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Decoupling analysis between economic growth and CO_2 emissions: Insights from estimation of consumption-based CO_2 emissions

Systems Analysis Group

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Background and purpose of this analysis

[Background]

- Historically a strong positive correlation between GDP and CO_2 has been observed globally. Some argue that positive correlation has vanished recent years, meaning that GDP growth and CO_2 emissions might have “decoupled”. However, possibility has been pointed out that developed countries might avoid emissions by importing CO_2 embodied in goods and services through international trade, instead of producing them within their countries (OECD analysis until 2011 (2015)).

[Purpose of this analysis]

- It is important to show various data on “decoupling” between GDP and CO_2 emissions, but more important to understand the factors and to draw implications for future projection or policy-making.

- In this analysis of major countries emissions in global economy, we estimate consumption-based* CO_2 emissions from energy by nation using latest statistics, and analyze their factors and time-series changes. CO_2 emissions embodied in trade are estimated between 2000 and 2014 to estimate consumption-based CO_2, which are compared with production-based CO_2. In nations with developed service economy, apparent CO_2 emissions (i.e. production-based) might look small, however consumption-based CO_2 emissions that include emissions embodied in trade (which are not considered in statistic emissions counting), should be included in analysis.

*According to IPCC(2014), OECD(2015) or IMF(2018), the term “Consumption-based” is used in this analysis. To be precise, the term should be “CO_2 Emissions Embodied in Final Demand and Net Imports”.

Production-based CO_2 emissions: CO_2 emissions generated inside the territory of the country, regardless of the kind of relevant activities. Equivalent to CO_2 emissions in common statistics.

Consumption-based CO_2: CO_2 emissions generated to meet the domestic demand (consumption and investment) of the country, which can be estimated by adding/subtracting CO_2 emissions embodied in imported/exported goods on/from production-based CO_2.

Definition of “Decoupling”

	GDP increases, while primary energy consumption or CO_2 intensity (CO_2 emissions divided by GDP) decreases (GDP elasticity: higher than 0 and less than 1.0)	GDP increases, while primary energy consumption or CO_2 emissions decrease (GDP elasticity: less than or equal to 0)
Handrich[1)]	weak decoupling	strong decoupling
PwC[2)]	relative decoupling	absolute decoupling

Unless otherwise stated, these cases are mentioned as “decoupling” in this analysis.

1) Handrich et al.(2015) Turning point: Decoupling Greenhouse Gas Emissions from Economic Growth
2) PwC(2013) Decarbonisation and the Economy

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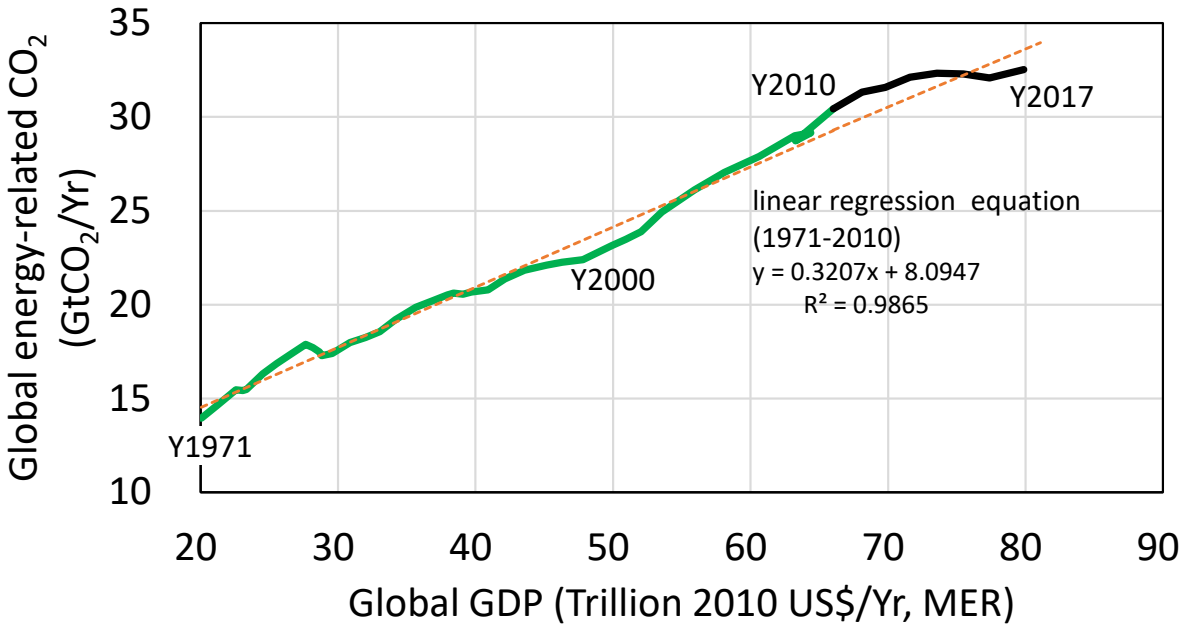
1. Global CO_2 Emissions Outlook
2. Analysis of CO_2 emissions from major countries: Implications from consumption-based CO_2 emissions
3. Conclusion

1. Decoupling trend in global economy and major countries

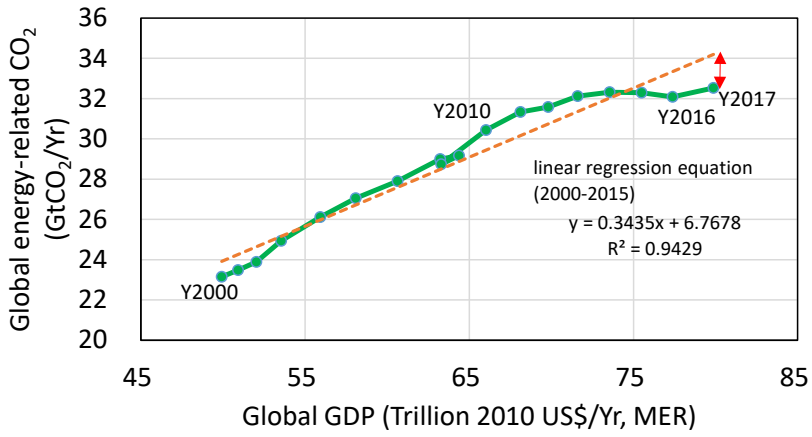
1.1 Correlation between global GDP growth and CO_2 emissions



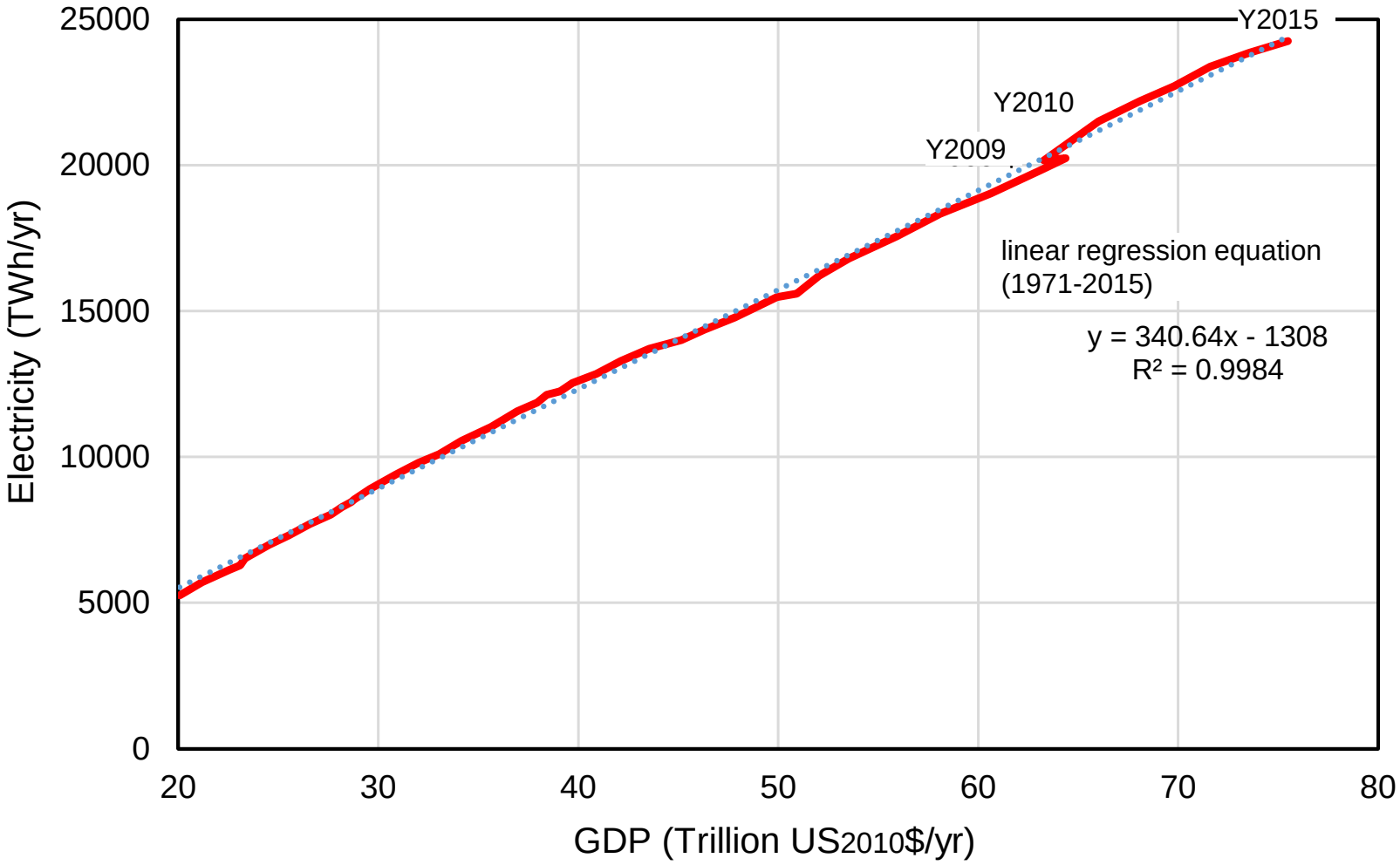
	GDP elasticity
1971-2015	0.63
2000-2015	0.81
2009-2015	0.66

Note:
IEA statistics(2017) except 2016-2017, which are complemented with a calculation using IEA preliminary 2017 for CO_2 and IMF(2018 Apr.) for GDP

Fundamentally, a strong positive correlation between global GDP and CO_2 emissions is observed.
Emissions were almost flat between 2013 and 2016, leading to an argument of global decoupling, but eventually increased again in 2017.
RITE has been pointing out that, based on the long-term analysis, emissions increased too fast for the world demand during 2009-2013 and that the flattening between 2013 and 2016 may be caused by a kind of economic counter-action for the too much CO_2 emitting activities during 2009-2013, adjusting the demand-supply relationship.



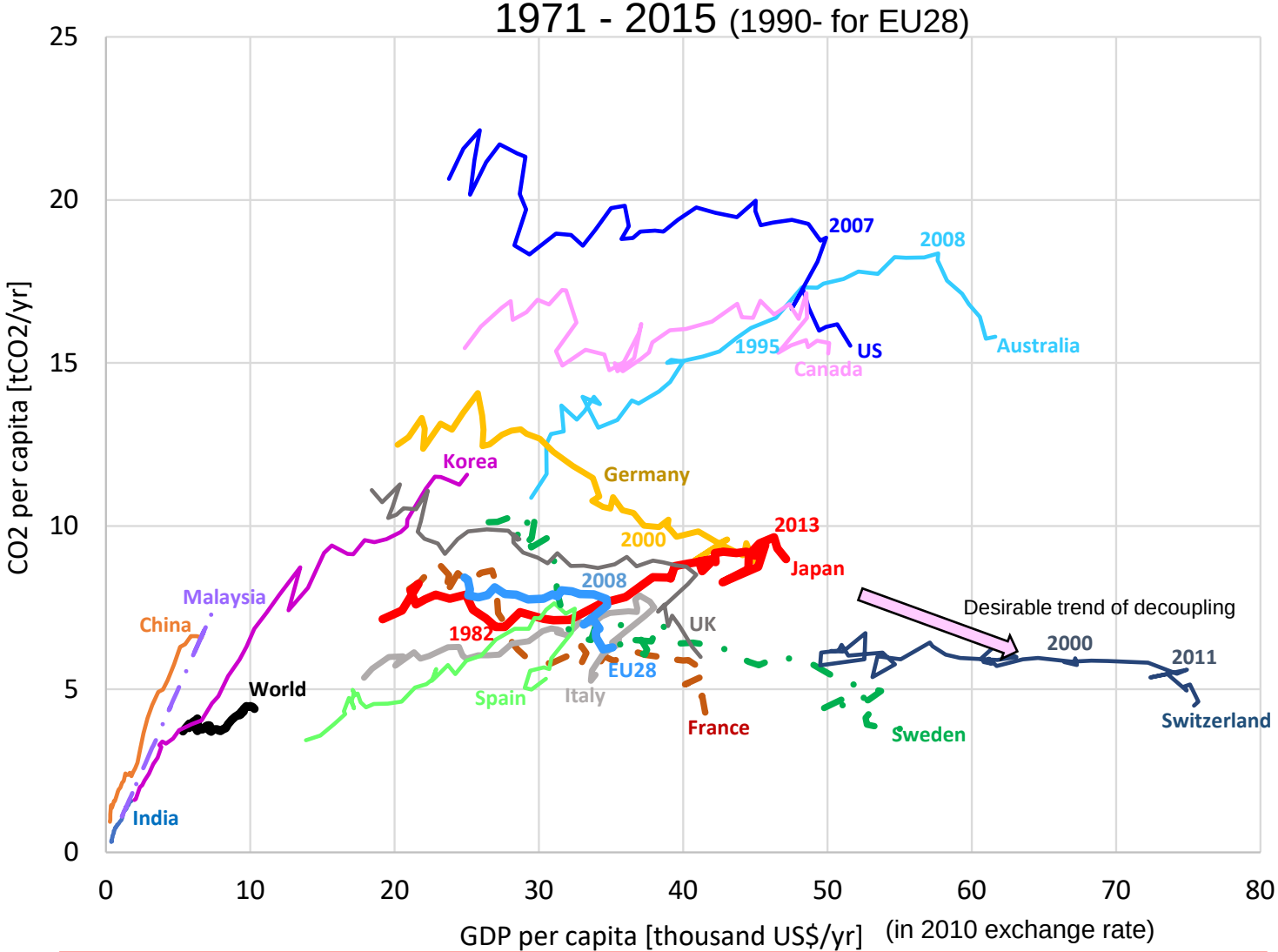
1.2 Correlation between global GDP and electricity consumption



Source) IEA Statistics 2017

Especially, a correlation between global GDP and electricity consumption remains strongly positive.

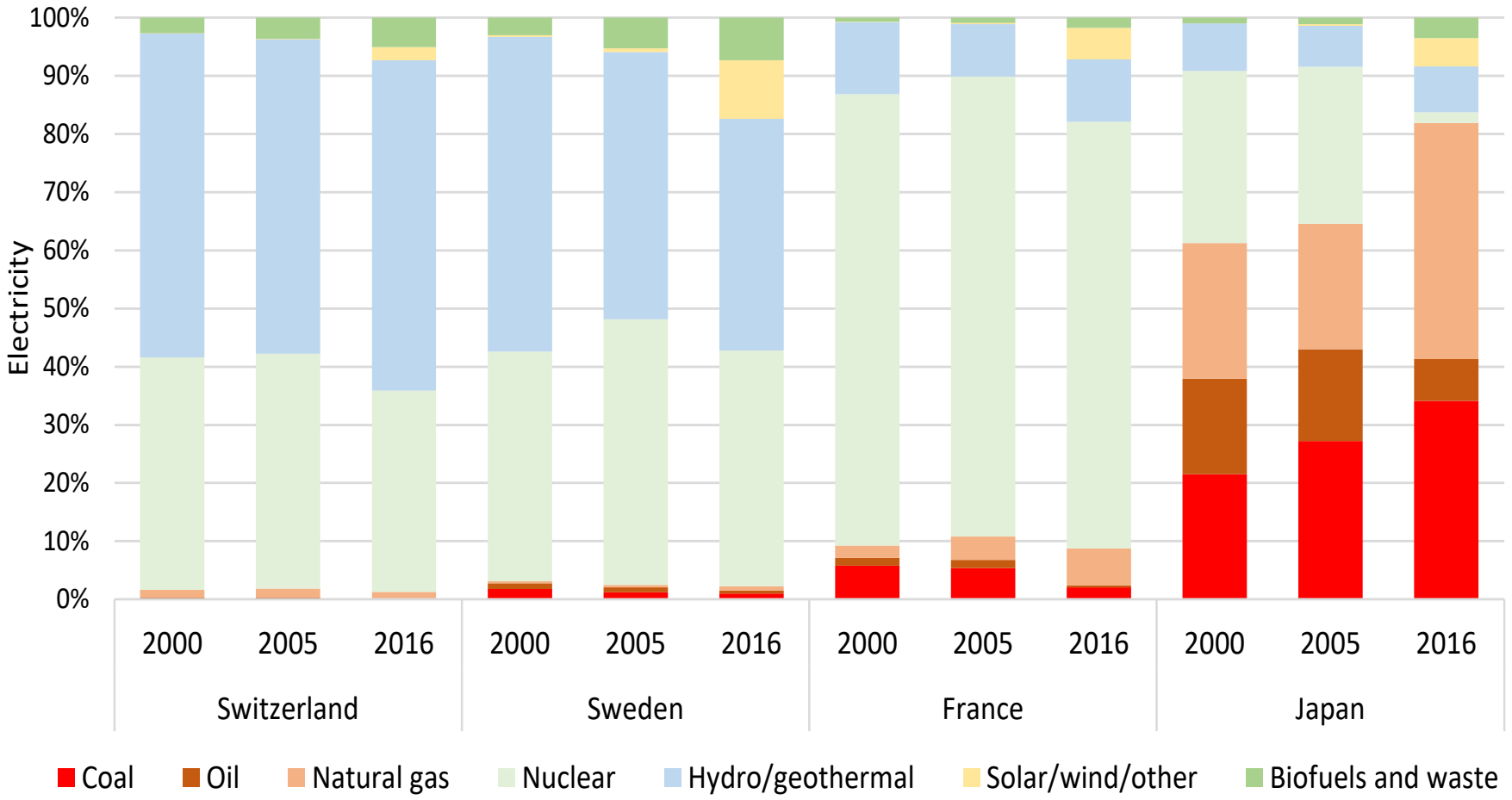
1.3 Relationship between GDP and CO_2 emissions in major countries



- Several developed countries seem to follow decoupling trend.
- On the other hand, CO_2 emissions per capita vary widely among countries with similar GDP per capita, due to heterogeneity in their land area and industrial structure.
- Switzerland, Sweden and France are thought to be on the leading edge of decoupling trend because of their small CO_2 emissions despite their relatively high GDP. But their emission levels have conventionally been low due to high ratios of hydro and nuclear.
- Increase of historical CO_2 emissions by China is much steeper than forerunners.
- Detailed investigation is required to conclude whether these trends are truly contributing to global decoupling, considering international sharing of industry and domestic industrial structure .

