Main Drivers of Carbon Emissions across the World: Does the Level of Development Matter?

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Preliminary Version

Abstract

As economies develop, their demand for environmental protection and climate change mitigation also increases. It is well-known that efforts to control global warming and reduce greenhouse gas emissions date back to the first Conference of the Parties (COP) in 1995, that culminated in to the Paris Agreement at COP 21. This paper examines whether the main drivers of carbon emissions remain constant over time or change as a country's development status transitions. The paper identifies two potential scenarios: (i) a country's development status remains the same according to the World Bank classification (i.e., it stays either developed or developing) over the time period 1995-2018, then its development status is considered unchanged as developed or developing, (ii) a country moves from a developing to a developed status during this period, then it is referred to as a transitioned economy. The analysis aims to identify the key drivers of carbon emissions in each of the three types of economies (i.e., developed, developing and transitioned), and to provide appropriate policy recommendations based on the findings. The paper has utilized a structural decomposition analysis using OECD inter-country input-output (ICIO) tables for 1995 and 2018. Through the use of a global modelling structure, the outcomes in the paper contribute to a better understanding of the complex relationship between development and carbon emissions so that more effective strategies for mitigating climate change could be designed.

Keywords: Structural Decomposition Analysis, Carbon Emissions, Economic Development

1. Introduction

For several decades, the scientific community has recognized the need to control global warming. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations and World Meteorological Organization to assess and provide scientific evidence of global warming and its potential impacts. In the same year, the World Conference on the Changing Atmosphere was held in Toronto, Canada, which brought together scientists and policymakers to discuss the issue of climate change. Since then, numerous international agreements and initiatives have been created to address global warming, including the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the Conference of the Parties (COP) in 1995 (which led to the Paris Agreement in 2015). These agreements and initiatives reflect the global consensus that climate change poses a significant threat to human society and the planet, and that urgent action is needed to mitigate its impacts.

As this realization of the need to address the issue of climate change has spanned over three decades now, it is important to explore how the world is directing its efforts to mitigating global warming and what factors have been contributing to the increase in CO_2 emissions. Identifying the key drivers of CO_2 emissions is crucial for developing effective strategies and policies to mitigate climate change. By understanding the main sources and causes of CO_2 emissions, policymakers can develop targeted interventions that address these drivers and reduce the overall level of emissions. There are two methods to identify key factors governing the temporal changes in emissions: (i) Index Decomposition Analysis (IDA), and (ii) Structural Decomposition Analysis (SDA). While both methods have their advantages, SDA is recognized as a comprehensive approach as it is based on input-output (IO) model and takes economic systems into account, both production and consumption sides of the economy (Su & Ang, 2012; Wang et al., 2017b)(Su & Ang, 2012; Wang et al., 2017b)(Su & Ang, 2012; Wang et al., 2017b)(Su & Ang, 2012; Wang et al., 2017b).

Several studies have shown the effectiveness of using structural decomposition analysis (SDA) to identify key drivers of CO_2 emissions for individual countries (Butnar & Llop, 2011; Cansino et al., 2016; Chang et al., 2008; De Haan, 2001; Wood, 2009; Yamakawa & Peters, 2011), as well as for regions (Baiocchi & Minx, 2010; Cellura et al., 2012; Feng et al., 2012; Zhu et al., 2012). A few studies have taken a global approach and investigated both global and individual countries' main drivers of CO_2 emissions (Arto & Dietzenbacher, 2014; Jiang et al., 2021; Wang et al., 2017a; Xu & Dietzenbacher, 2014), with Wang et al. (2017a) comparing emerging and advanced economies based on individual countries' analyses.

Identifying the main drivers of CO_2 emissions for a group of countries is crucial for developing effective macro-level policies to address global warming. However, it is interesting to note that the increase in CO_2 emissions have been vastly different for economies that have remained at the same level of development (i.e., developed or developing) compared to the countries that have transitioned from developing to developed economies.

