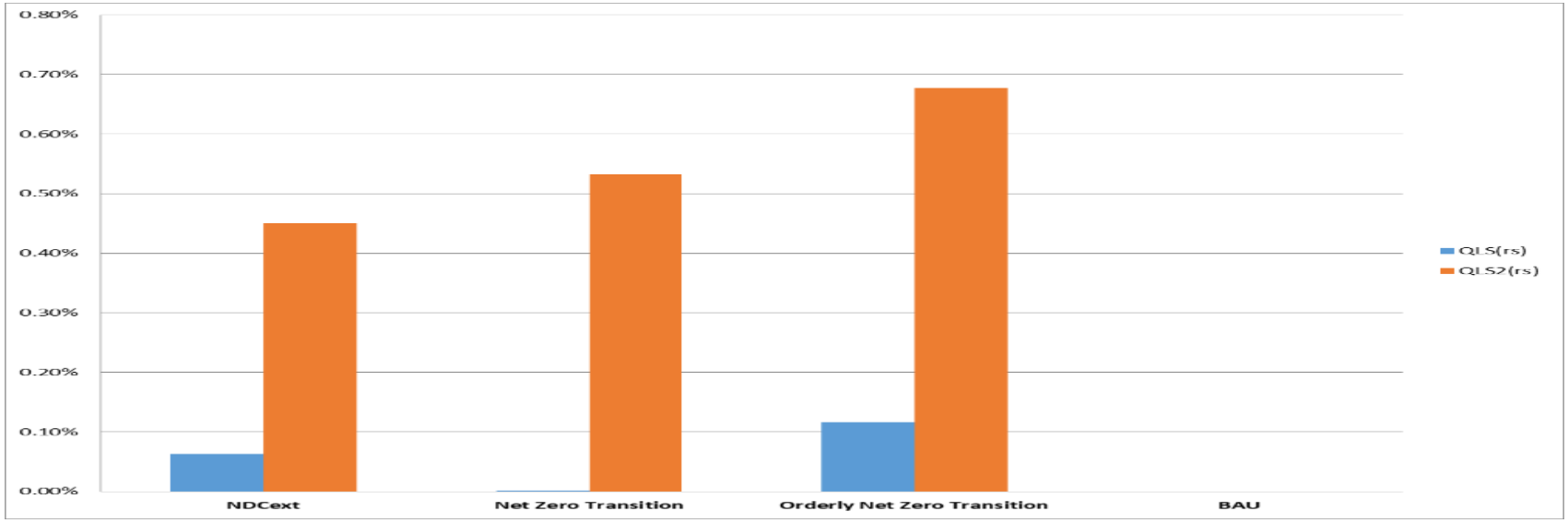
Changes in total labor (skilled and unskilled) by sector (2022–2050) (% difference from BAU level)



Changes in Skilled and Unskilled labor (2022–2050)

- Positive impacts on the payments of skilled and unskilled labors in general
- Larger positive impacts on the unskilled labor compared to the skilled labor in all scenarios
- Unskilled labor: relatively more influenced by the low-carbon transition
- Positive impacts of an international carbon market in Asia on both skilled and unskilled labor

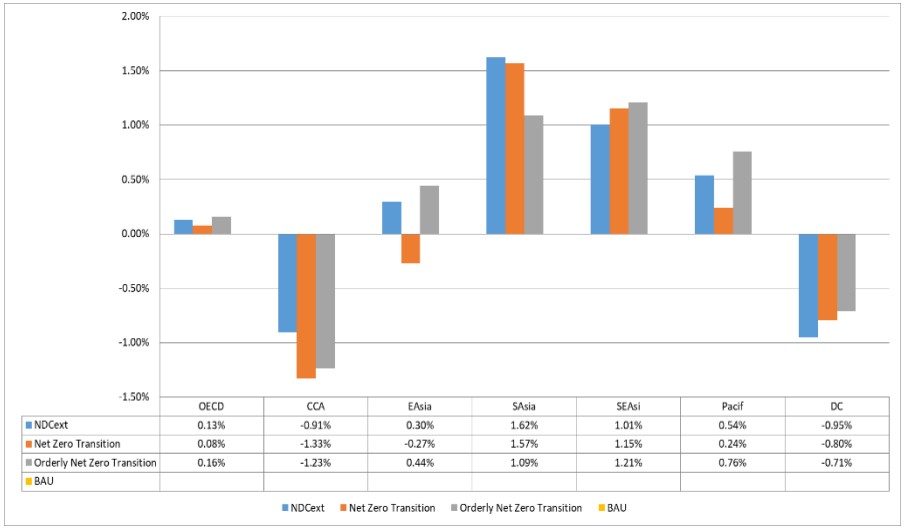
Changes in skilled and unskilled labor (2022–2050) by scenario (% difference from BAU level)