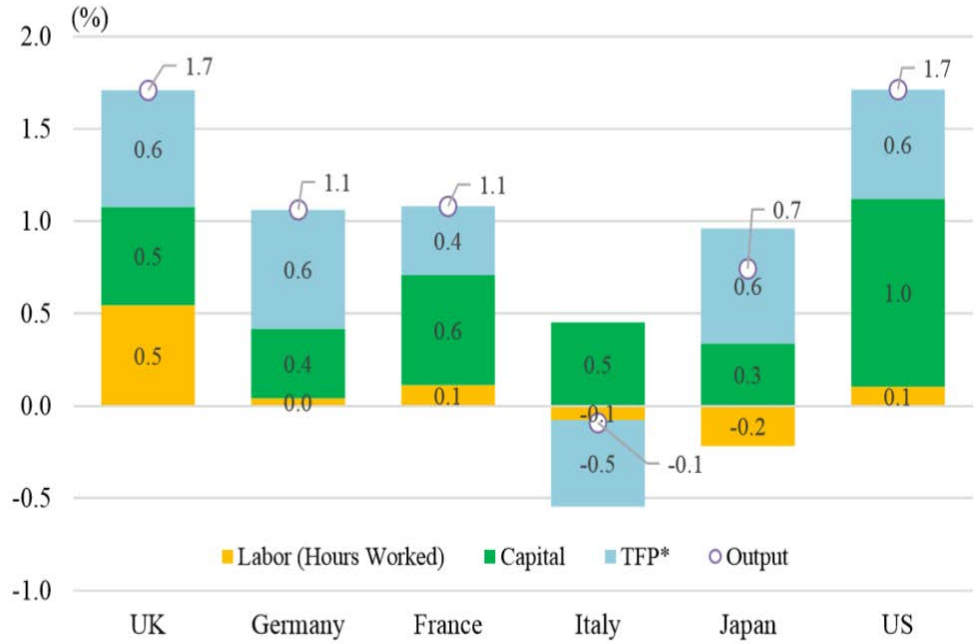
Although several developed countries appear to be following decoupling trend as a whole, it is hard to reach a clear conclusion as various and complicated factors are entangled.

1.3 Relationship between GDP and CO_2 emissions in major countries: Energy mix of Switzerland, Sweden, France and Japan (ref)



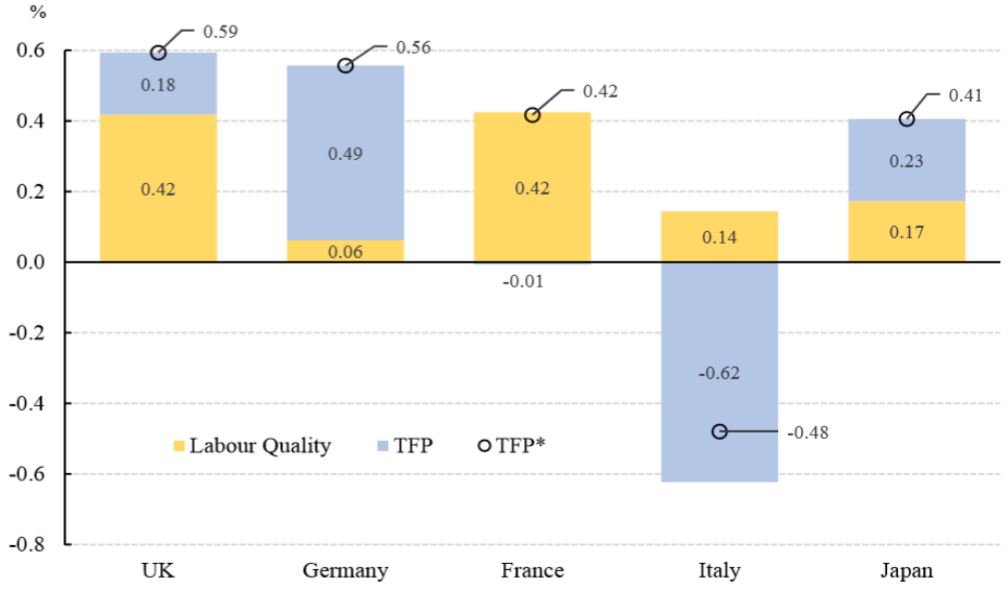
CO_2 emissions from Switzerland, Sweden and France are relatively small despite their relatively high GDP. These trends build upon conventionally high ratios of nuclear and hydro, and these countries are not reducing their ratios of fossil fuel power generation after 2000.

1.3 Relationship between GDP and CO_2 emissions in major countries: Economic growth factor of UK and Germany (ref)



Source: Koji Nomura,
https://www.dbj.jp/ricf/pdf/research/DBJ_RCGW_DP60.pdf

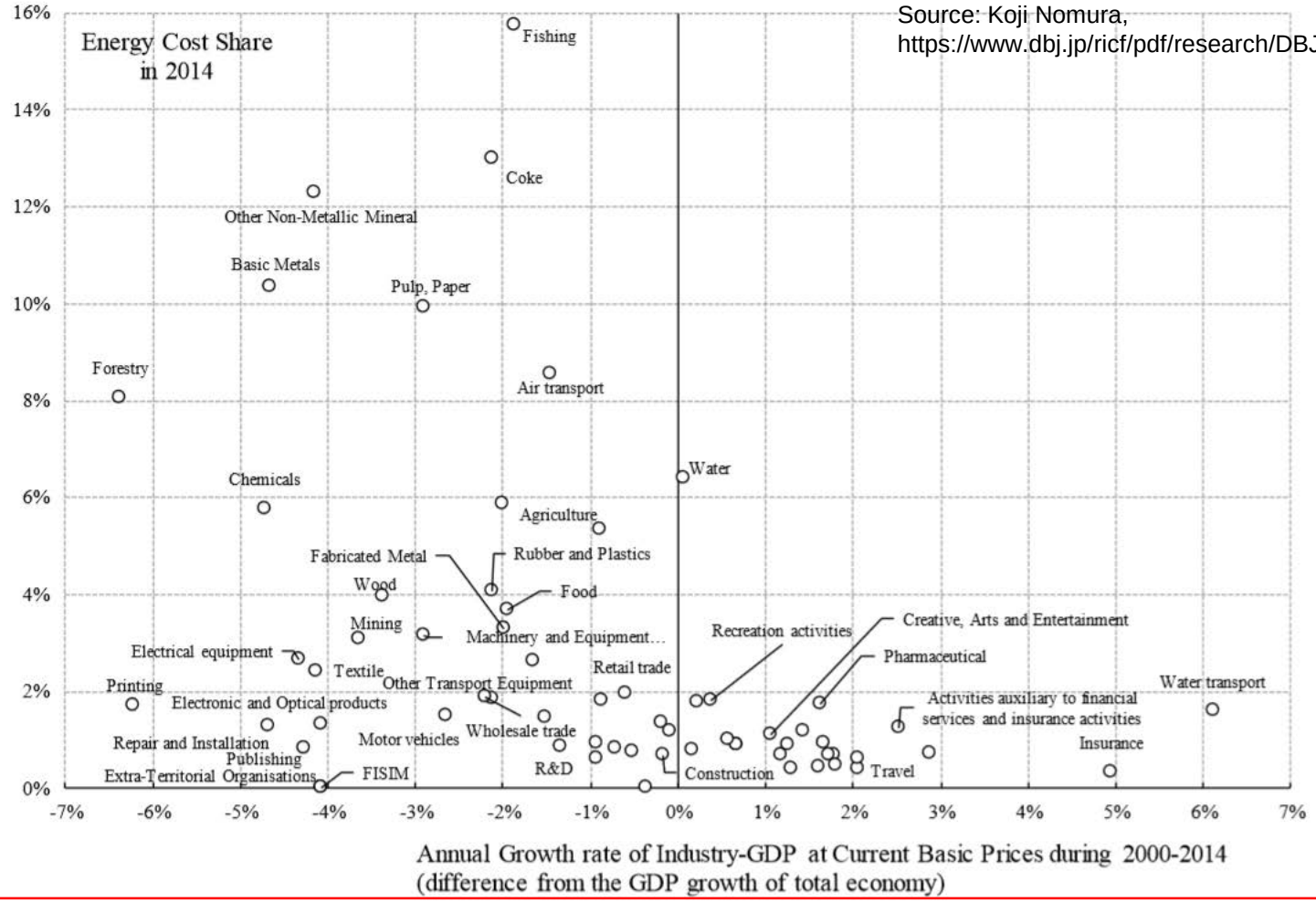
- **Presumed factors of GDP growth are increased workforce caused by an immigration policy for the case of UK, and increased labor quality by immigrants for the cases of UK and France.**
- **Decreasing employment of blue-collar caused by increased immigrants and declining manufacturing industry are pointed out as one of the factors of Brexit. Similar social conditions are seen also in Sweden.**



1.3 Relationship between GDP and CO_2 emissions in major countries: GDP growth by industrial sector in UK (ref)

Energy cost share (2014) and growth rate (2000-2014) by industry

Source: Koji Nomura, https://www.dbj.jp/ricf/pdf/research/DBJ_RCGW_DP60.pdf

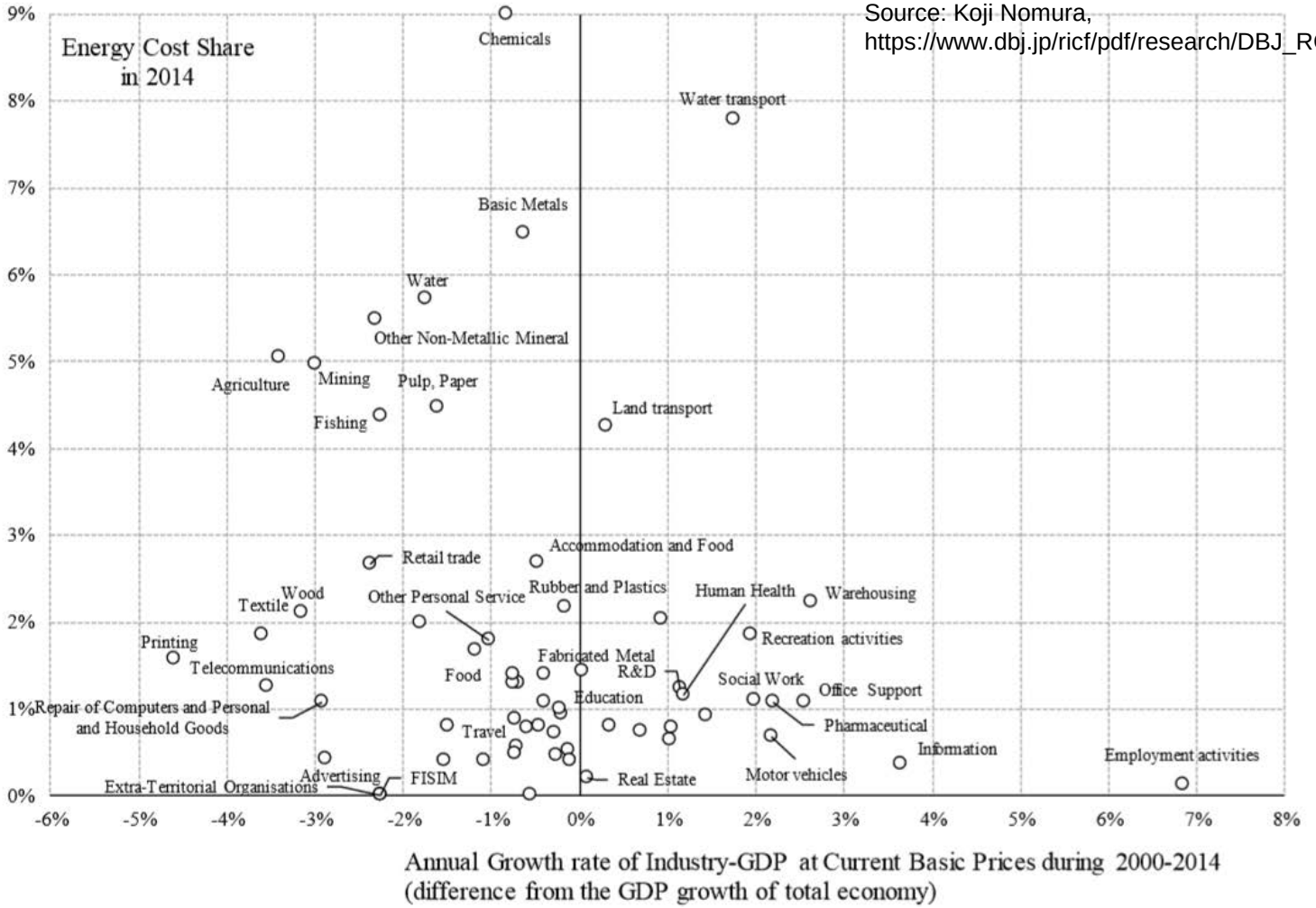


While insurance or financial services have achieved higher growth rate, energy-consuming industries such as manufacturing industry marked negative growth. Production supply has been transferring from domestic manufacturing to foreign countries, thus leading to a concern that global CO_2 emissions might not be reduced as a result. => Analysis of consumption-based CO_2 emission is essential.

1.3 Relationship between GDP and CO_2 emissions in major countries: GDP growth by industrial sector in Germany (ref)

Energy cost share (2014) and growth rate (2000-2014) by industry

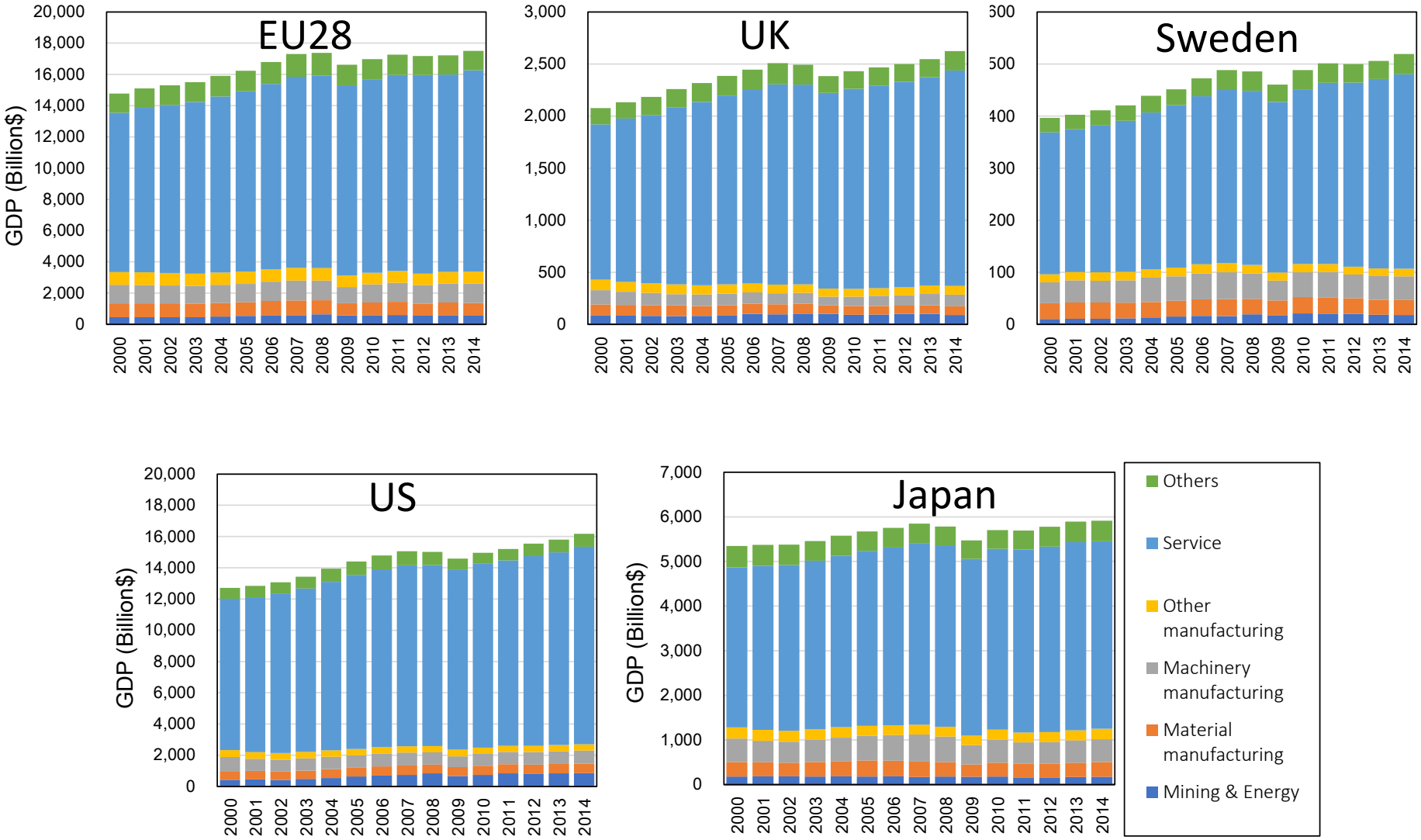
Source: Koji Nomura, https://www.dbj.jp/ricf/pdf/research/DBJ_RCGW_DP60.pdf



Higher growth rates have been achieved in office support or information, as well as motor vehicles. However, Germany has not achieved so much emissions reduction after 2000, and steady export of motor vehicles affected by relatively weaker euro seems to have contributed to its economic growth.