Figure 1: Total Direct CO_2 Emissions (Mtons)

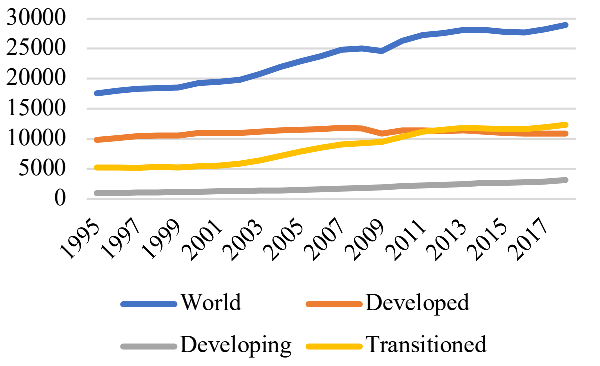


Figure 2: Average Direct CO_2 Emissions (Mtons)

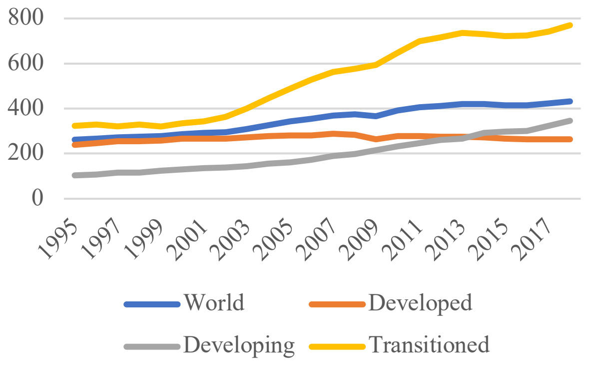


Figure 1 and 2 (above) uses carbon emission data from OECD Trade in embodied CO_2 (TeCO2) Database to visualize the carbon emissions trajectory of economies[1] based on their development journey from 1995 to 2018. Figure 1 depicts how the total emissions from developed economies remain almost the same over the 24 years period while that for developing countries increased slightly. On the other hand, the economies that transitioned

[1] For the classification of the economies refer to Section 3 and Table A1 in the Appendix.

from being developing to developed over this period of time has led to the substantial increase in world total direct carbon emissions. However, as the number of countries is not the same across the three categories based on the development journey, therefore, figure 2 shows the trajectory of average carbon emissions over time based on the development journey of the economies. It shows that the average direct carbon emissions for the developed economies have remained almost the same during the time period under consideration, while that of the developing economies has increased over time to surpass the average carbon emissions of the developed economies in 2014, and it is on the trajectory of converging with or surpassing the world average carbon emissions. On the other hand, average direct carbon emissions of the transitioned economies have always been more than the world average, and in 2018, it stood at almost two times of the world average carbon emissions.

This warrants studying the main drivers of the carbon emissions for developed, developing, and transitioned economies between 1995 to 2018, to learn from the experiences of the transitioned economies and make better policies to avoid similar emission trajectory by the developing economies on their way to become developed. This paper aims to use SDA technique to decompose the carbon emissions for all the three sets of economies and draw valuable insights that helps steer the economies (especially, developing) to a more sustainable and low-carbon development path. Specifically, the study focuses on understanding the influences of net migration, natural population growth, and income per capita on carbon emissions, which have received limited attention in previous research. By examining these factors, the paper aims to provide a comprehensive understanding of the drivers of carbon emissions and contribute to the formulation of effective policies for a greener future.

The paper is organized as follows. Section 2 provides information on the method and modelling technique utilized for this analysis. In section 3, detailed information is presented regarding the data utilized in this paper, including its sources and relevant considerations. Section 4 presents and discusses the results obtained from the SDA analysis. Finally, section 5 concludes the paper.

2. Methodology

The economic model or approach generally adopted to study the factors affecting environment is IPAT, i.e. $Impact = Population \times Affluence \times Technology$. This study uses IPAT-IOA for the SDA by including factors representing these three main factors. SDA decomposes the changes in a variable (total CO_2 emissions, here) over two points in time, into its constituents. For the purpose of this paper, these are: carbonization, energy intensity, productivity, income per capita, natural population growth, and net migration. SDA helps understand the contribution of different constituents in change noted in the variable of interest over time.