Changes in Skilled and Unskilled (2022–2050) by region

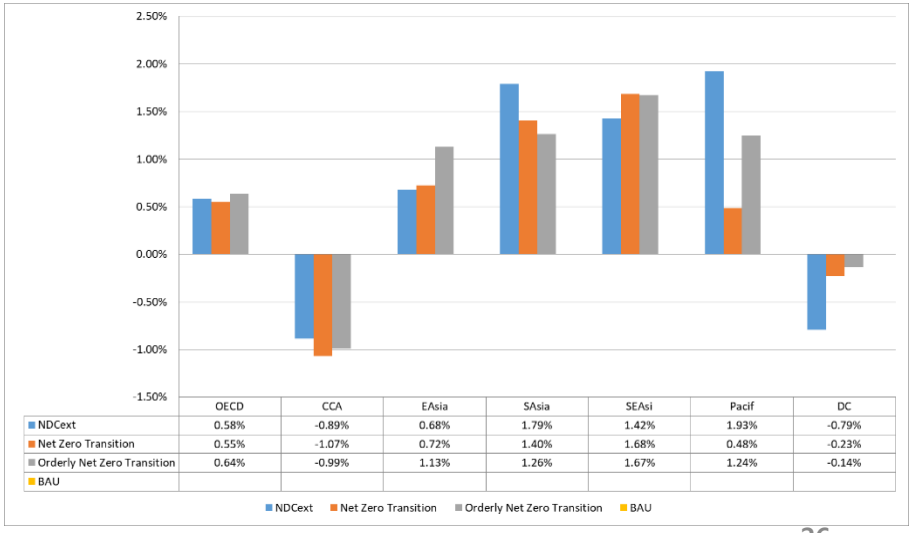
- (Skilled labor) gains from the mitigation efforts and carbon pricing in Asian regions, excl. CCA
- Largest gains in skilled labor (relative to BAU level) in South Asia under NDC Extension and Net Zero Transition Scenario ⇔ Losses in skilled employment in CCA and DC region
- Negative impacts of transitions on the payments to unskilled labor in CCA and DC regions
- Relatively better outcome under the Orderly Net Zero Transition compared to the Net Zero Transition

Changes in Skilled Labor by region (2022–2050)
(% difference from BAU level)



	OECD	CCA	EAsia	SAsia	SEAsi	Pacif	DC
NDCext	0.13%	-0.91%	0.30%	1.62%	1.01%	0.54%	-0.95%
Net Zero Transition	0.08%	-1.33%	-0.27%	1.57%	1.15%	0.24%	-0.80%
Orderly Net Zero Transition	0.16%	-1.23%	0.44%	1.09%	1.21%	0.76%	-0.71%
BAU							

Changes in Unskilled Labor by region (2022–2050)
(% difference from BAU level)