2. Analysis of CO_2 emissions from major countries: Implications from consumption-based CO_2 emissions

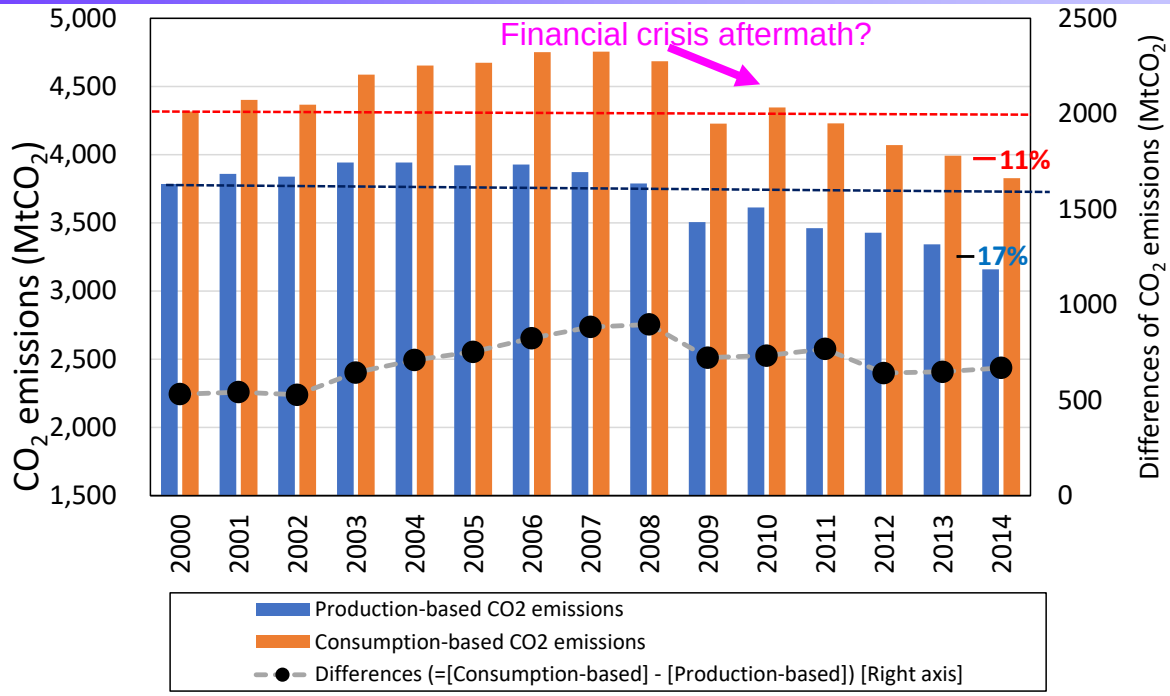
GDP & value-added by industry of major countries



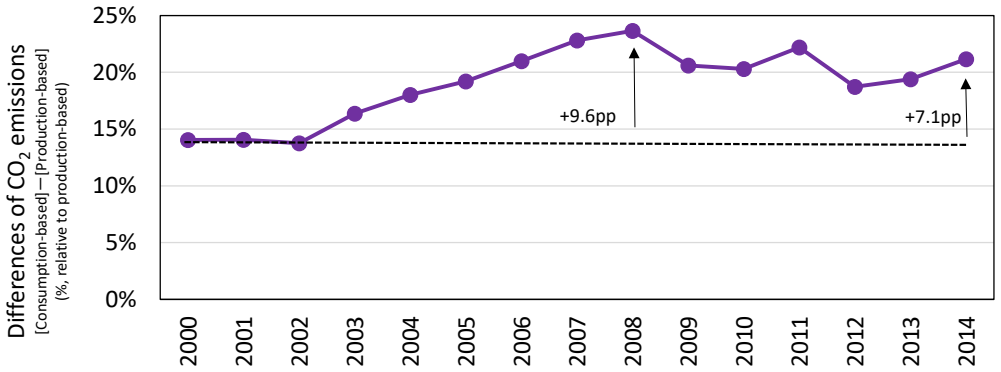
Note) Estimations (2010US$) based on IEA statistics (2017), WIOD2016.

EU

2.1.1 EU28: production-based and consumption-based CO_2 emissions (2000-2014)



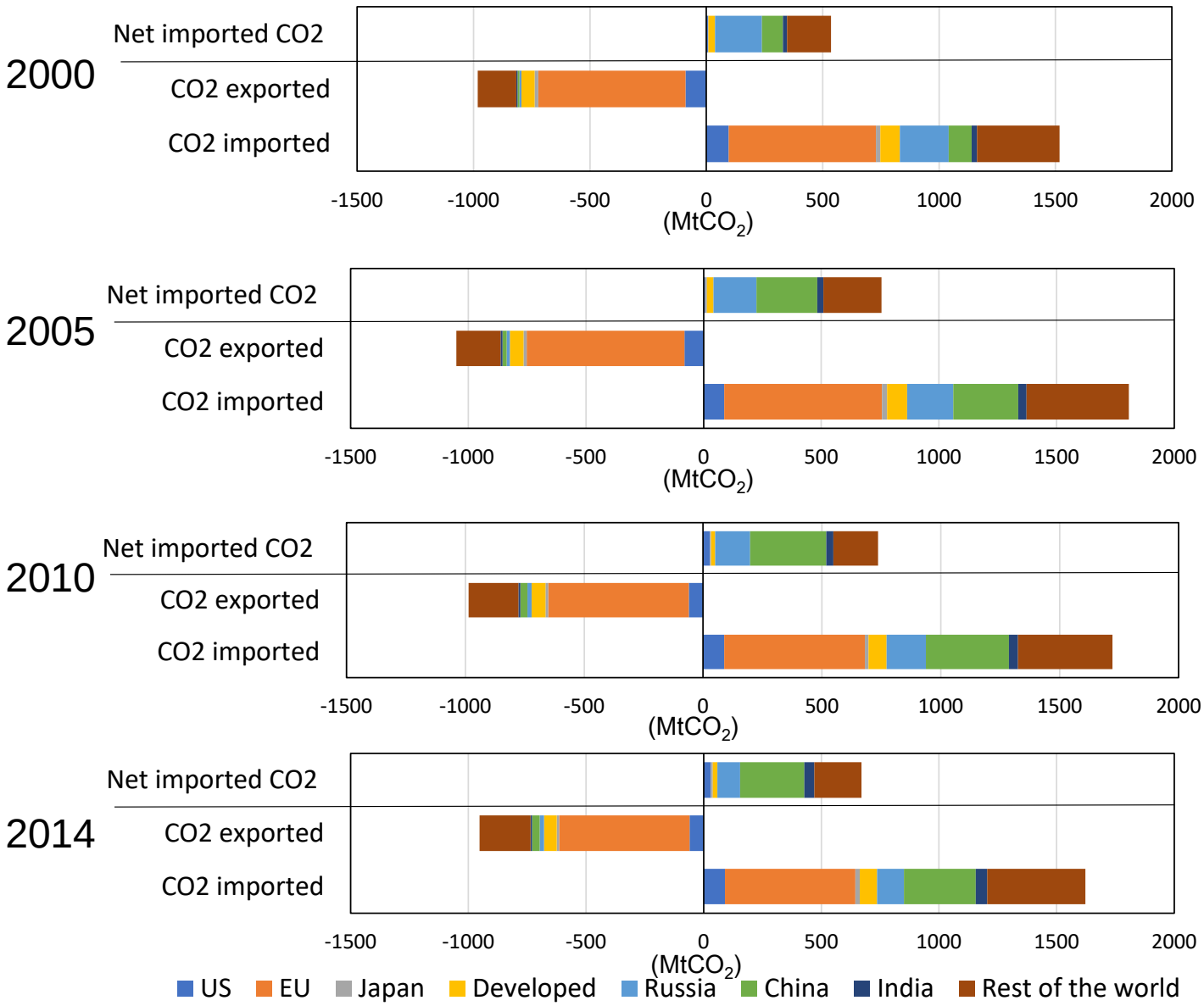
Note) Analyzed using IEA statistics(2017) for CO_2 emissions, WIOD2016 for International Input-Output Table. Consumption-based CO_2 emissions are estimated based on Peters et al.(2008).



pp: percentage point

- Although Ministry of the Environment of Japan argues a progress in carbon productivity for EU after EU ETS implementation in 2005, growth of consumption-based CO_2 was larger until 2008, expanding difference between consumption-based CO_2 and production-based CO_2.
- This difference is shrinking after the financial crisis. Still, consumption-based CO_2 in 2014 decreased by 11% compared with 2000, which is smaller than decrease of production-based CO_2 of 17%.
- When normalized by production-based CO_2, the difference became almost flat after 2009, and increased by 7.1pp during 2000-2014.

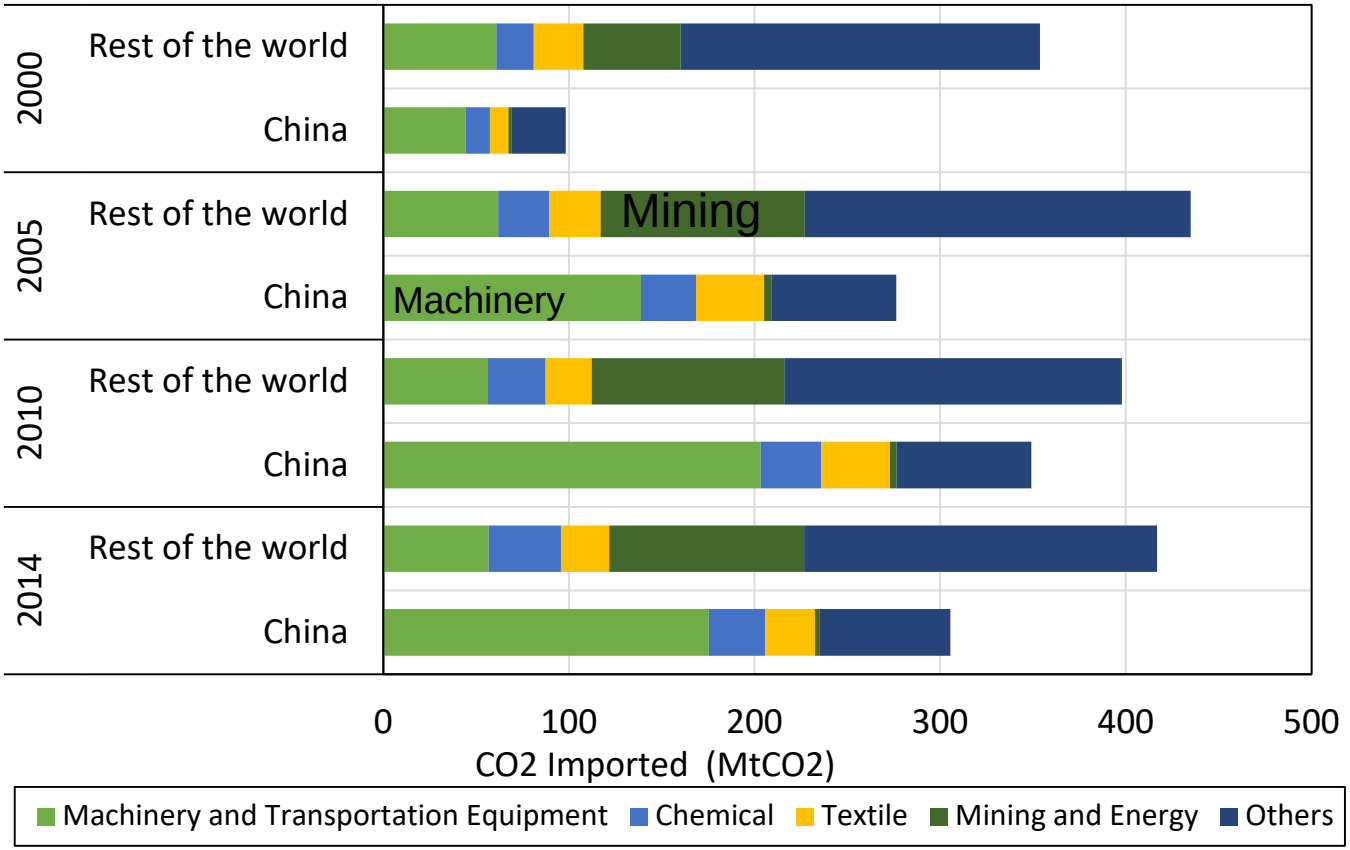
2.1.2 EU: CO_2 emissions embodied in trade by region



- CO_2 emissions embodied in imports from China (mainly of machinery) or Rest of the world (mining) have increased after 2005.
- Although imports in value increased continuously after 2005, CO_2 intensity of imports decreased considerably, thus contributing to modest decrease of CO_2 emissions embodied in imports.

Note: import is exhibited as positive, export as negative

2.1.2 EU: CO_2 emissions embodied in imports from China and Rest of the world by industrial sector



2.1.3 EU: Factor analysis of CO_2 emissions embodied in Trade

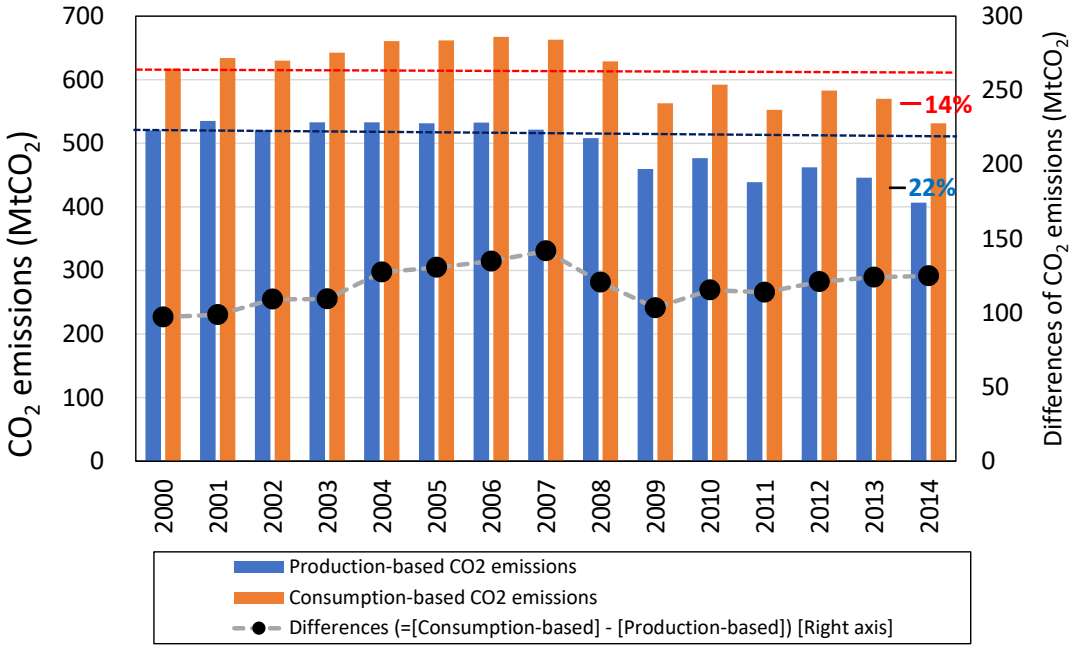
Imported CO_2

Exported CO_2

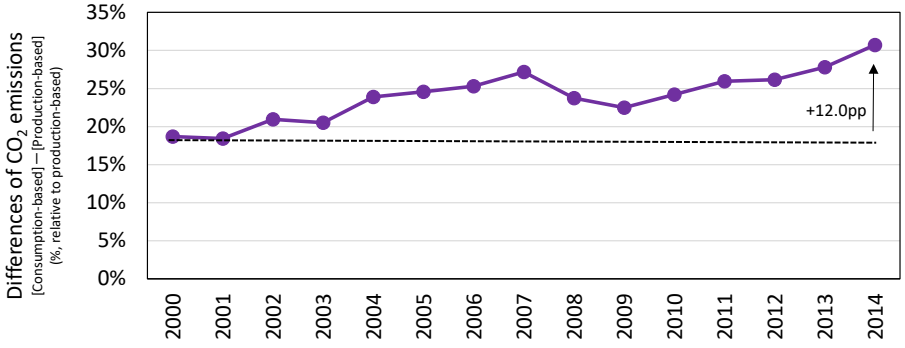
Note: Import and export have been converted to real values using WDI-US deflator(2010 standard)

Changes in import and export values (shown in orange) were almost same during 2000-05, but decrease in intensity for import (shown in light green) was less than those of export due to more imports from regions with higher intensity, causing increased consumption-based CO_2 emissions compared to production-based CO_2. The difference in intensity change became smaller between imports and exports after 2005.