SDA is based on IO modelling and this paper uses multi-country IO model, therefore, the Environment Multi-Country Input-Output model is used to estimate total CO_2 emissions for all the countries:

$$\varepsilon = e'LY \tag{1}$$

Here, ε is a $n \times 1$ matrix that represents total CO_2 emissions for n countries, while e is the emission intensity of the same dimensions.[2] L is an $n \times n$ matrix representing the Leontief

[2] The symbol (') accompanying a matrix or a vector denotes the transposition of the corresponding element.

inverse $[L = (I - A)^{-1}]$. where I is identity matrix and A is the matrix of technical coefficient. Finally, Y is the $n \times 1$ final demand column vector.

Now, ε is decomposed into carbonization (C), i.e., total CO_2 emissions divided by energy consumption for each country n, and energy intensity (E), i.e., energy consumption divided by total output. To account for productivity (P), total output is divided by total value added that shows how efficiently value added is transformed into final output (Cobbold, 2003). Income is accounted for as income per capita (I) which takes the scale of population into account. Additionally, as several studies point out that only the size of the population is not of interest but also its growth and flow, therefore, the factors also include natural population growth (N), which is the difference between crude birth rate and crude death rate, and net migration (M). There, population for a given year (O_1) can be written as:

$$O_1 = O_0 + N_1 + M_1 \tag{2}$$

In eq.(2), O_0 is population in previous year, N_1 & M_1 is natural population growth and net migration in the given year.

Furthermore, Dietzenbacher & Los (1998) pointed out that there are $m!$, m being the number of factors under consideration (in our case 6!) valid manners to compute the decomposition. This paper uses the average of the two polar decompositions as suggested by Miller & Blair (2009). Based on that, the final decomposition statement can be expressed as:[3]

$$\begin{aligned}\Delta\varepsilon = \Delta CEPIO + C\Delta EPIO + CE\Delta PIO + CEP\Delta IO + CEPI(O_0 + \Delta N + M_1) \\ + CEPI(O_0 + N_1 + \Delta M)\end{aligned} \tag{3}$$

Here, in each component the factors that does not change is the sum of its value in year 2 and year 1, and the factor whose value changes is the difference of the two. The sum of the change in all the factors indicate the change in total CO_2 emissions over time.

3. Data

This paper uses the OECD Inter-Country Input-Output (ICIO) Tables for the year 1995 and 2018. The OECD ICIO tables provide information about the flow of final and intermediate goods and services for all countries. It is assumed that each industry produces one aggregated good. The ICIO tables comprise of 66 countries and rest of the world (RoW) with information for 45 sectors each that are considered aggregated. Additionally, to account for inflation, the ICIO table for 1995 was converted to 2018 prices by using the price indices like GDP deflator for production side and consumer price index for consumption side of the table.

Furthermore, the direct CO_2 emissions data based on production for each of the 66 economies for the 45 sectors is obtained from the OECD TeCO2 Database. The World Bank is the source for the income-based classification data for each of the economies, with low income and lower-middle income economies being referred to as developing economies, while upper-middle income and high income economies are categorized as developed economies (Gbadamosi, 2013). Based on this, the economies are divided into three development trajectories: (i) developed, the countries which have remained developed from 1995 to 2018, (ii) developing, the countries which have remained developing from 1995 to 2018, and (iii) transitioned, the

[3] The symbol Δ accompanying a variable denotes the difference between the final value and the corresponding initial ones.

countries which have transitioned to developed from developing between 1995 and 2018. Of the 66 countries under consideration, 41 are developed, 9 are developing and 16 are transitioned economies. For detailed classification of the countries based on income and their categorization into the three development trajectories, see Tables A1 in the Appendix.