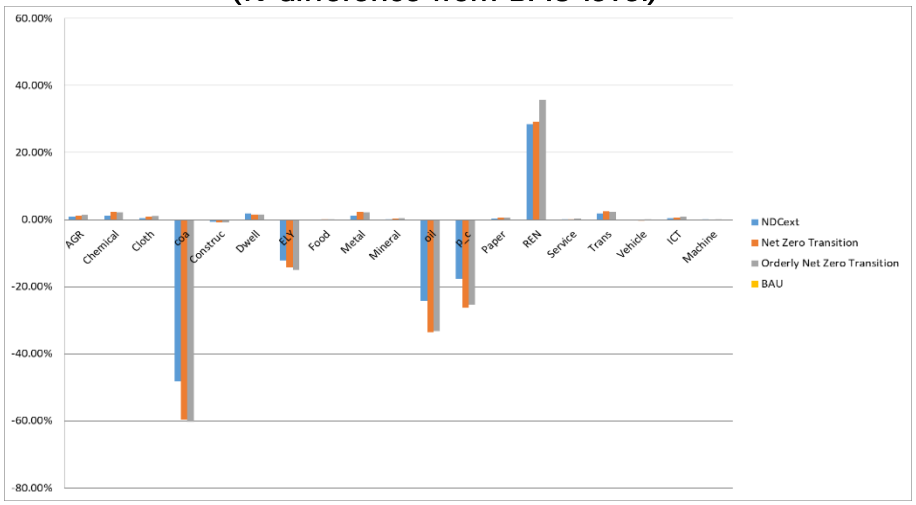


	OECD	CCA	EAsia	SAsia	SEAsi	Pacif	DC
NDCext	0.58%	-0.89%	0.68%	1.79%	1.42%	1.93%	-0.79%
Net Zero Transition	0.55%	-1.07%	0.72%	1.40%	1.68%	0.48%	-0.23%
Orderly Net Zero Transition	0.64%	-0.99%	1.13%	1.26%	1.67%	1.24%	-0.14%
BAU							

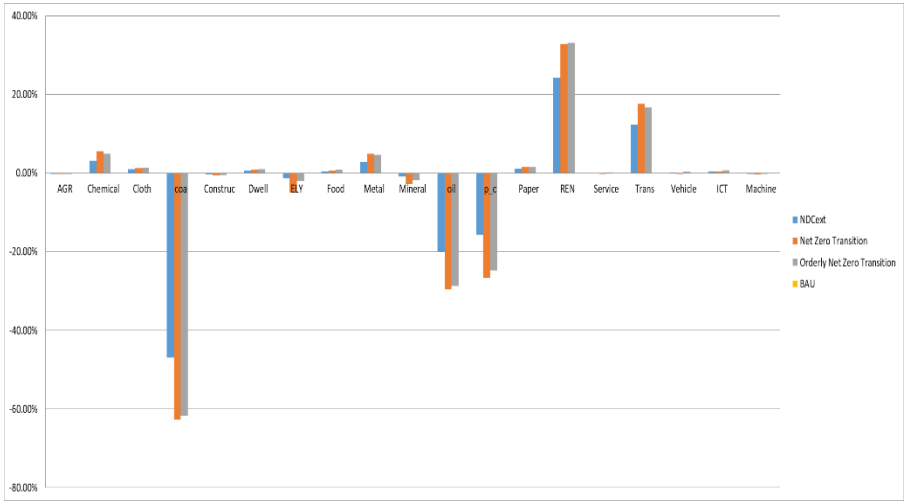
Changes in Skilled and Unskilled (2022–2050) by sector

- Sectoral reallocation of employment of skilled and unskilled labor
  - Substantial losses of both skilled and unskilled labor largely focused on fossil-fuel-related industries ⇔ Significant increase in the renewable electricity sector
- Generally positive changes in other sectors though varying size (relatively larger increase in transport)
- Further losses of skilled and unskilled labor in fossil-fuel-related industries to achieve Net Zero

Changes in Skilled Labor by sector (2022–2050)
(% difference from BAU level)



Changes in Unskilled Labor by sector (2022–2050)
(% difference from BAU level)



Sensitivity Analysis

- Sensitivity Analysis to check the robustness of the results
- Scenario Setting 1: Different learning rates
  - Baseline learning rate of 15% ⇔ Two alternative learning rates of 12.5% and 17.5%
- Scenario Setting 2: Reduced elasticities of substitution
  - Elasticities of substitution between electricity and fossil fuel, Elasticities of substitution between renewable and non-renewable electricity:
    4 (baseline) ➔ 2