2.1.4 UK: production-based and consumption-based CO_2 emissions (2000-2014)



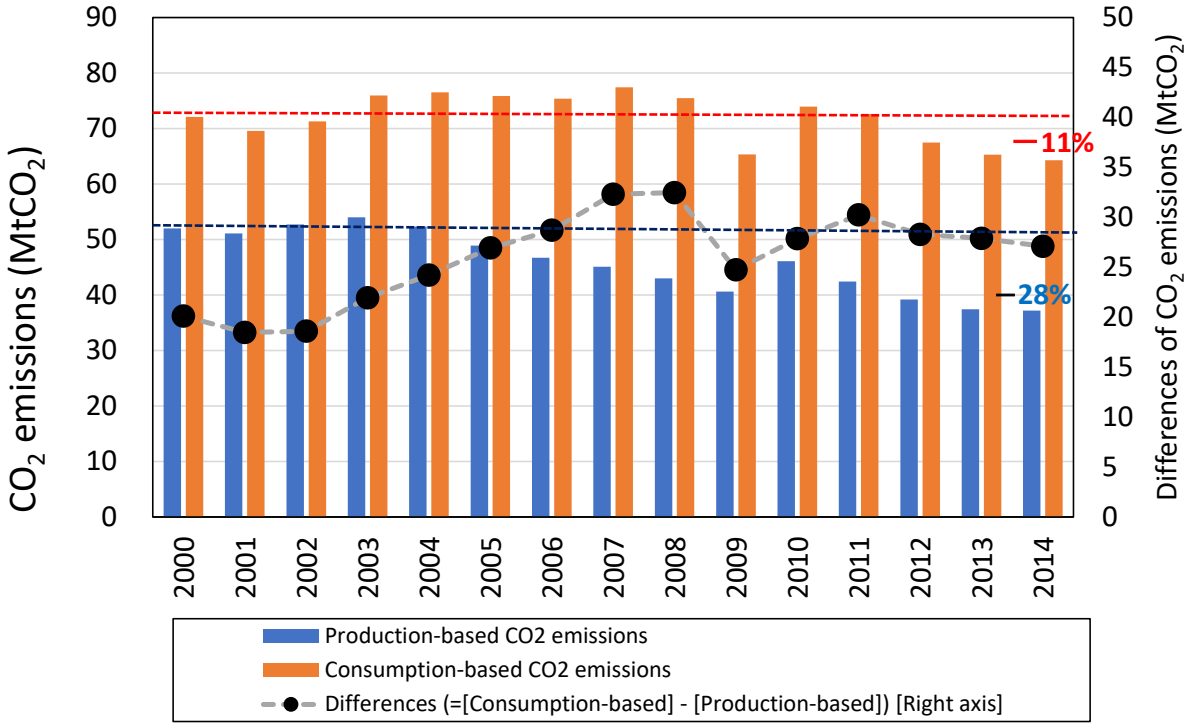
Note) Analyzed using IEA statistics(2017) for CO_2 emissions, WIOD2016 for International Input-Output Table. Consumption-based CO_2 emissions are estimated based on Peters et al.(2008).



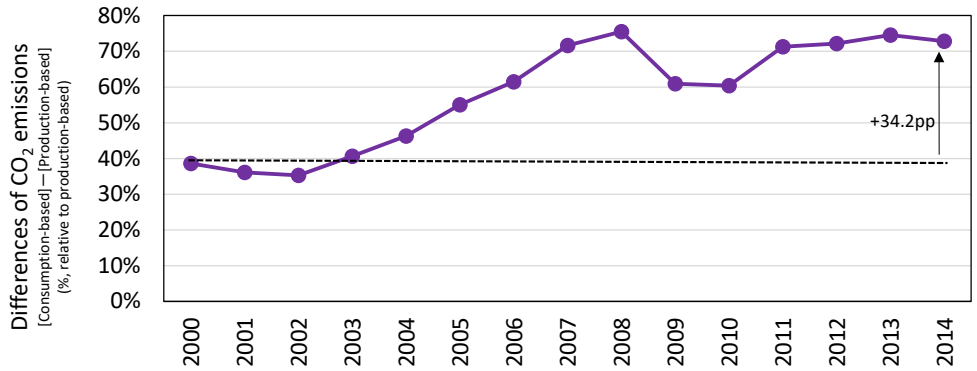
pp: percentage point

- Report from Ministry of the Environment explains that carbon productivity has substantially progressed for UK (especially on a local currency basis), but consumption-based CO_2 is larger than production-based CO_2 (i.e. larger contribution of CO_2 emissions embodied in import, which is counted as emissions outside the area and not counted as UK emissions in usual statistics).
- Difference between consumption-based CO_2 and production-based CO_2 increased toward 2007, and slightly increasing after 2010.
- Although production-based CO_2 in 2014 decreased by 22% relative to 2000, consumption-based CO_2 decreased by 14%, falling smaller than production-based one. The share of CO_2 emissions embodied in trade is 30% in 2014 (compared to production-based), higher than that of Japan, US or EU average.

2.1.5 Sweden: production-based and consumption-based CO_2 emissions (2000-2014)



Note) Analyzed using IEA statistics(2017) for CO_2 emissions, WIOD2016 for International Input-Output Table. Consumption-based CO_2 emissions are estimated based on Peters et al.(2008).

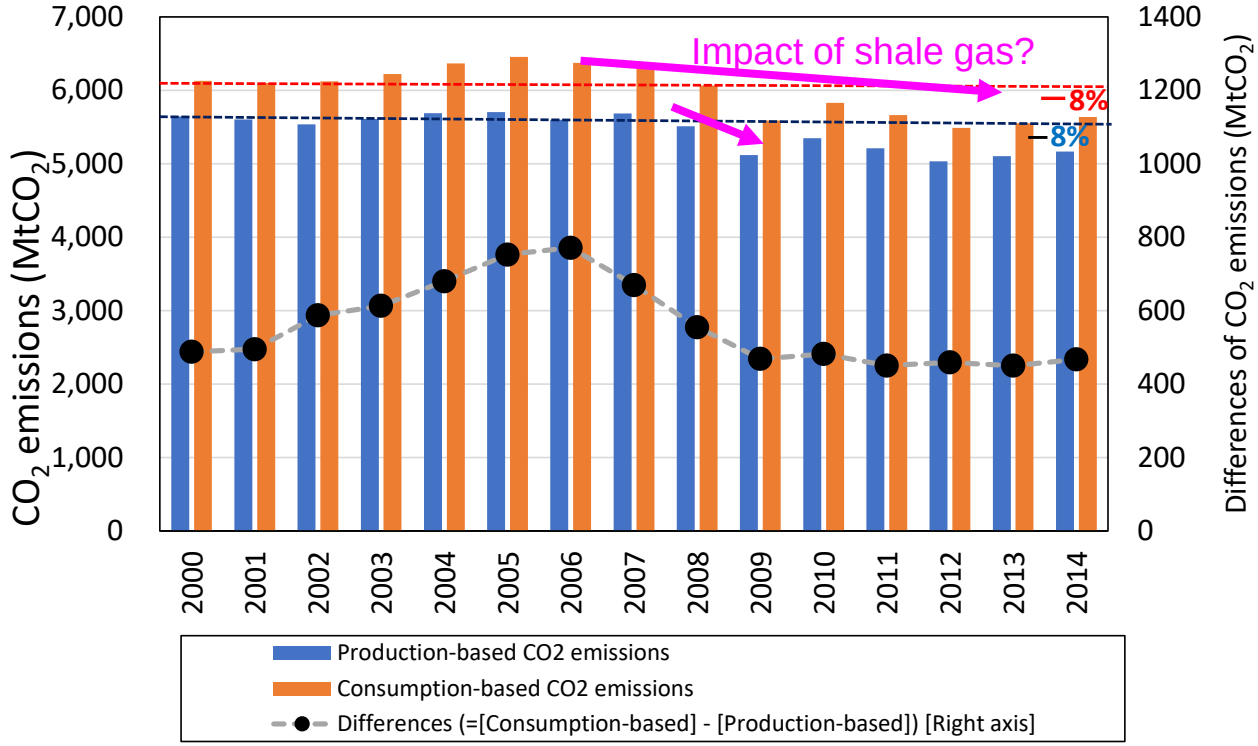


pp: percentage point

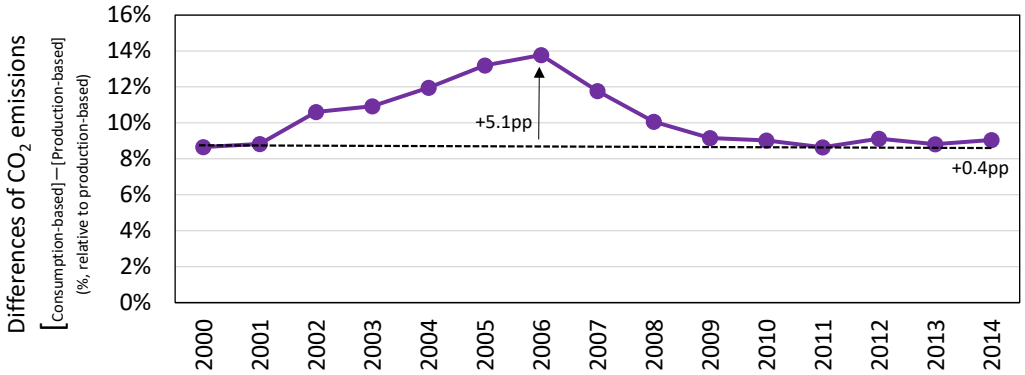
- Report from Ministry of the Environment explains that carbon productivity is extremely high, but consumption-based CO_2 is larger than production-based CO_2 (i.e. larger contribution of CO_2 emissions embodied in import).
- Difference between consumption-based CO_2 and production-based CO_2 increased toward 2008, and became almost flat or decreased slightly after 2011.
- Consumption-based CO_2 did not decrease as production-based CO_2 did. The share of CO_2 emissions embodied in trade was extremely high,73% in 2014 (compared to production-based).

US

2.2.1 US: production-based and consumption-based CO_2 emissions (2000-2014)



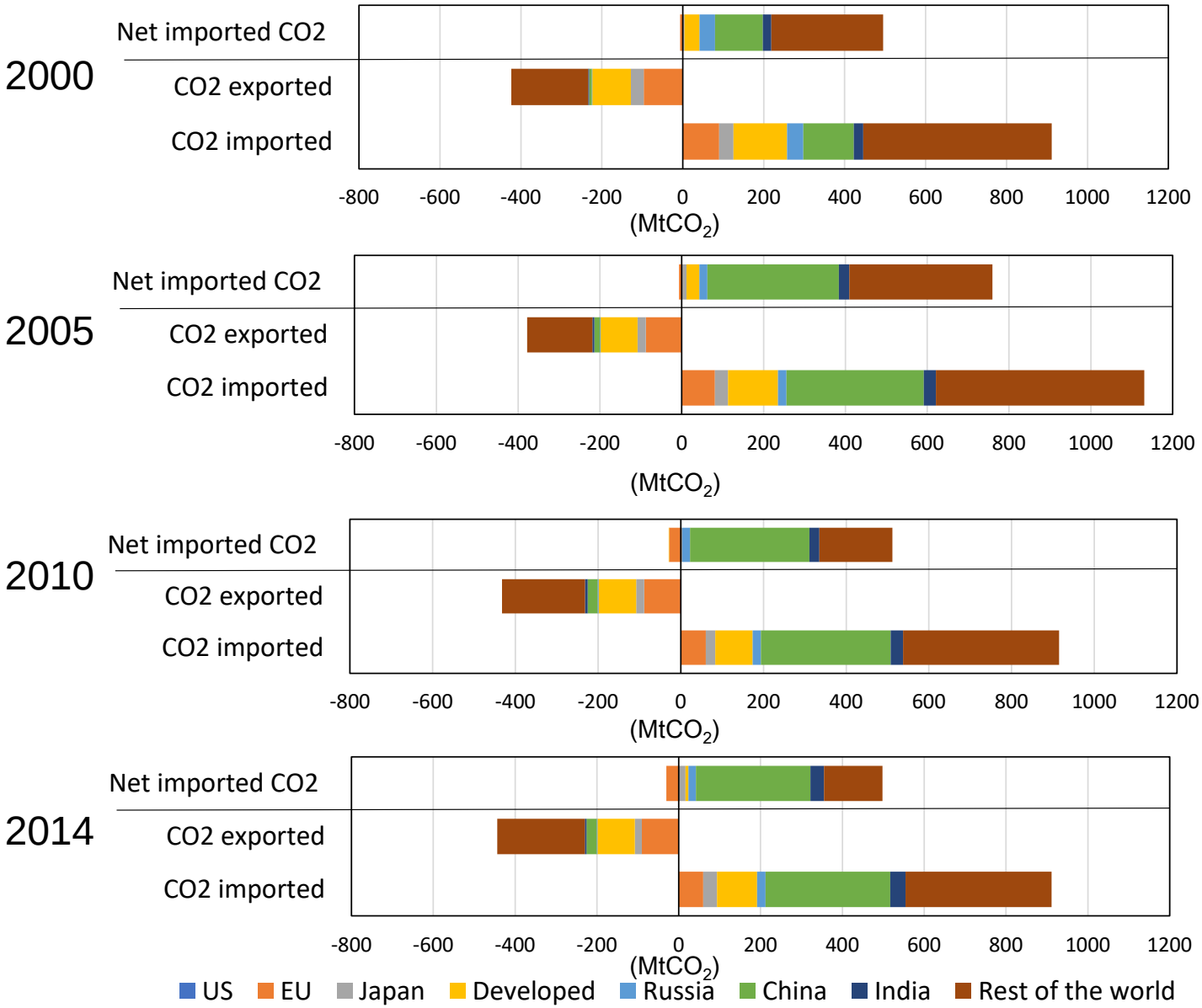
Note) Analyzed using IEA statistics(2017) for CO_2 emissions, WIOD2016 for International Input-Output Table. Consumption-based CO_2 emissions are estimated based on Peters et al.(2008).



pp: percentage point

- Difference between consumption-based CO_2 and production-based CO_2 in US increased substantially towards 2006.
- However, this difference turned to decrease after expansion of shale gas production in 2006, possibly caused by reshoring of manufacturing industry due to the availability of cheaper energy. This difference became flat after 2009.

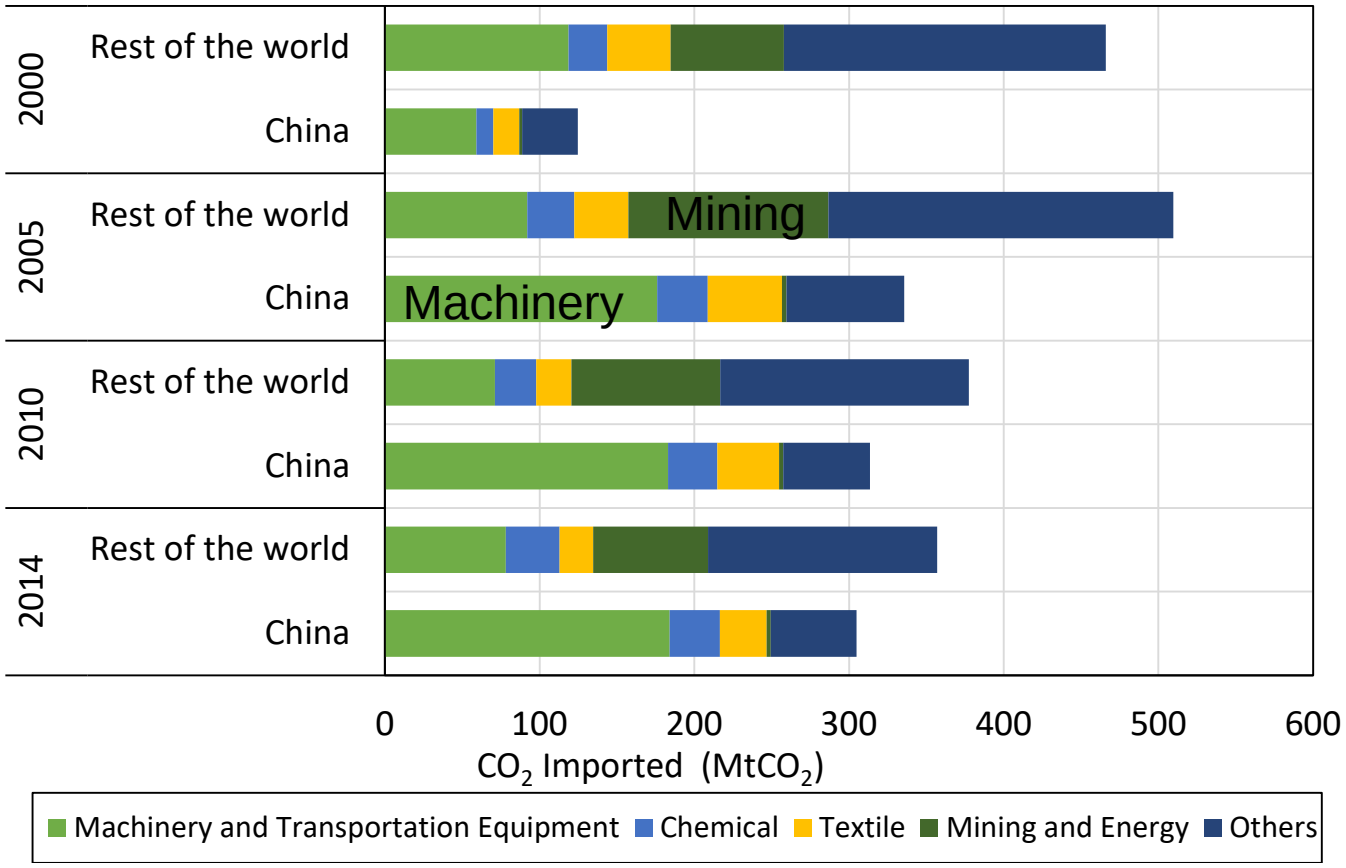
2.2.2 US：CO_2 emissions embodied in trade by region



- CO_2 emissions embodied in imports from China (mainly of machinery) increased towards 2005, followed by continuing emissions of similar level.
- Although imports in value increased continuously after 2005, decrease in CO_2 intensity of imports affected larger, thus contributing to modest decrease of CO_2 emissions embodied in imports.