For the purpose of decomposition, data on energy consumption gives total primary annual energy consumption in terawatt-hours (TWh). ICIO tables give information on output, consumption and value added in 2018 prices. Data for natural population growth, population and net migration is collected from UNPD. For more information on the data sources see Table A2 in the Appendix.

4. Results & Discussion

Figure 3 depicts the difference in average change in total CO_2 emissions for the world and the three development trajectory for the years 1995-2018. Over this time period, on average one country contributed 4.5 billion tons of carbon emissions. The average emissions from developing or developed country has been almost same, 2.23 billion tons and 2.27 billion tons respectively. On average a transitioned economy increase emissions by 11.7 billion tons.

Figure 3: Average change in emissions by type of economy (1995-2018)

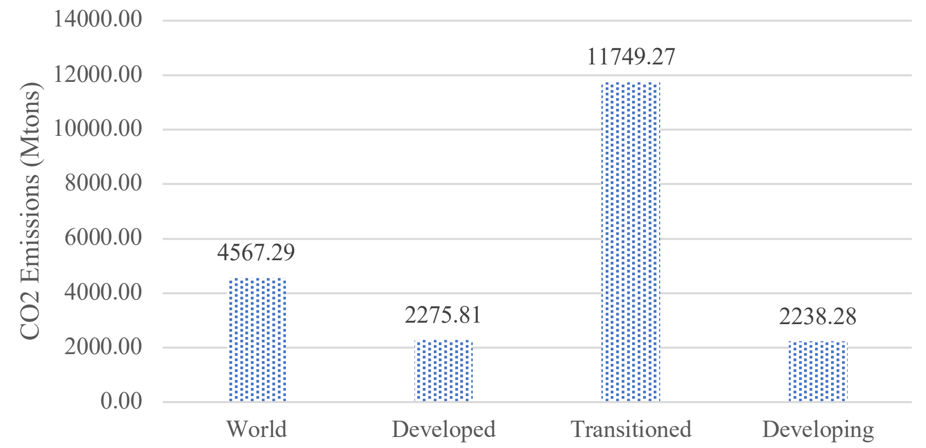
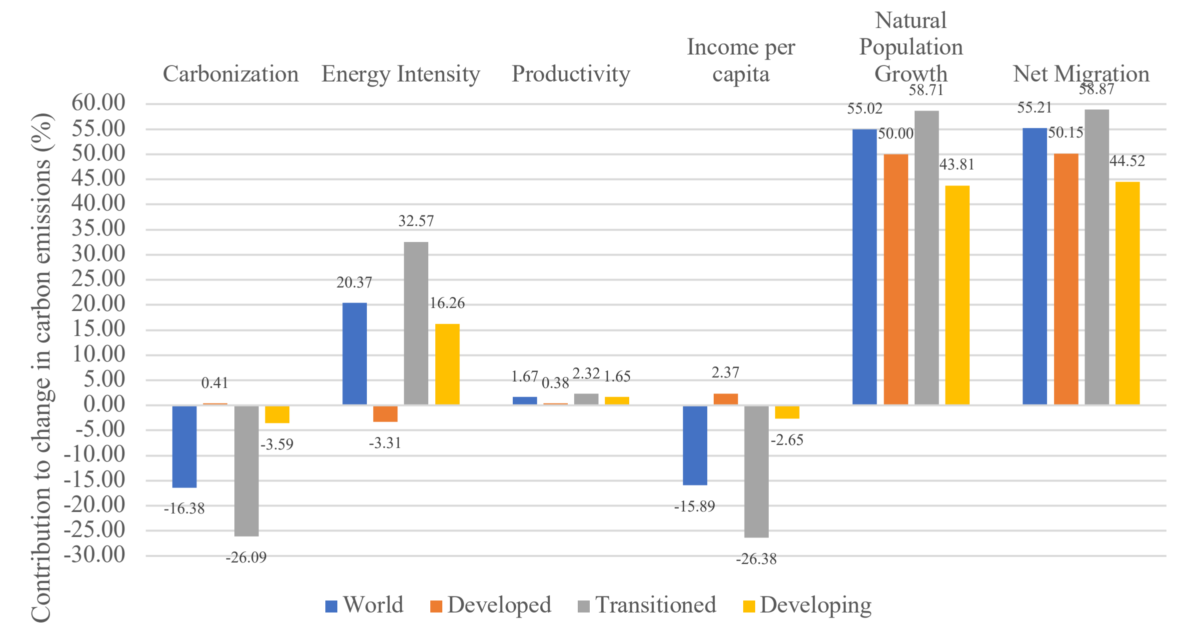