Sensitivity Analysis: Different Learning Rate for Renewables

- Decrease (Increase) in learning rate from 15% (LR15) to 12.5% (LR125) (from 15% to 17.5%) ➔ larger (smaller) real GDP losses and real GDI losses relative to the BAU level
- Negative impacts on real GDP and GDI ➔ Mitigated with a higher learning rate for clean energies
- Higher learning rate ➔ smaller real GDP and the real GDI losses relative to the BAU level in all regions

Changes in Real GDP and Real GDI (2022–2050) by different learning rates (% difference from BAU level)

(RGDP)	NDCext	Net Zero	Orderly Net Zero
LR125	−1.40%	−1.90%	−1.66%
LR15	−1.01%	−1.60%	−1.37%
LR175	−0.57%	−1.22%	−1.00%

RGDI	NDCext	Net Zero	Orderly Net Zero
LR125	−1.41%	−1.90%	−1.66%
LR15	−1.01%	−1.60%	−1.37%
LR175	−0.58%	−1.22%	−1.00%

Sensitivity Analysis: Different Learning Rate for Renewables

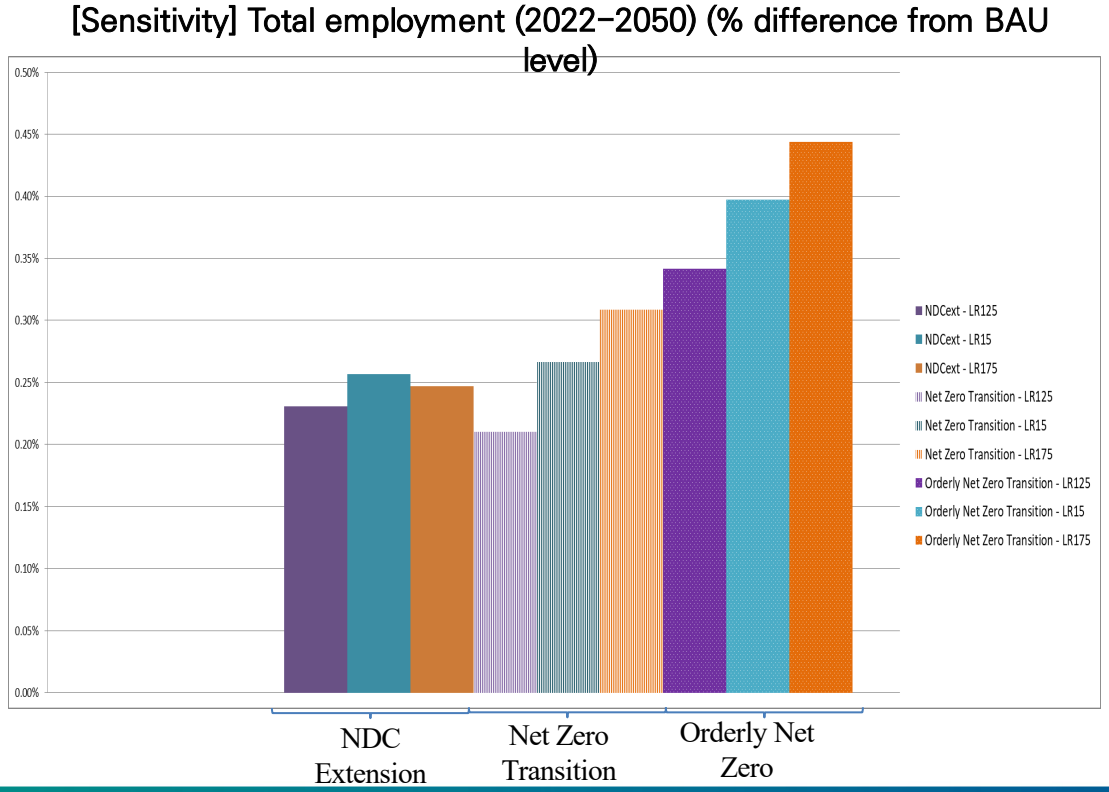
Sectoral Production by Scenario and Learning Rate (% difference from BAU level)