Note: import is exhibited as positive, export as negative

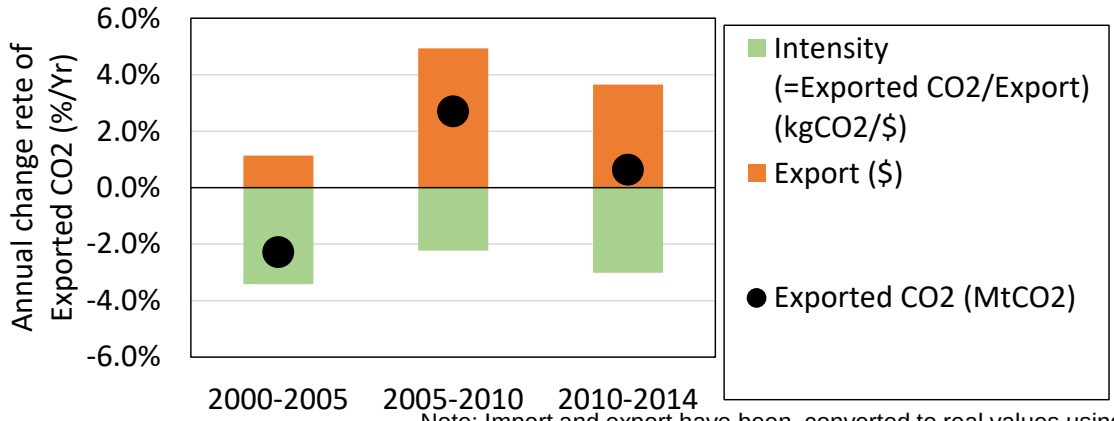
2.2.3 US: CO_2 emissions embodied in imports from China and Rest of the world by industrial sector



2.2.4 US: Factor analysis of CO_2 emissions embodied in Trade

Imported CO_2

Exported CO_2

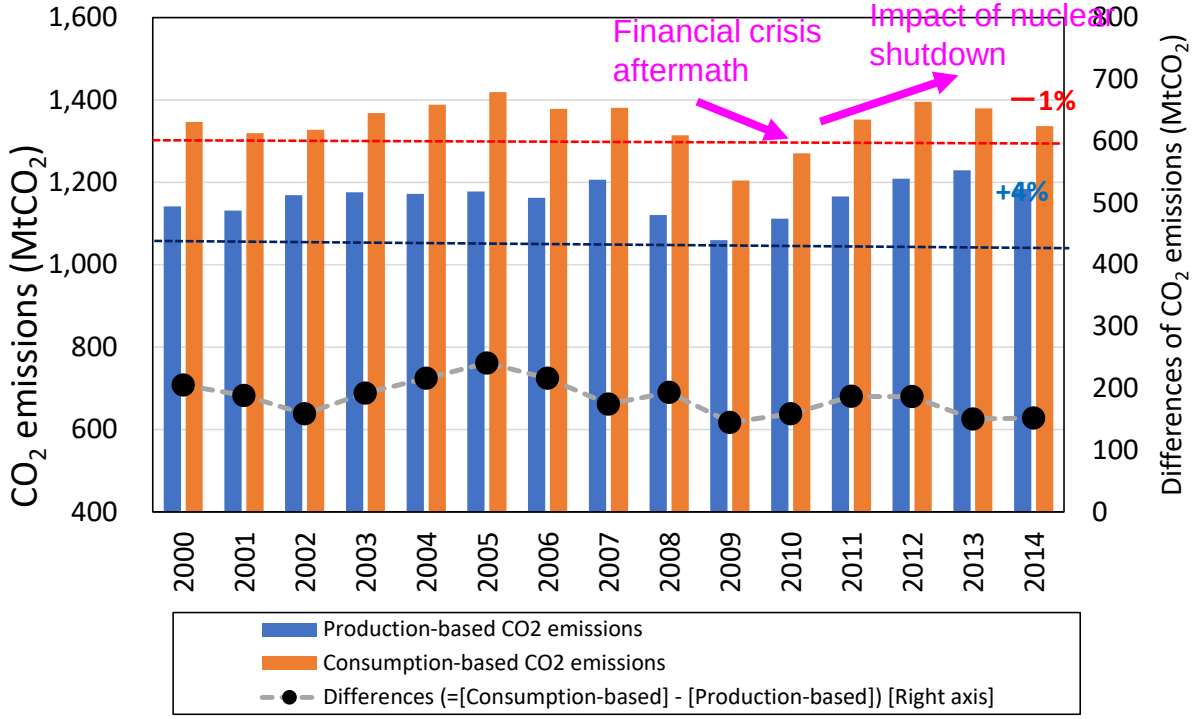


Note: Import and export have been converted to real values using WDI-US deflator(2010 base year)

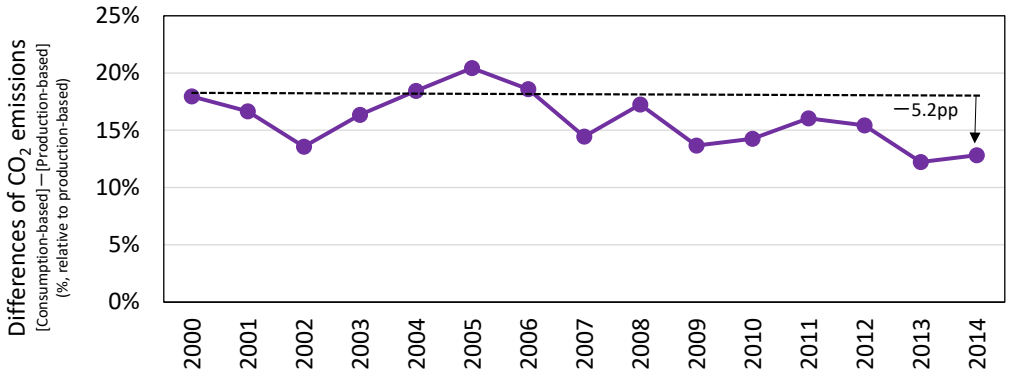
As increase in import value was greater than that in export value (shown in orange) during 2000-05, and intensity for import (shown in light green) became larger, consumption-based CO_2 emissions increased more than production-based ones. After 2005, changes in import value of mining, crude oil and coal (incl. energy) with higher intensity were small due to a shale gas production of her own (shown in orange), and intensity of imported CO_2 decreased substantially (shown in light green, as explained in page 25 ; a 2005-2010 change in CO_2 from mining of rest of the world). At the same time, export value of most industries except textile increased substantially. These factors shrank a difference between consumption-based and production-based CO_2 emissions in 2005-2010.

Japan

2.3.1 Japan: production-based and consumption-based CO_2 emissions (2000-2014)



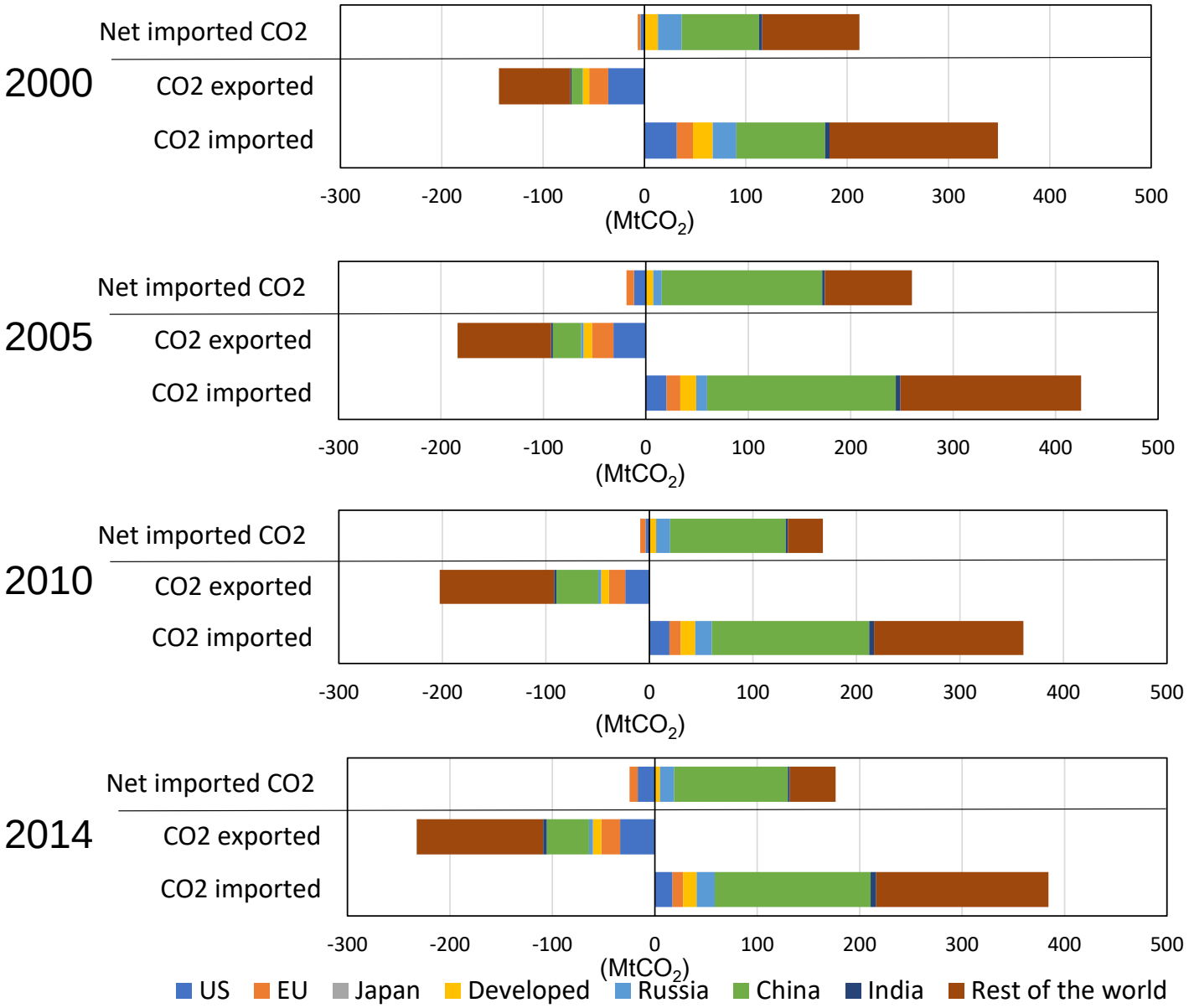
Note) Analyzed using IEA statistics(2017) for CO_2 emissions, WIOD2016 for International Input-Output Table. Consumption-based CO_2 emissions are estimated based on Peters et al.(2008).



pp: percentage point

- A trend in consumption-based CO_2 is similar to that in production-based CO_2, moderately diminishing the difference. This indicates that Japan maintains manufacturing industry while avoiding expansion of carbon leakage. As a result, decrease of CO_2 intensity of Japan might be less than that in EU or US.
- During 2000-2014, production-based CO_2 increased by 4%, while consumption-based CO_2 decreased by 1%. When the difference is normalized by production-based CO_2, it decreased by 5.2 pp during 2000-2014.

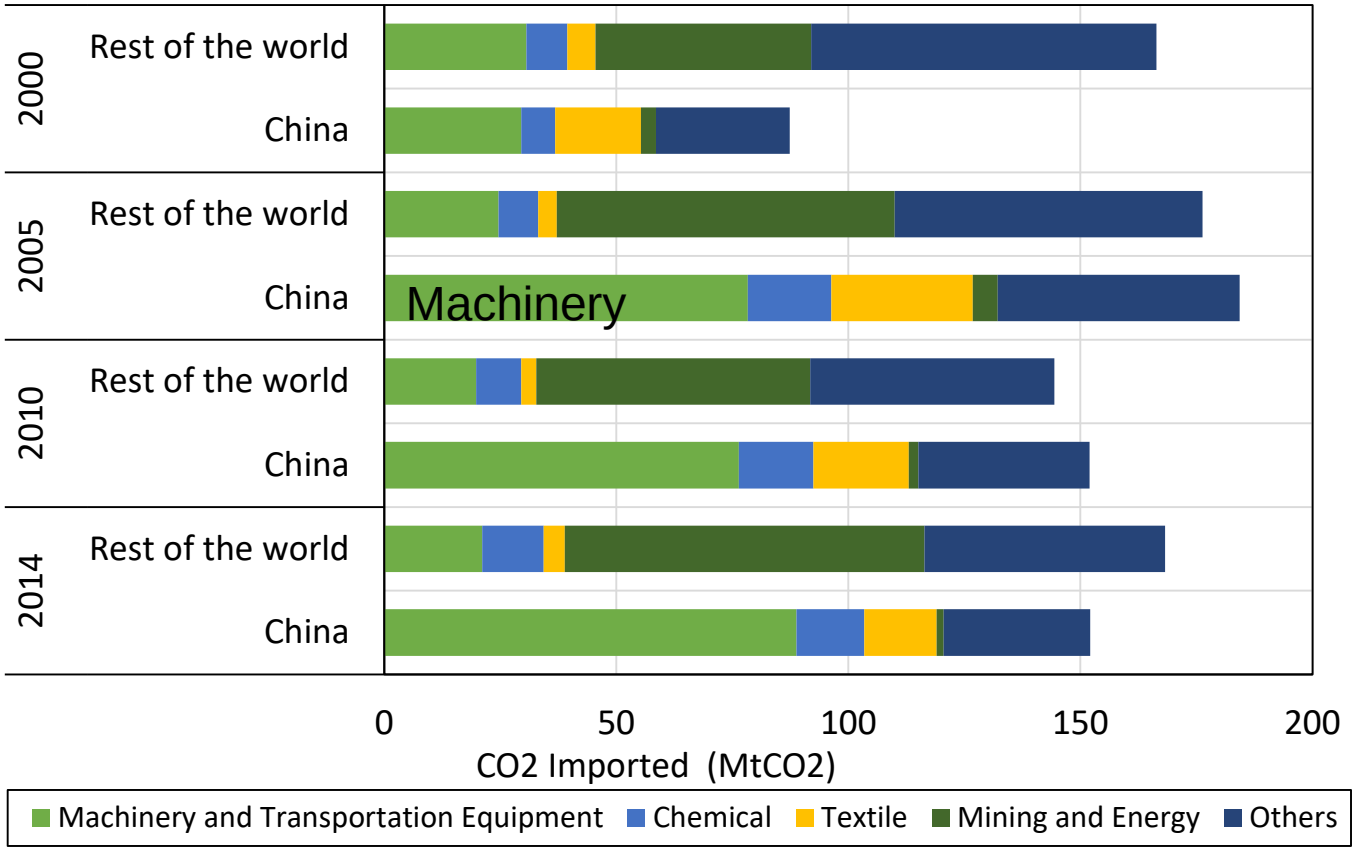
2.3.2 Japan: CO_2 emissions embodied in trade by region



- CO_2 emissions embodied in imports from China (mainly of machinery) increased towards 2005.
- Although imported value increased after 2005, decrease of CO_2 intensity of imports had larger impact.