Figure 4 shows the contribution of the decomposition factors to this change in total CO_2 emissions.[4] For all the economies, population factors, i.e. natural population growth and net migration, makes substantial contribution to increase in CO_2 emissions. For developed economies carbonization increased by 0.4% while energy intensity decreased by 3.3%. This shows that for every unit of energy consumed carbon is emitted 0.4% more in 2018 as compared to 1995. On the other hand, for every unit of output produced, 3.3% less energy is consumed in 2018 as compared to 1995. However, this trend is exact opposite for both transitioned and developed economies where carbonization has decreased (i.e. for every unit of energy consumed less carbon is emitted), but energy intensity is increased (i.e. for every unit of output produced more energy is consumed). This is similar to Jevons Paradox where decrease in per unit energy consumption, leads to increase on total energy consumption. In our

[4] Country level analysis is given in Table A3 in the Appendix.

case, the decrease in carbon emission per unit of energy is offset by total increase in carbon emissions due to substantial increase in energy consumption per unit of output.

Figure 4: Contribution of Decomposed Factors to CO2



Increase in productivity has contributed to the emissions of all the economies. Income per capita, on the other hand, has decreased in developing and transitioned economies, and it has contributed only to emissions of developed economies (2.3%). All the factors show same direction for transitioned and developing economies, the only difference is their contribution is remarkably more for transitioned economies as compared to developing economies.

5. Conclusion

This paper aims to provide a comprehensive understanding of the changes in the global CO_2 emissions landscape, which can inform international efforts to tackle climate change. For this purpose, structural decomposition analysis (SDA) is used to explore the main drivers of CO_2 emissions for developed, developing, and transitioned economies between 1995 and 2018.

The analysis revealed important insights into the factors contributing to changes in CO_2 emissions over time. Population factors, particularly in natural growth and migration, have driven significant CO2 emission increases across all economies. Developed economies experienced a slight increase in carbonization but a notable decrease in energy intensity, while transitioned and developing economies saw a decrease in carbonization but an increase in energy intensity, resembling the Jevons Paradox. Productivity growth impacted emissions in all economies, while income per capita only influenced emissions in developed economies. This analysis will be extended to include export, imports, demand structure and demand mix to draw more robust conclusions.

The findings highlight the need for policymakers to address specific drivers of CO_2 emissions in each type of economy. By understanding the specific factors governing the countries' emissions according to their development profile, effective and successful mitigation measures can be defined and applied in the next years. The outcomes in this paper suggest that the individualised situations are not symmetrical as changes in emissions depend, to a larger extent, on the development condition of each economy. Accordingly, global commitments in international forums should consider the changes in the various explaining factors of emissions jointly with the income and development levels of countries. This would ensure not only a successful and effective low-carbon development path, but also a more equitable trajectory of climate change mitigation.

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References

Arto, I., & Dietzenbacher, E. (2014). Drivers of the growth in global greenhouse gas emissions. *Environmental Science and Technology*, *48*(10). https://doi.org/10.1021/es5005347

Baiocchi, G., & Minx, J. C. (2010). Understanding changes in the UK's CO2 emissions: A global perspective. In *Environmental Science and Technology* (Vol. 44, Issue 4). https://doi.org/10.1021/es902662h

Butnar, I., & Llop, M. (2011). Structural decomposition analysis and input-output subsystems: Changes in CO2 emissions of Spanish service sectors (2000-2005). *Ecological Economics*, *70*(11). https://doi.org/10.1016/j.ecolecon.2011.05.017