	NDCext			CPrice			ETS		
	LR125	**LR15**	**LR175**	**LR125**	**LR15**	**LR175**	**LR125**	**LR15**	**LR175**
AGR	-1.20%	-0.79%	-0.46%	-1.56%	-1.16%	-0.75%	-1.48%	-1.08%	-0.64%
Chemical	-2.26%	-1.54%	-0.83%	-3.48%	-2.85%	-2.14%	-2.88%	-2.31%	-1.65%
Cloth	-1.35%	-0.88%	-0.48%	-2.05%	-1.59%	-1.12%	-1.70%	-1.27%	-0.82%
coa	**-54.54%**	**-49.57%**	**-41.77%**	**-63.95%**	**-62.54%**	**-60.15%**	**-64.31%**	**-62.94%**	**-60.58%**
Construc	-1.46%	-1.03%	-0.58%	-2.16%	-1.82%	-1.40%	-1.79%	-1.47%	-1.07%
Dwell	1.06%	0.77%	0.50%	1.07%	0.96%	0.95%	1.11%	0.99%	0.97%
ELY	**-31.60%**	**-28.21%**	**-22.82%**	**-38.91%**	**-38.76%**	**-37.80%**	**-37.87%**	**-37.82%**	**-36.97%**
Food	-1.14%	-0.78%	-0.50%	-1.53%	-1.18%	-0.83%	-1.25%	-0.92%	-0.58%
ICT	-1.81%	-1.27%	-0.72%	-2.78%	-2.31%	-1.80%	-2.21%	-1.78%	-1.31%
Machine	-1.85%	-1.31%	-0.76%	-2.76%	-2.32%	-1.81%	-2.27%	-1.87%	-1.39%
Metal	-2.15%	-1.49%	-0.81%	-3.28%	-2.68%	-1.98%	-2.71%	-2.16%	-1.52%
Mineral	-2.28%	-1.51%	-0.71%	-4.07%	-3.28%	-2.35%	-3.28%	-2.58%	-1.73%
oil	**-20.13%**	**-17.65%**	**-14.25%**	**-26.28%**	**-26.22%**	**-25.71%**	**-25.73%**	**-25.74%**	**-25.39%**
p_c	**-18.94%**	**-16.74%**	**-13.62%**	**-24.79%**	**-25.28%**	**-25.79%**	**-23.67%**	**-24.20%**	**-24.82%**
Paper	-1.52%	-1.04%	-0.58%	-2.22%	-1.77%	-1.28%	-1.83%	-1.42%	-0.95%
REN	**38.15%**	**26.89%**	**16.86%**	**49.51%**	**38.49%**	**27.52%**	**47.28%**	**37.43%**	**27.27%**
Service	-0.81%	-0.54%	-0.28%	-1.19%	-0.93%	-0.64%	-0.95%	-0.71%	-0.43%
Trans	-4.75%	-3.69%	-2.47%	-5.83%	-5.29%	-4.59%	-5.63%	-5.10%	-4.42%
Vehicle	-1.39%	-0.94%	-0.50%	-2.16%	-1.77%	-1.34%	-1.67%	-1.32%	-0.92%

- Higher learning rates ➔ Lower production losses from carbon pricing in the carbon-intensive sectors (relative to BAU level)
- (With higher learning rate) those carbon-intensive sectors' absolute production reduced while the renewable sector's absolute production increased significantly

Sensitivity Analysis: Different Learning Rate for Renewables

- Higher learning rates ➔ Positively affect the total employment (% difference from BAU) when achieving Net Zero
- With higher learning rate (LR175), relatively larger increases in total employment when achieving Net Zero (Net Zero & Orderly Net Zero)



Sensitivity Analysis: Different Elasticities of Substitution

- Smaller elasticity of substitution parameter ➔ Larger real GDP and GDI losses relative to BAU
- Focusing on Asian regions, the smaller elasticity of substitution parameters lowers the real GDI relative to BAU level in all regions and scenarios with only one exception (Pacific region, Net Zero Transition scenario).