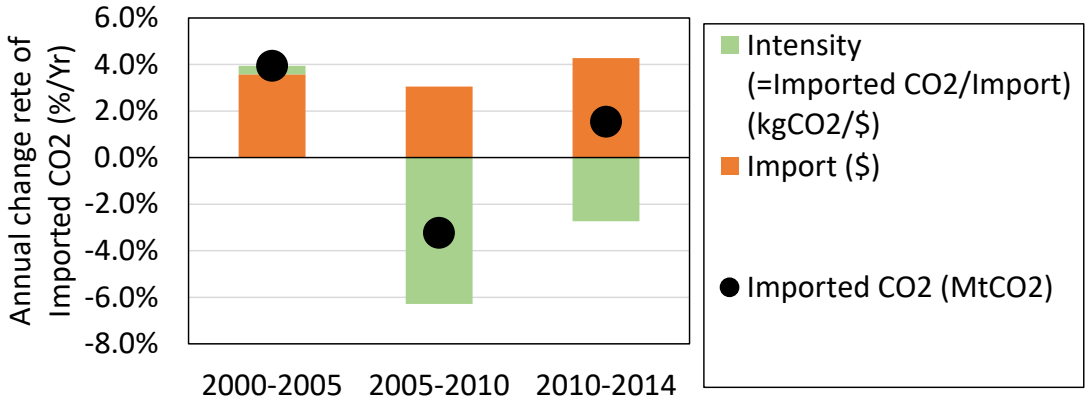
Note: import is exhibited as positive, export as negative

2.3.3 Japan: CO_2 emissions embodied in imports from China and Rest of the world by industrial sector

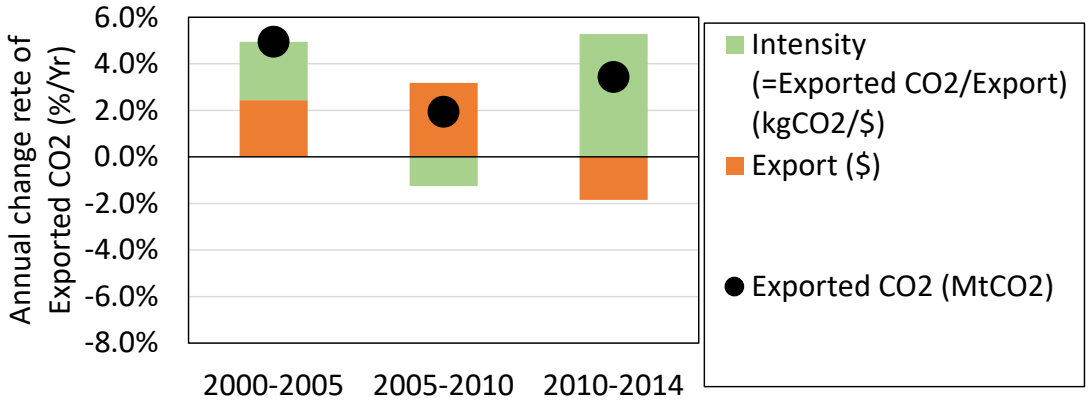


2.3.4 Japan: Factor analysis of CO_2 emissions embodied in Trade

Imported CO_2



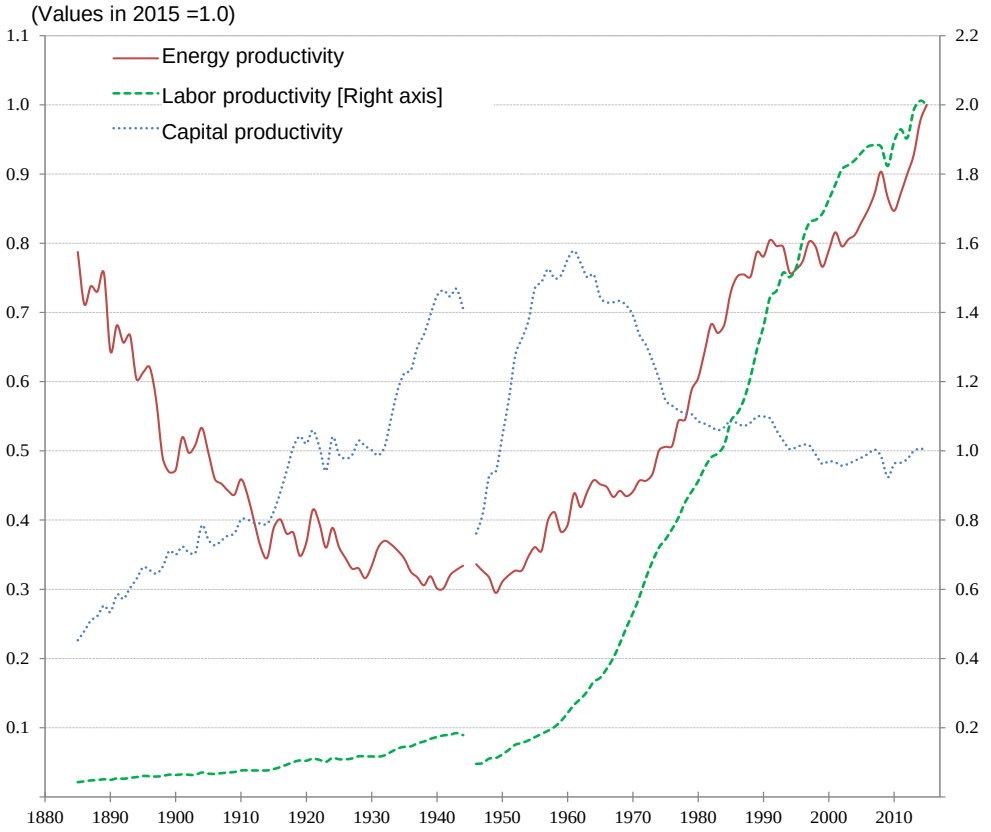
Exported CO_2

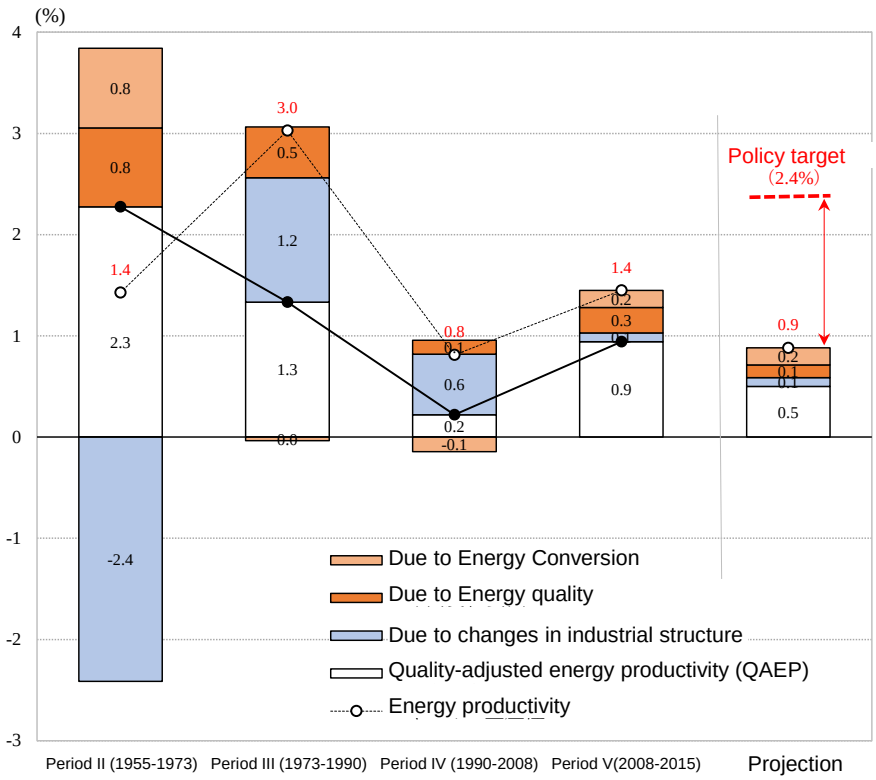


Note: Import and export have been corrected to real values using WDI-US deflator(2010 standard)

Imports continue to increase steadily from China or Rest of the world (machinery from China, or mining from Rest of the world (substantially after the Great East Japan Earthquake)). Imported CO_2 decreased during 2005-2010 due to substantial decrease in intensity of imports such as China.
As for exported CO_2, intensity of individual industries decreased during 2000-2005, however, overall intensity increased due to higher share of metal products among export value, which led to an increase in exported CO_2. During 2010-2014, exported CO_2 increased because of large increase of intensity after the Earthquake, although export value decreased due to strong yen.

2.3.5 Energy productivity in Japan and its decomposition analysis (1/2)





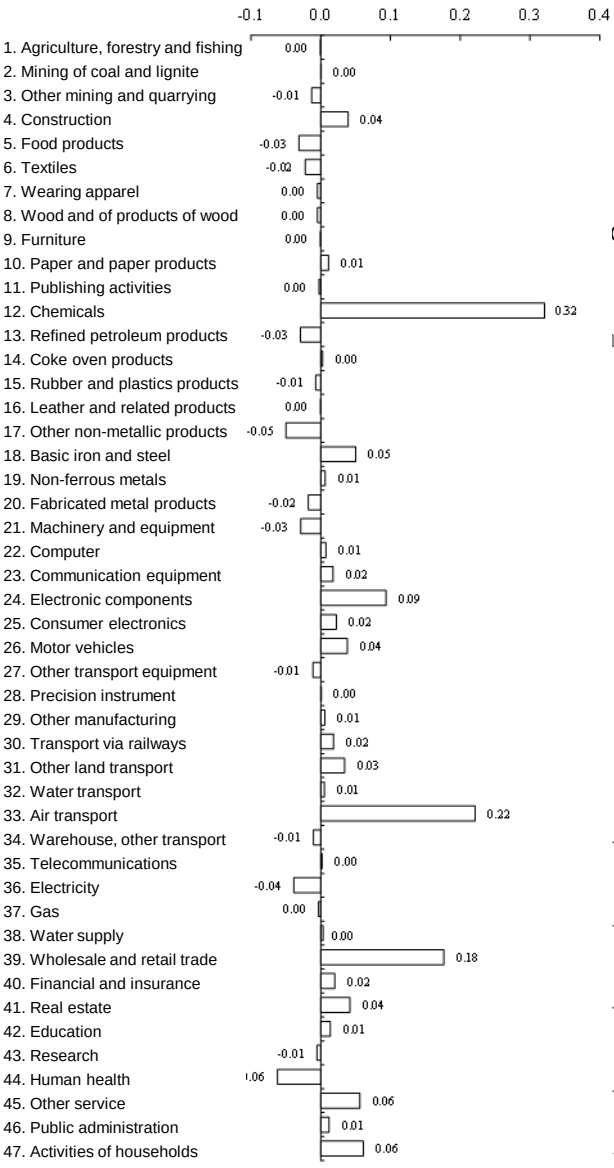
Source) H29 ALPSIII Report, Analysis by Prof. Nomura

- Considerable improvement has been achieved during recent Period V (2008-2015), not with a change in industrial structure

2.3.5 Energy productivity in Japan and its change factors (2/2)

Source) H29 ALPSIII Report, Analysis by Prof. Nomura

Industrial contribution rate to energy productivity (0.9%)

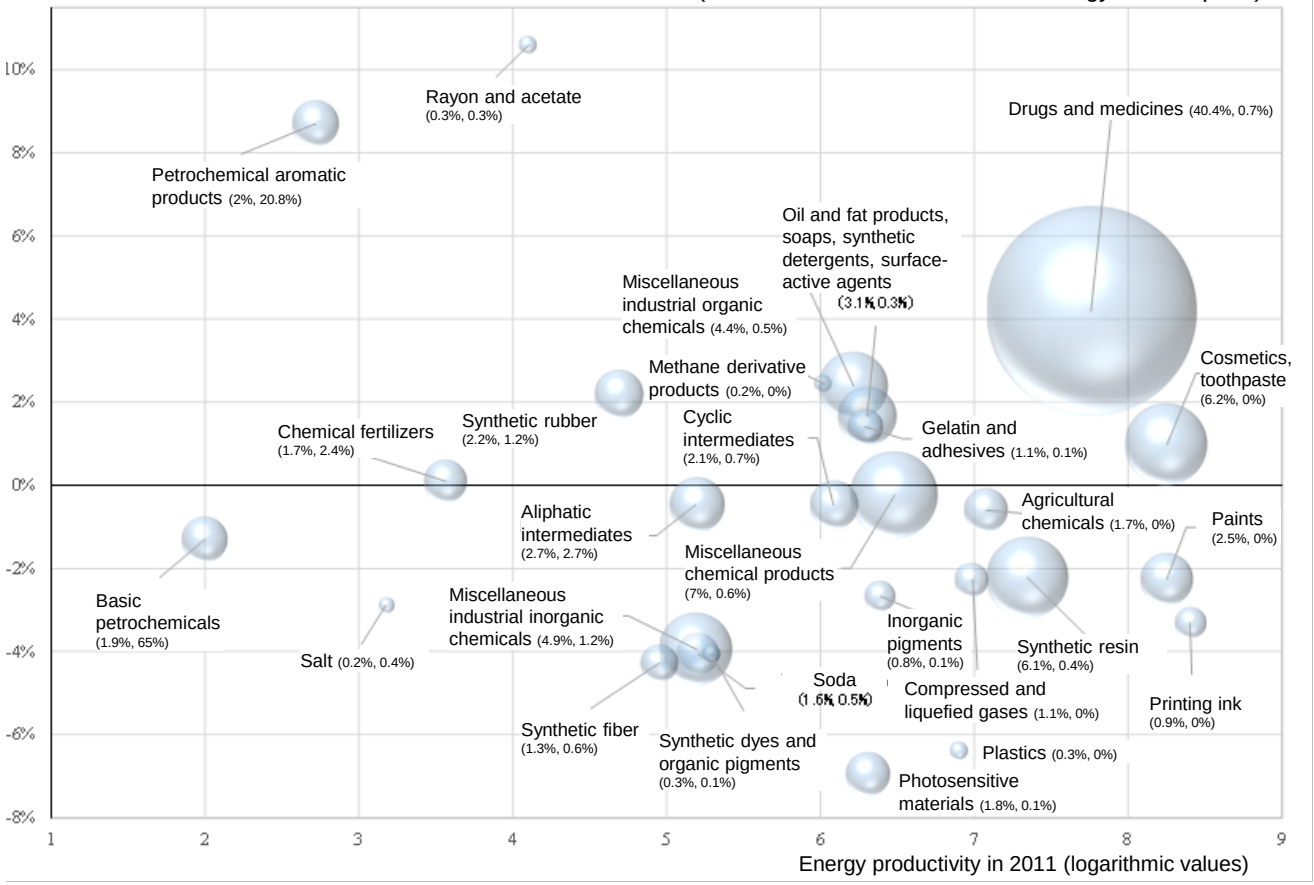


Period V(2008-2015)

Energy productivity and growth rate by chemical products

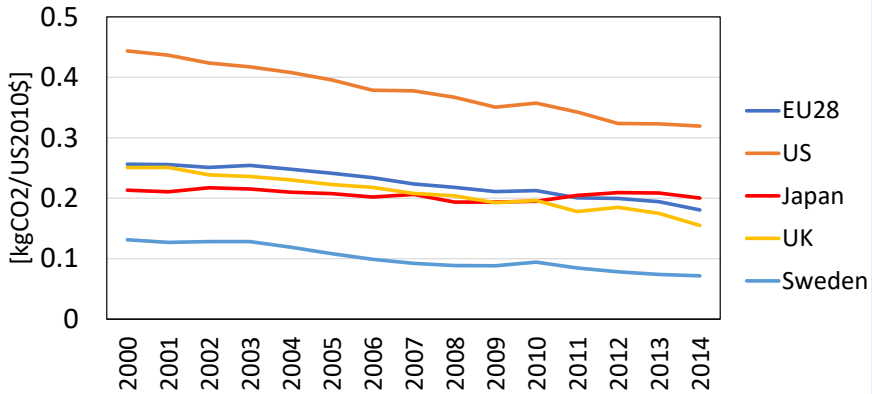
Changes in gross output
(Period V: 2008-2015,average annual growth rates)

Note: Figures in parentheses indicate
(share of value-added, share of energy consumption)



2.4 Comparison of CO_2 emissions per GDP (intensity)

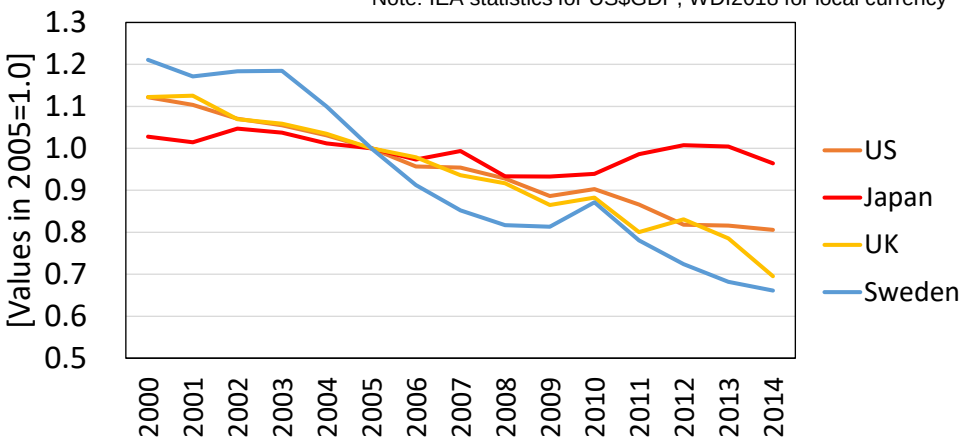
Production-based CO_2/GDP [2010US$]



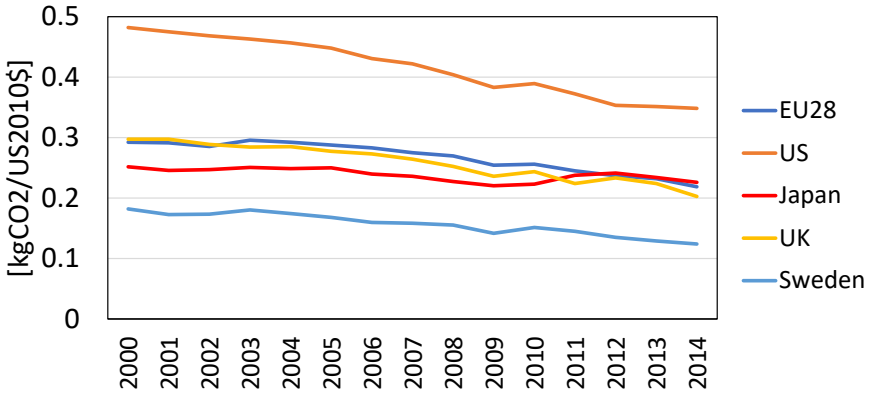
Production-based CO_2/GDP [2010 local currency basis]

<Normalization at 2005=1.0>

Note: IEA statistics for US$GDP, WDI2018 for local currency

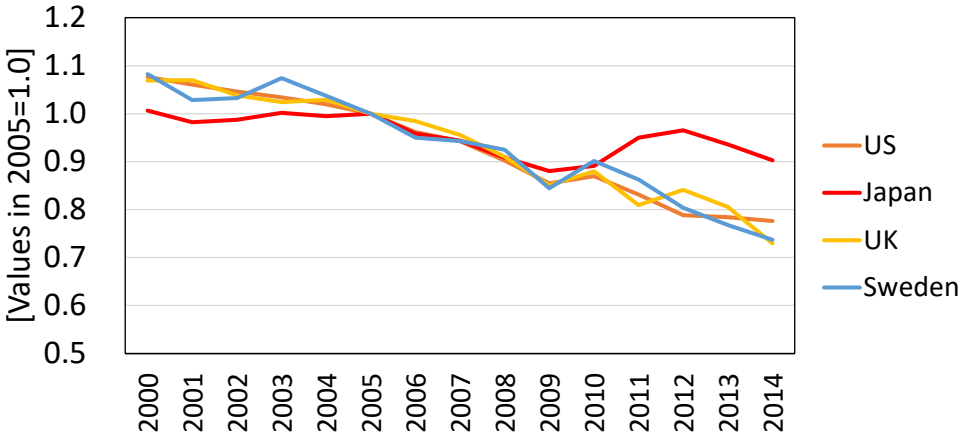


Consumption-based CO_2/GDP [2010US$]