Cansino, J. M., Román, R., & Ordóñez, M. (2016). Main drivers of changes in CO2 emissions in the Spanish economy: A structural decomposition analysis. *Energy Policy*, *89*. https://doi.org/10.1016/j.enpol.2015.11.020

Cellura, M., Longo, S., & Mistretta, M. (2012). Application of the Structural Decomposition Analysis to assess the indirect energy consumption and air emission changes related to Italian households consumption. In *Renewable and Sustainable Energy Reviews* (Vol. 16, Issue 2). https://doi.org/10.1016/j.rser.2011.11.016

Chang, Y. F., Lewis, C., & Lin, S. J. (2008). Comprehensive evaluation of industrial CO2 emission (1989-2004) in Taiwan by input-output structural decomposition. *Energy Policy*, *36*(7). https://doi.org/10.1016/j.enpol.2008.01.043

Cobbold, T. (2003). *A Comparison of Gross Output and Value-Added Methods of Productivity Estimation*. https://www.pc.gov.au/research/supporting/comparison-gross-output-value-added-methods/cgovam.pdf

De Haan, M. (2001). A structural decomposition analysis of pollution in the Netherlands. *Economic Systems Research*, *13*(2). https://doi.org/10.1080/09537320120052452

Dietzenbacher, E., & Los, B. (1998). Structural decomposition techniques: Sense and sensitivity. *Economic Systems Research*, *10*(4). https://doi.org/10.1080/09535319800000023

Feng, K., Siu, Y. L., Guan, D., & Hubacek, K. (2012). Analyzing drivers of regional carbon dioxide emissions for China: A structural decomposition analysis. *Journal of Industrial Ecology*, *16*(4). https://doi.org/10.1111/j.1530-9290.2012.00494.x

Gbadamosi, A. (2013). *Understanding the Developed/Developing Country Taxonomy*. A4ID. https://www.a4id.org/policy/understanding-the-developeddeveloping-country-taxonomy/

Jiang, M., An, H., Gao, X., Jia, N., Liu, S., & Zheng, H. (2021). Structural decomposition analysis of global carbon emissions: The contributions of domestic and international input changes. *Journal of Environmental Management*, *294*. https://doi.org/10.1016/j.jenvman.2021.112942

Miller, R. E., & Blair, P. D. (2009). Input-output analysis: Foundations and extensions, second edition. In *Input-Output Analysis: Foundations and Extensions, Second Edition*. https://doi.org/10.1017/CBO9780511626982

NASDAQ. (2023). *Taiwan Province of China GDP Deflator*. https://data.nasdaq.com/data/ODA/TWN_NGDP_D-taiwan-province-of-china-gdp-deflator

National Statistics Republic of China (Taiwan). (2022). *CPI Change Rate*. https://eng.stat.gov.tw/Point.aspx?sid=t.2&n=4201&sms=11713

OECD. (2021a). *OECD Inter-Country Input-Output Database*. http://oe.cd/icio

OECD. (2021b). *Trade in Embodied CO2 Database (TECO2)*. https://stats.oecd.org/Index.aspx?DataSetCode=IO_GHG_2021

OECD. (2022). *Inflation (CPI)*. https://data.oecd.org/price/inflation-cpi.htm

Our World In Data. (2022). *Explore data on Energy*. https://ourworldindata.org/energy

Su, B., & Ang, B. W. (2012). Structural decomposition analysis applied to energy and emissions: Some methodological developments. *Energy Economics*, *34*(1). https://doi.org/10.1016/j.eneco.2011.10.009

The World Bank. (2022a). *Consumer price index (2010 = 100)*. https://data.worldbank.org/indicator/FP.CPI.TOTL

The World Bank. (2022b). *GDP deflator: linked series (base year varies by country)*. https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.AD

The World Bank. (2023). *The World by Income and Region*. https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html

UNECE Statistical Database. (2022). *Price Indices by Country and Year*. https://w3.unece.org/PXWeb2015/pxweb/en/STAT/STAT__20-ME__4-MEPI/0_en_MECCPriceInterestY_r.px/