Changes in Real GDP and GDI (2022–2050) by the elasticity of substitution (% difference from BAU level)

(RGDP)	NDCext	Net Zero	Orderly Net Zero
LR15	−1.01%	−1.60%	−1.37%
LR15Sen05	−2.62%	−2.08%	−1.84%

RGDI	NDCext	Net Zero	Orderly Net Zero
LR15	−1.01%	−1.60%	−1.37%
LR15Sen05	−2.62%	−2.08%	−1.84%

Sensitivity Analysis: Different Elasticities of Substitution

Sectoral Production by Scenario and Learning Rate (% difference from BAU level)

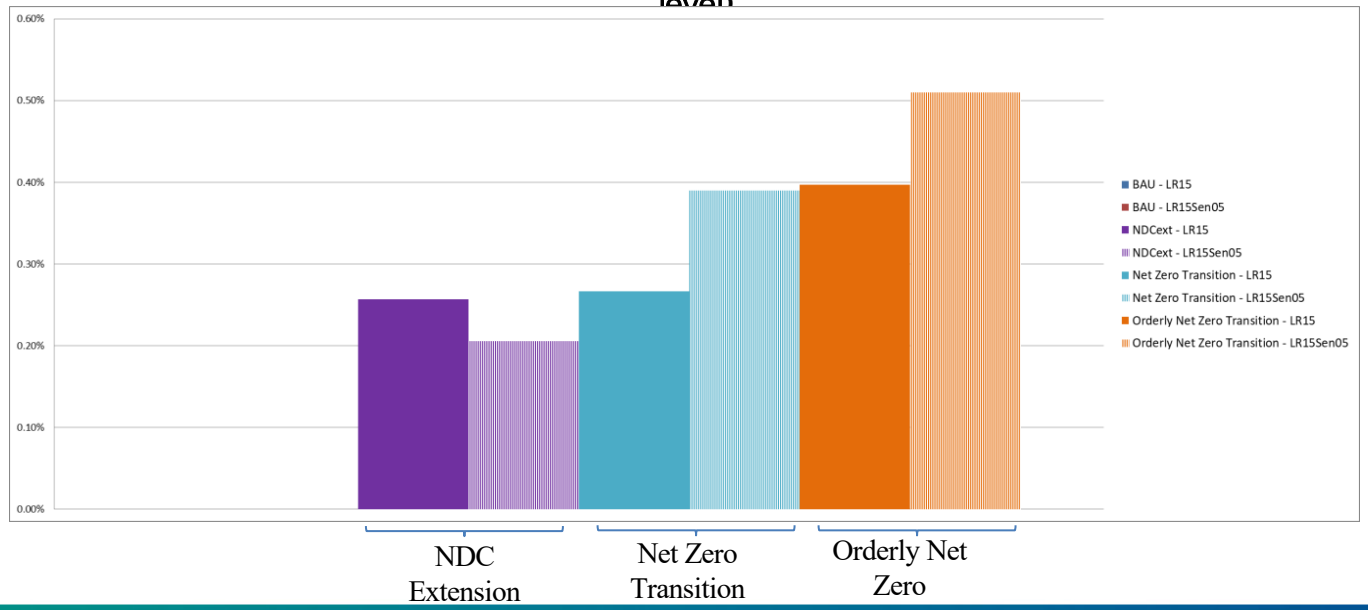
	NDC Extension		Net Zero Transition		Orderly Net Zero Transition	
	LR15	LR15Sen05	LR15	LR15Sen05	LR15	LR15Sen05
AGR	-0.79%	-2.96%	-1.16%	-2.19%	-1.08%	-2.14%
Chemical	-1.54%	-4.72%	-2.85%	-4.41%	-2.31%	-3.74%
Cloth	-0.88%	-3.37%	-1.59%	-2.91%	-1.27%	-2.47%
coa	**-49.57%**	**-60.93%**	**-62.54%**	**-60.14%**	**-62.94%**	**-60.38%**
Construc	-1.03%	-2.77%	-1.82%	-2.39%	-1.47%	-2.02%
Dwell	0.77%	3.57%	0.96%	2.66%	0.99%	2.70%
ELY	**-28.21%**	**-38.56%**	**-38.76%**	**-34.62%**	**-37.82%**	**-34.54%**
Food	-0.78%	-2.77%	-1.18%	-2.11%	-0.92%	-1.77%
ICT	-1.27%	-3.89%	-2.31%	-3.63%	-1.78%	-2.99%
Machine	-1.31%	-3.66%	-2.32%	-3.29%	-1.87%	-2.76%
Metal	-1.49%	-4.32%	-2.68%	-4.11%	-2.16%	-3.48%
Mineral	-1.51%	-4.77%	-3.28%	-5.31%	-2.58%	-4.34%
oil	**-17.65%**	**-26.90%**	**-26.22%**	**-24.17%**	**-25.74%**	**-23.92%**
p c	**-16.74%**	**-25.76%**	**-25.28%**	**-22.31%**	**-24.20%**	**-21.68%**
Paper	-1.04%	-3.23%	-1.77%	-2.89%	-1.42%	-2.46%
REN	**26.89%**	**8.84%**	**38.49%**	**8.38%**	**37.43%**	**7.89%**
Service	-0.54%	-1.69%	-0.93%	-1.39%	-0.71%	-1.13%
Trans	-3.69%	-8.33%	-5.29%	-6.52%	-5.10%	-6.40%
Vehicle	-0.94%	-3.04%	-1.77%	-2.64%	-1.32%	-2.11%