Consumption-based CO_2/GDP [2010 local currency basis]

<Normalization at 2005=1.0>



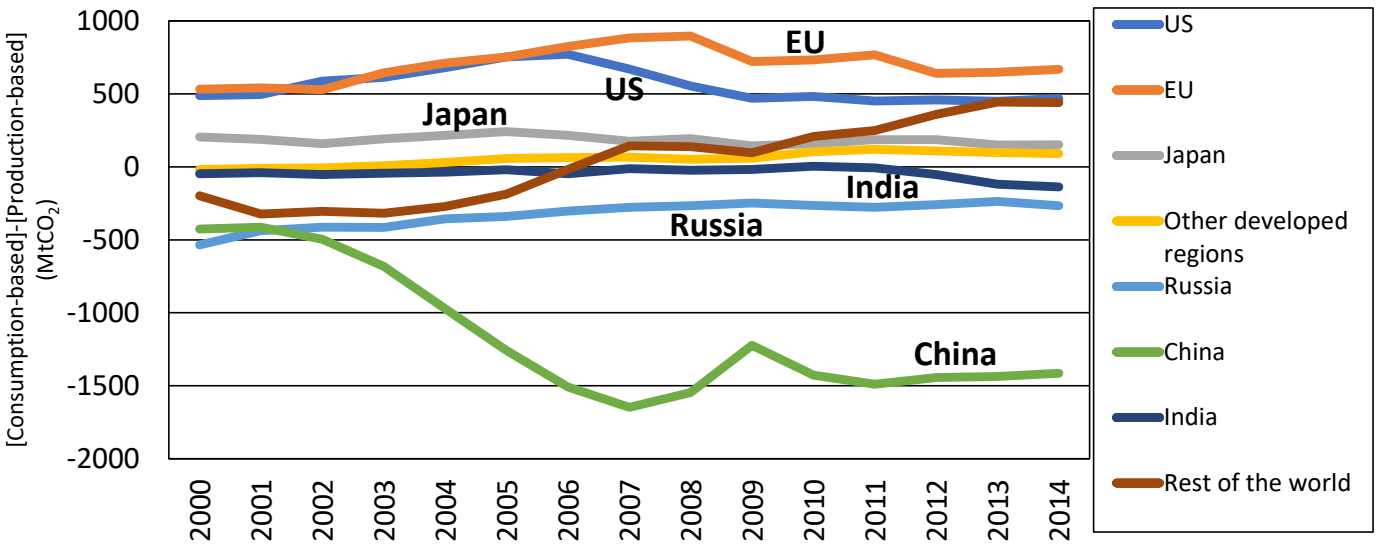
- CO_2 intensity of Japan increased after the Earthquake, but almost the same level as that in EU28 average or UK after 2011 when comparing by using consumption-based CO_2 intensity in US$ (left below)
- Decrease in intensity of Japan tends to be smaller than other regions when comparing by using production-based CO_2 in local currency basis(upper right). On the other hand, when comparing by using consumption-based CO_2 intensity (right below), Japan's trend is much the same as other regions except for emissions increase due to nuclear shutdown after the Earthquake,

2.5 Comparison by region: Difference between production-based CO_2 emissions and consumption-based CO_2 emissions during 2000-2014

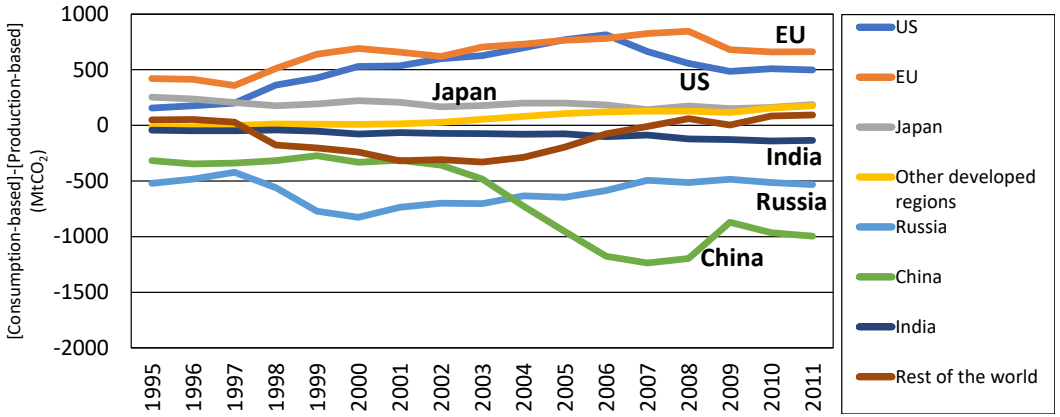
Net CO_2 emissions imports: Consumption-based emissions higher than production-based emissions

Net CO_2 emissions exports: Consumption-based emissions lower than production-based emissions

Difference: [consumption-based CO_2 emissions] – [production-based CO_2 emissions]



Reference: OECD(2015) analysis *(Note: time point is not same as above)*



Note) Analyzed using IEA statistics(2017) for CO_2 emissions, WIOD2016 for International Input-Output Table. Consumption-based CO_2 emissions are estimated based on Peters et al.(2008).

Note: Rearranged regional classification of OECD(2015) to above

3. Conclusion

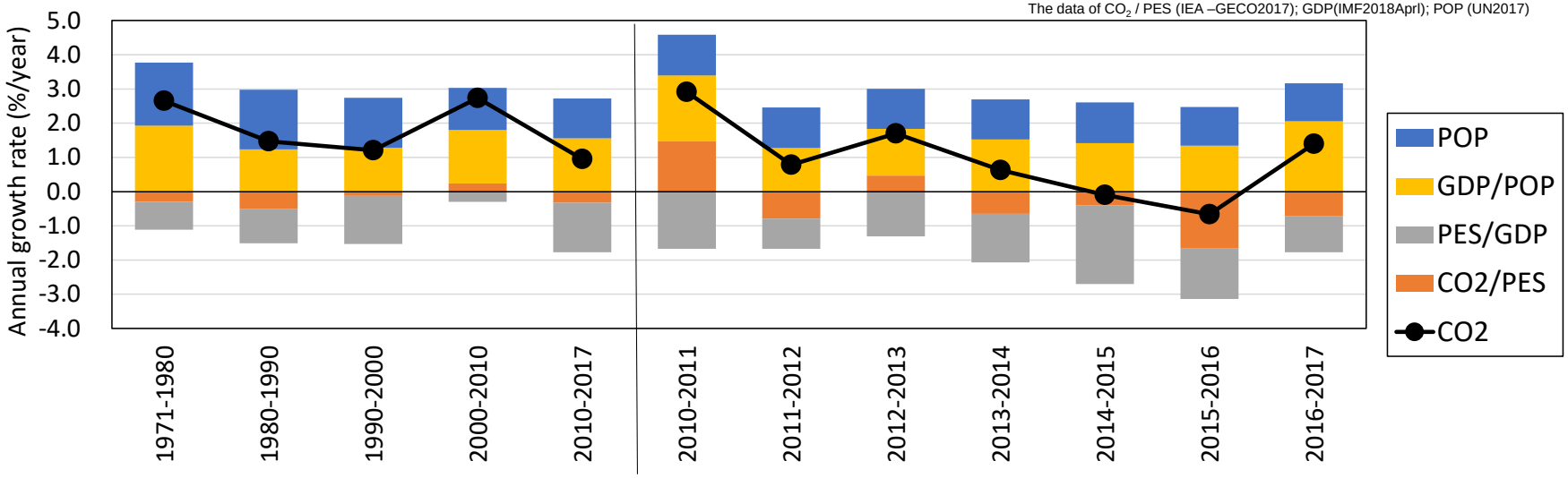
Conclusion

- In this analysis, we estimated consumption-based CO_2 emissions of major regions during 2000-2014 in time-series and compared them with production-based CO_2 emissions to examine decoupling between economic growth and CO_2 emissions.
  - ✓ Decoupling has been seemingly observed in some nations in EU (such as Sweden or UK) or EU average, but our estimates show that deepened foreign-dependency of these nations on imports, which is caused by shifts in industrial structure, has a significant impact. CO_2 emissions embodied in their imports are so large that their contribution to the global emissions reduction seem to be minor. (In terms of policy aspects, their economic growth might have been achieved through the integration of EU as well as increase of immigrants, unlikely to be an effect of EU ETS).
  - ✓ Improvement of production-based CO_2 intensity seems to be modest in Japan, which reflects its maintaining manufacturing industries relatively more than EU or US. Meanwhile, there are little or no differences from EU or US when comparing the improvement in CO_2 intensity by using consumption-based CO_2 (and excluding the impact of its dependency on fossil-fuel power generation due to nuclear shutdown after the Earthquake).

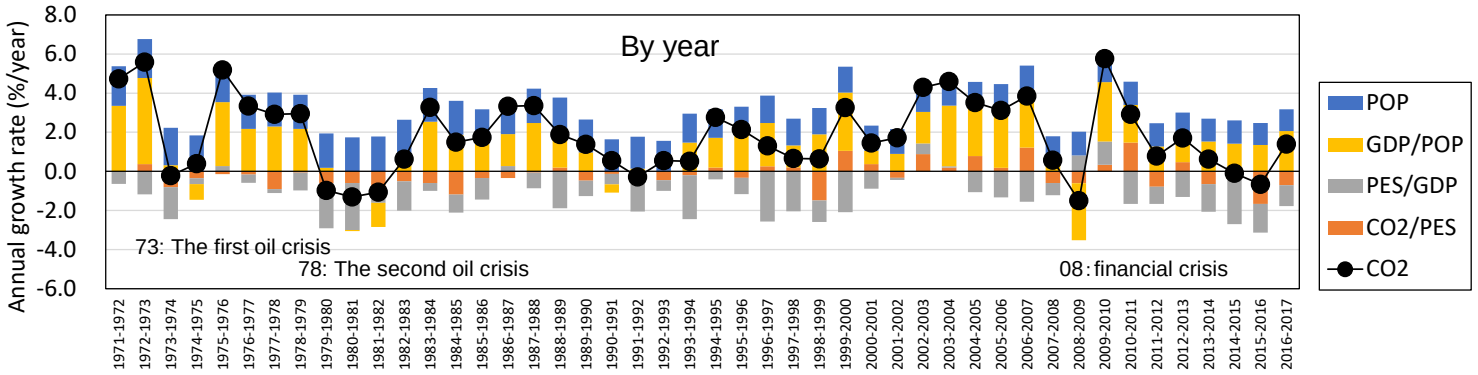
Appendix 1
Overview of global CO_2 emissions and energy supply

Appendix 1-1：Factorial decomposition of global CO_2 emission（energy-related; 1971-2017）（Kaya identity）

Note:
Based on IEA emission database (2017). GDP is in constant 2010 market price. For 2016～17
The data of CO_2 / PES (IEA –GECO2017); GDP(IMF2018Aprl); POP (UN2017)

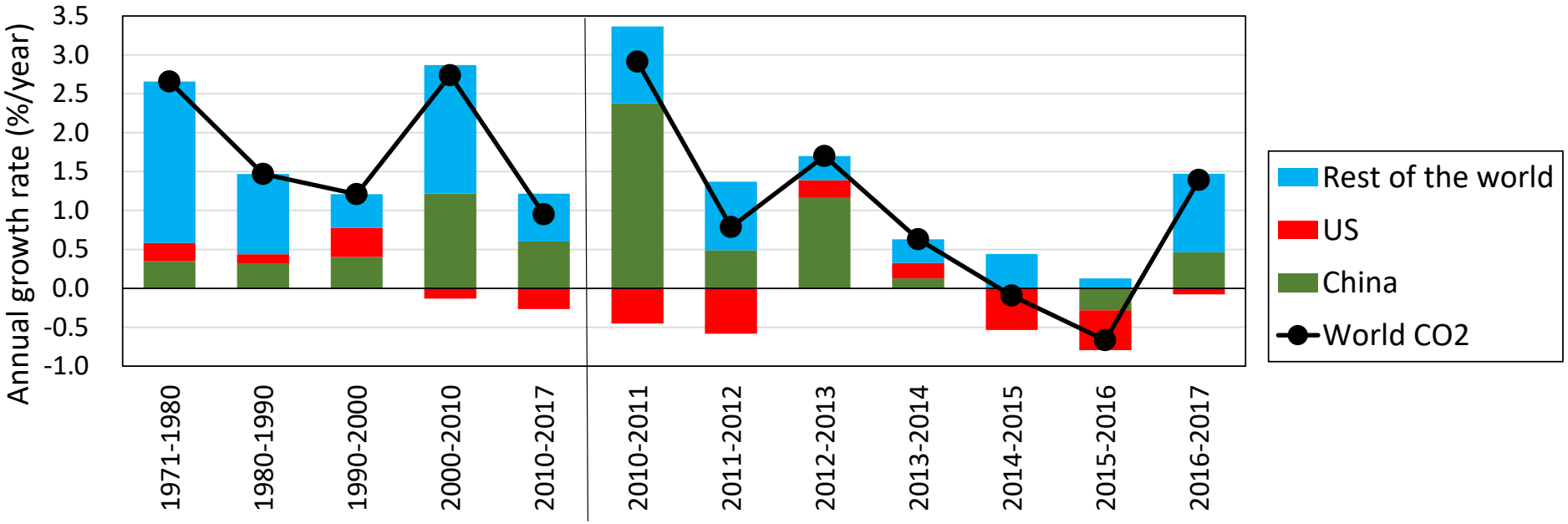


In the long-term trend of global emissions there is no major change in the trend of energy saving（PES/GDP）[include industrial structural change] and decarbonization (CO_2/PES) in the 2010s.

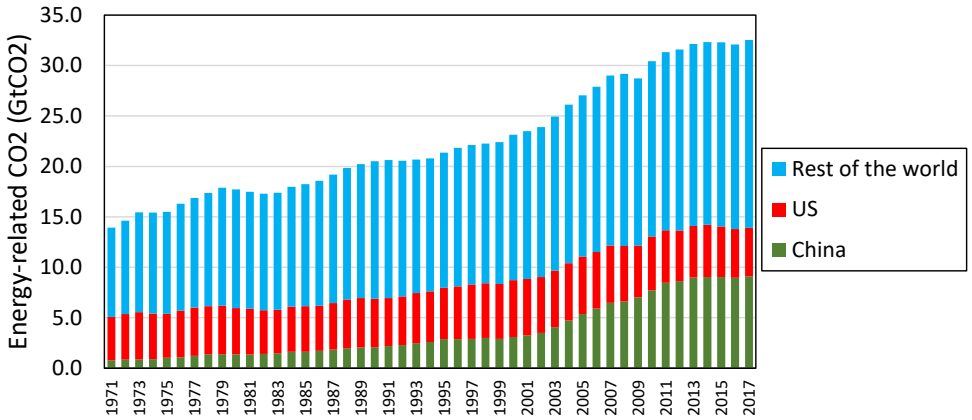


Appendix 1-2: Regional contributions of global CO_2 emission (energy-related; 1971-2017)

Note: IEA CO_2 emission database (2017) 2016, 2017 CO_2 is from (IEA –GECO2017). In IEA – GECO2017, only US, China and global emission data is reported.

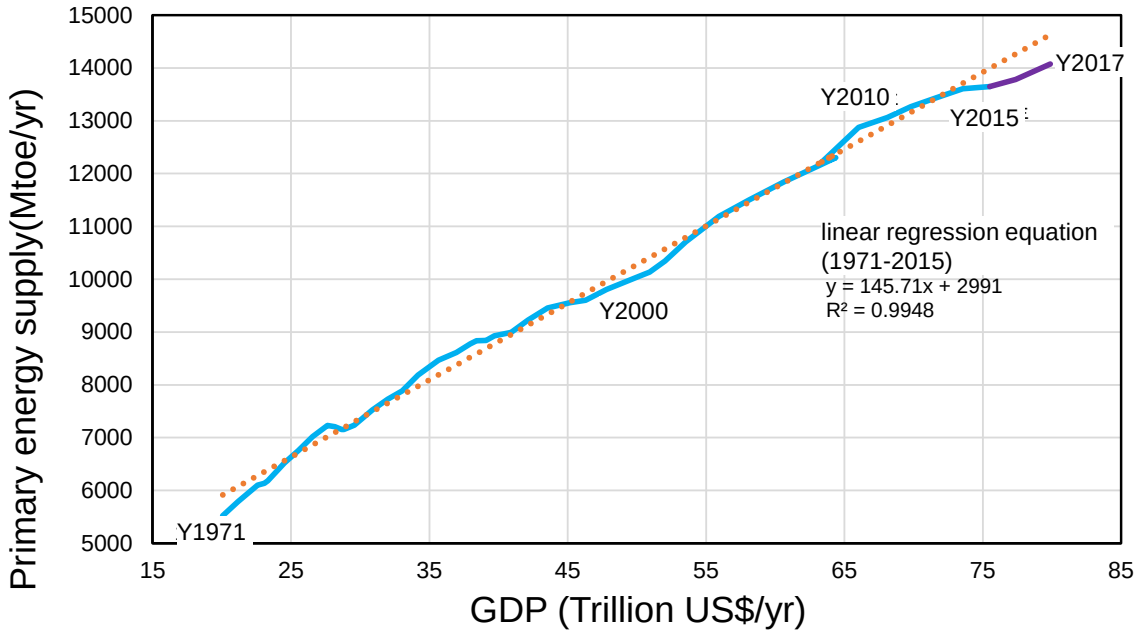


After 2010, the contributions of US and China are increasing.



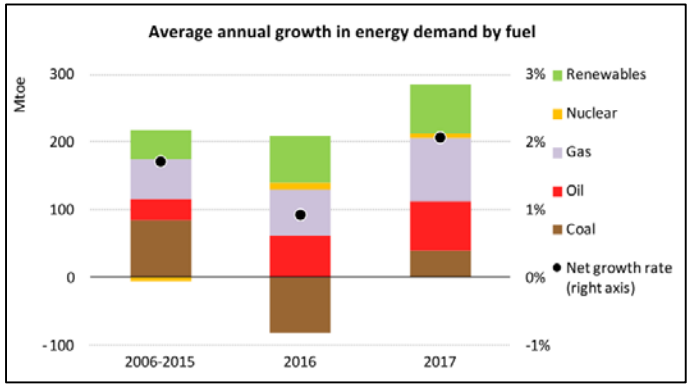
Appendix 1-3: The relationship between global economy growth and primary energy supply

Global primary energy supply(1971-2017)



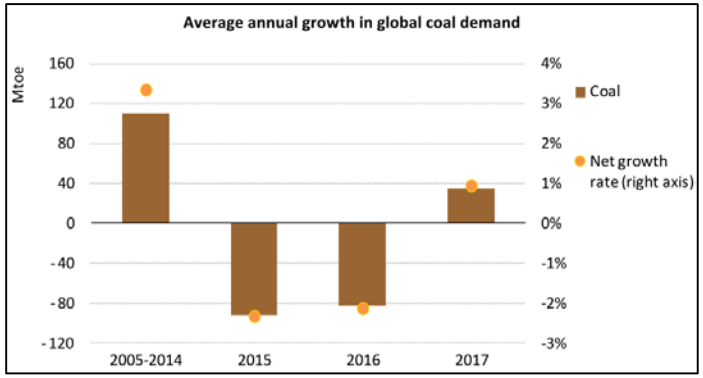
Note:
Based on IEA emission database (2017). GDP is in constant 2010 market price. For 2016～17 The data of CO_2 / PES (IEA –GECO2017); GDP(IMF2018Aprl).

Change of global energy demand in 2016 and 2017



Soure:IEA-GECO2017

Change of global coal demand in 2016 and 2017



Source :IEA-GECO2017

According to IEA-GECO2017, China and US contributed the decline of coal demand in 2015 and 2016.

Similar to CO_2 emission, Primary energy supply is positively correlated with global GDP.

Appendix 2: Preconditions and methods of estimating consumption-based CO_2 emission

Method for estimating consumption-based CO_2 emission

- **The production-based CO_2 emissions**（by industry sector）use the database of IEA (CO_2 emission from fossil fuel combustion, 2017）. **Consumption-based CO_2 emissions** is estimated with Input-output table. The calculation method is described below:

Consumption-based CO_2 emission（$ConsCO_2$）function:(based on Peters et al.(2008))：

$$ConsCO_2(r) = EF(r)\cdot(I-(I-M(r))A(r))^{-1}\cdot(1-M(r))(C(r)+I(r)) + ImCO_2(r) + RCO_2(r) \quad (1)$$

$EF(r)\cdot(I-(I-M(r))A(r))^{-1}\cdot(1-M(r))(C(r)+I(r))$: CO_2 emission from domestic goods/ final demand

$ImCO_2(r)$: CO_2 emission from import goods/domestic consumption

$RCO_2(r)$: Direct emission by household

Where $L(r)=EF(r)\cdot(I-(I-M(r))A(r))^{-1}$,

$$ImCO_2(r)=\Sigma_{(s)}\{L(s)\cdot Ex(s,r)\} \quad (=\Sigma_{(s)}\{L(s)\cdot Im(r,s)\}) \quad (2)$$

← aggregated CO_2 emission embodied in the trading goods from region ***s***(exporter) to region ***r*** (importer)

The relationship between consumption-based CO_2 emission（$ConsCO_2$）and production-based CO_2 emission($ProdCO_2$)：

$$ConsCO_2(r) = ProdCO_2(r) + ImCO_2(r) - ExCO_2(r) \quad (3)$$

$$ExCO_2(r)=\Sigma_{(r)}\{L(r)\cdot Ex(r,s)\}$$

$$ConsCO_2(r) - ProdCO_2(r) = ImCO_2(r) - ExCO_2(r) \quad (4)$$

r, s: country/region
I：Unit Matrix
A: Input coefficient matrix
M: Import coefficient matrix
EF: CO_2 emission factor for each sector(CO_2/output for sector i)
C: Final demand（household+ government）
I: Investment
$ImCO_2$：CO_2 emissions embodied in imports
RCO_2: Direct emission by household
Ex：Export
Im: Import

Data assumption for estimating consumption-based CO_2 emissions(1)

The amount of CO_2 emission:

- Country/ sector emission data from IEA-CO_2 database (2017) is used in this study (Following Davis&Caldeira (2010), exclude international transport）。
  - ✓ If sector emission is zero in the database, the estimated emission is calculated with sectoral production and emission factors.
  - ✓ Emissions from coke oven and blast furnace are included in the steel sector（The emissions from by-product electricity are included in the electricity sector）。

The economic data:

- WIOD2016 (World Input-Output Database）is applied in this research
  - ✓ 2000-2014 annual nominal data(USD)
  - ✓ 44 regions（43countries+others）
  - ✓ 56 sectors(According to International Standard Industrial Classification)
  - ✓ basic price (tax is excluded)

Page 45 presents the industrial classification and Page 46 presents the classification by region. The overall economy is classified into 16 sectors and household in order to fit in the IEA emission database.

* *http://www.wiod.org/database/wiots16

Data assumption for estimating consumption-based CO_2 emissions(2)

＜Correspondence table of industrial classification ＞

Sector classification assumed in this study		WIOT sector classification
Sec01	Agriculture	Crop and animal production, hunting and related service activities
		Forestry and logging
		Fishing and aquaculture
Sec02	Mining	Mining and quarrying
Sec03	Food manufacturing	Manufacture of food products, beverages and tobacco products
Sec04	Paper and pulp manufacturing	Manufacture of paper and paper products
		Printing and reproduction of recorded media
Sec05	Textile manufacturing	Manufacture of textiles, wearing apparel and leather products
Sec06	Coal and petroleum manufacturing	Manufacture of coke and refined petroleum products
Sec07	Chemical manfacturing	Manufacture of chemicals and chemical products
		Manufacture of basic pharmaceutical products and pharmaceutical preparations
		Manufacture of rubber and plastic products
Sec08	Other non-metallic mineral manufacturing	Manufacture of other non-metallic mineral products
Sec09	Basic metal manufacturing	Manufacture of basic metals
Sec10	Machinery manufacturing	Manufacture of fabricated metal products, except machinery and equipment
		Manufacture of computer, electronic and optical products
		Manufacture of electrical equipment
		Manufacture of machinery and equipment n.e.c.
Sec11	Transportation equipment manufacturing	Manufacture of motor vehicles, trailers and semi-trailers
		Manufacture of other transport equipment
Sec12	Other manufacturing	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
		Manufacture of furniture; other manufacturing
		Repair and installation of machinery and equipment
Sec13	Construction	Construction
Sec14	Electricity and gas	Electricity, gas, steam and air conditioning supply
Sec15	Transport	Land transport and transport via pipelines
		Water transport
		Air transport
		Warehousing and support activities for transportation

Sector classification assumed in this study		WIOT sector classification
Sec16	Service	Water collection, treatment and supply
		Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
		Wholesale and retail trade and repair of motor vehicles and motorcycles
		Wholesale trade, except of motor vehicles and motorcycles
		Retail trade, except of motor vehicles and motorcycles
		Postal and courier activities
		Accommodation and food service activities
		Publishing activities
		Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
		Telecommunications
		Computer programming, consultancy and related activities; information service activities
		Financial service activities, except insurance and pension funding
		Insurance, reinsurance and pension funding, except compulsory social security
		Activities auxiliary to financial services and insurance activities
		Real estate activities
		Legal and accounting activities; activities of head offices; management consultancy activities
		Architectural and engineering activities; technical testing and analysis
		Scientific research and development
		Advertising and market research
		Other professional, scientific and technical activities; veterinary activities
		Administrative and support service activities
		Public administration and defence; compulsory social security
		Education
		Human health and social work activities
		Other service activities
		Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
		Activities of extraterritorial organizations and bodies

Data assumption for estimating consumption-based CO_2 emissions(3)

＜Correspondence table for regions＞

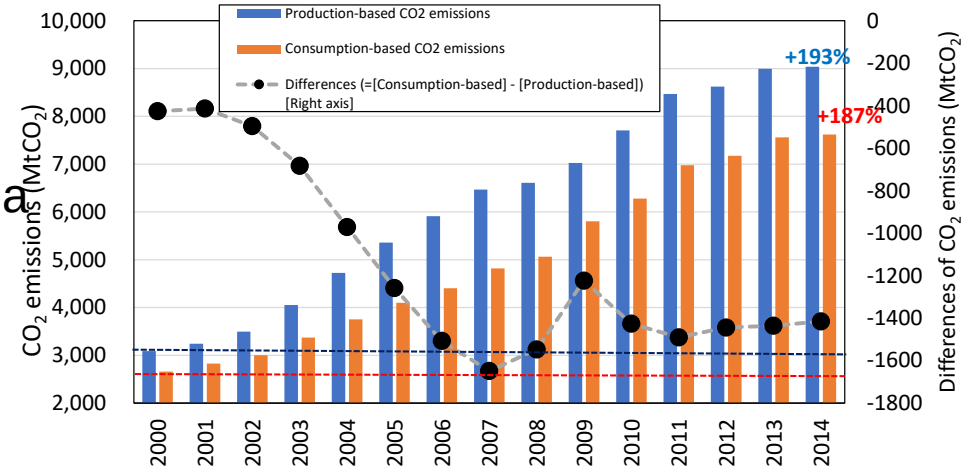
Regions assumed in this study	WIOT regions	
US	USA	
EU28	AUT	HUN
	BEL	IRL
	BGR	ITA
	CYP	LTU
	CZE	LUX
	DEU	LVA
	DNK	MLT
	ESP	NLD
	EST	POL
	FIN	PRT
	FRA	ROU
	GBR	SVK
	GRC	SVN
	HRV	SWE
Japan	JPN	
Developed regions	AUS	
	CAN	
	CHE	
	NOR	

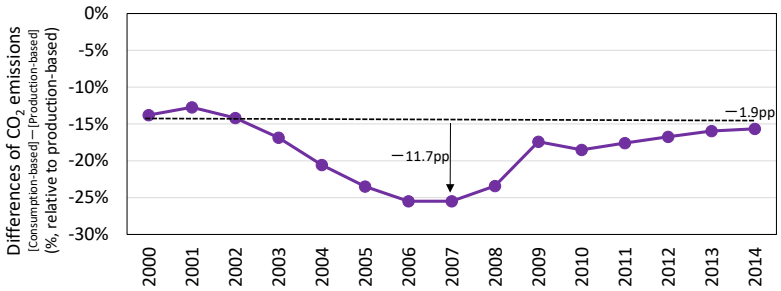
Regions assumed in this study	WIOT regions
Russia	RUS
China	CHN
India	IND
Rest of the world	BRA
	IDN
	KOR
	MEX
	TUR
	TWN
	ROW

In WIOT, reset countries (around 150 countries) are aggregated as “rest of the world (ROW)”

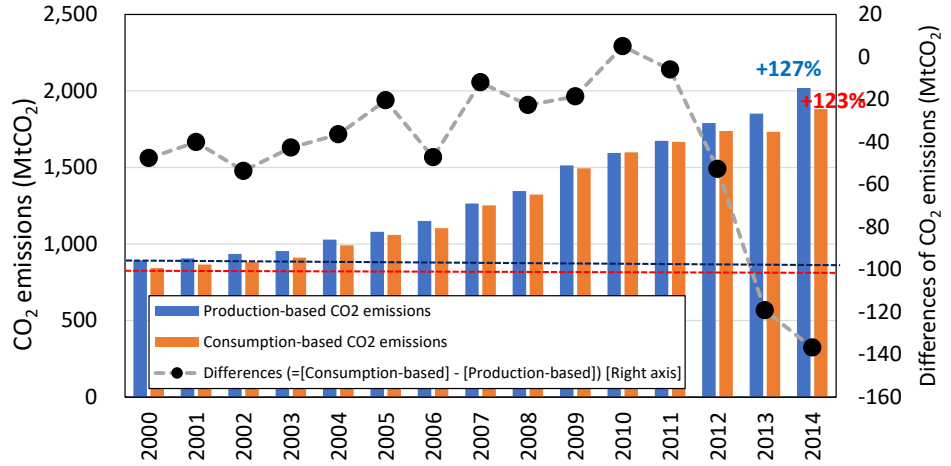
China and India：Production/Consumption-based CO_2 emission（2000-2014）

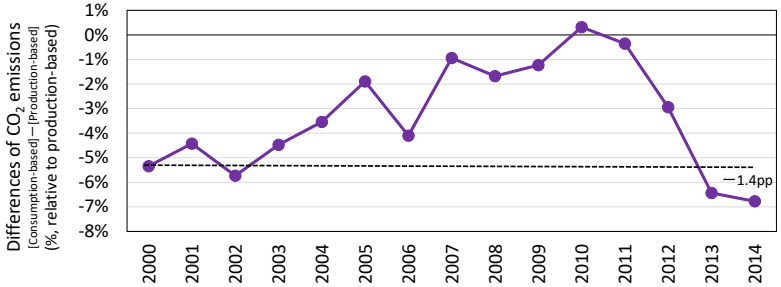
China





India





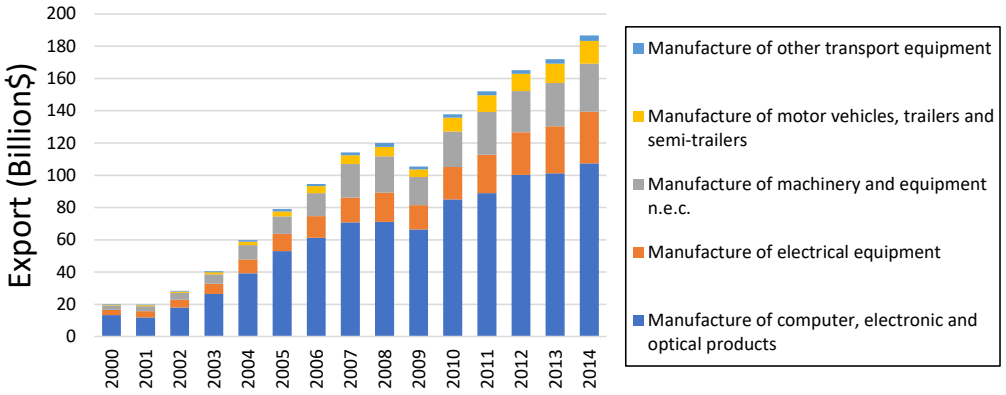
pp: percentage point

- China: The gap between consumption-based and production-based emission became larger until 2007（the CO_2 emission embodied in exports increased）. After 2010, the gap became smaller/ flat.
- India: The gap between consumption-based and production-based emission declined before 2010. However, after 2011, the gap increased.

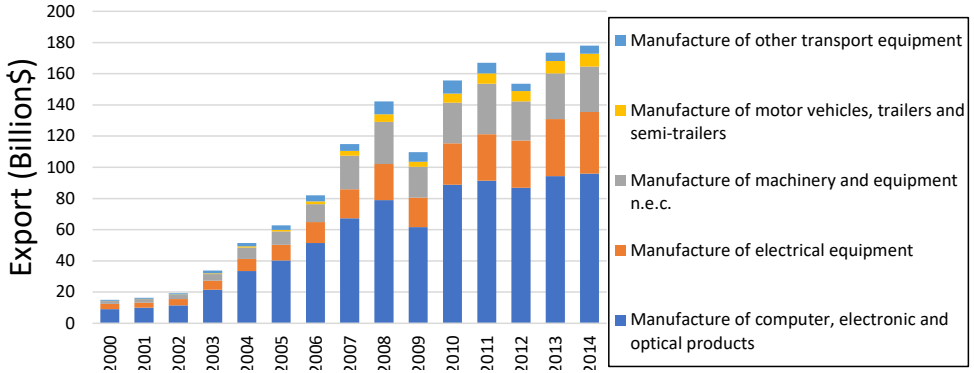
Note: Production-based CO_2 emission：IEA emission database (2017); consumption based CO_2 estimation is based on Peters et al.(2009) using WIOD 2016.

Appendix3：Trends in exports of Chinese machinery / transport machinery (2000-2014)

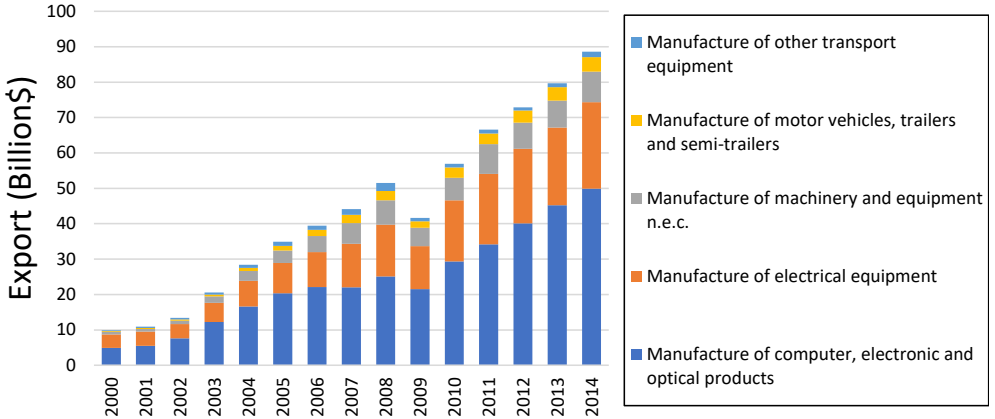
Export to U.S.



Export to EU



Export to Japan



Note：Estimated with WIOT