- (Absolute production of coal, oil, and petroleum and coal product) LR15 〈 LR15Sen05 in all scenarios.
- (LR15Sen05) Carbon-intensive sectors indicating larger reductions of production relative to the BAU level under NDC Extension scenario ⇔ percent reductions of production becoming less under two Net Zero scenarios

Sensitivity Analysis: Different Learning Rate for Renewables

- (Smaller elasticity of substitution parameters) Smaller percent increase in total employment relative to BAU level under the NDC Extension scenario ⇔ larger percent increase in total employment relative to BAU level under the two Net Zero Transition scenarios
- (Skilled) a smaller percent increase in skilled labor compared to the baseline in all three scenarios ⇔ (Unskilled) a higher percent increase in unskilled labor compared to the baseline in all three scenarios

[Sensitivity] Total employment (2022–2050) (% difference from BAU level)



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PART V

Key Findings and Implications

Key Findings and Implications

- Achieving Net Zero would incur some GDP and GDI losses relative to BAU level, but the size of losses would be much smaller than emissions reductions
- The low-carbon transition would bring a general but slight decrease in production, except for fossil-fuel-related sectors and renewable. The changes in investment showed similar results, but additional sectors, such as transport, metal, and chemical, experienced some positive investment changes (though negative production changes) relative to the BAU level
- Total employment would be benefited by low carbon transitions
    - Both skilled and unskilled employment increase in all scenarios
    - International carbon market in Asia could support employment in many Asian regions

Key Findings and Implications

- Sectoral reallocation of skilled and unskilled labor
  - Significant decrease in fossil-fuel-related industries (coal, oil, gas, and gas distribution, non-renewable electricity, petroleum and coal product) ⇔ Substantial increase in the renewable energy sector
  - Policy actions and social safety net to embrace and support those fossil-fuel and carbon-intensive sectors
- Particularly, Orderly Net Zero transition with an international carbon market in Asia could benefit the economies and employment levels when achieving the Net Zero target compared to carbon prices only.
  - Regional and sectoral discrepancies for introducing international carbon market are necessary to be considered
- Necessary to consider and support Just Transition, which reduces the potential social and economic challenges, such as inequality, poverty and, job losses, under low-carbon transition pathways

Key Findings and Implications

- Various policy measures, including financial and technological supports, for industries likely to receive damages from low-carbon transition, particularly fossil-fuel-related industries, and their employment
- Re-education/training of unemployed workers, especially unskilled, to facilitate the sectoral reallocation of employment
- Consider Stranded assets being vulnerable to low-carbon transition and Net Zero transition
- A wide range of supportive measures, including transfer of technology and finance, within and among countries
- Necessity of understanding potential co-benefits, such as health benefits, reducing greenhouse gas emissions and low-carbon transition

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PART VI

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