United Nations - Population Division. (2022). *World Population Prospects 2022*. https://population.un.org/wpp/Download/Standard/MostUsed/

United Nations Department of Economic and Social Affairs (UN DESA). (2021). *International Migrant Stock*. https://www.un.org/development/desa/pd/content/international-migrant-stock

Wang, H., Ang, B. W., & Su, B. (2017a). A Multi-region Structural Decomposition Analysis of Global CO2 Emission Intensity. *Ecological Economics*, *142*. https://doi.org/10.1016/j.ecolecon.2017.06.023

Wang, H., Ang, B. W., & Su, B. (2017b). Assessing drivers of economy-wide energy use and emissions: IDA versus SDA. *Energy Policy*, *107*. https://doi.org/10.1016/j.enpol.2017.05.034

Wood, R. (2009). Structural decomposition analysis of Australia's greenhouse gas emissions. *Energy Policy*, *37*(11). https://doi.org/10.1016/j.enpol.2009.06.060

Xu, Y., & Dietzenbacher, E. (2014). A structural decomposition analysis of the emissions embodied in trade. *Ecological Economics*, *101*. https://doi.org/10.1016/j.ecolecon.2014.02.015

Yamakawa, A., & Peters, G. P. (2011). Structural decomposition analysis of greenhouse gas emissions in Norway 1990-2002. *Economic Systems Research*, *23*(3). https://doi.org/10.1080/09535314.2010.549461

YCharts. (2020). *Argentina Consumer Price Index (I:ACPI2EX6)*. https://ycharts.com/indicators/argentina_consumer_price_index_wdi

Zhu, Q., Peng, X., & Wu, K. (2012). Calculation and decomposition of indirect carbon emissions from residential consumption in china based on the input-output model. *Energy Policy*, *48*. https://doi.org/10.1016/j.enpol.2012.05.068

Appendix

Table A1: Classification of countries based on their income level and consequential categorization of their development status and trajectory

S.no.	Country Code	Country	World Bank Status		Development Status		Development Trajectory
			1995	2018	1995	2018	
1	AUS	Australia	High Income	High Income	Developed	Developed	Developed
2	AUT	Austria	High Income	High Income	Developed	Developed	Developed
3	BEL	Belgium	High Income	High Income	Developed	Developed	Developed
4	CAN	Canada	High Income	High Income	Developed	Developed	Developed
5	CHL	Chile	Upper middle income	High Income	Developed	Developed	Developed
6	COL	Colombia	Lower middle income	Upper middle income	Developing	Developed	Transitioned
7	CRI	Costa Rica	Lower middle income	Upper middle income	Developing	Developed	Transitioned
8	CZE	Czech Republic - Czechia	Upper middle income	High Income	Developed	Developed	Developed
9	DNK	Denmark	High Income	High Income	Developed	Developed	Developed
10	EST	Estonia	Lower middle income	High Income	Developing	Developed	Transitioned
11	FIN	Finland	High Income	High Income	Developed	Developed	Developed
12	FRA	France	High Income	High Income	Developed	Developed	Developed
13	DEU	Germany	High Income	High Income	Developed	Developed	Developed
14	GRC	Greece	Upper middle income	High Income	Developed	Developed	Developed
15	HUN	Hungary	Upper middle income	High Income	Developed	Developed	Developed
16	ISL	Iceland	High Income	High Income	Developed	Developed	Developed
17	IRL	Ireland	High Income	High Income	Developed	Developed	Developed
18	ISR	Israel1	High Income	High Income	Developed	Developed	Developed
19	ITA	Italy	High Income	High Income	Developed	Developed	Developed
20	JPN	Japan	High Income	High Income	Developed	Developed	Developed
21	KOR	Korea	High Income	High Income	Developed	Developed	Developed

22	LVA	Latvia	Lower middle income	High Income	Developing	Developed	Transitioned
23	LTU	Lithuania	Lower middle income	High Income	Developing	Developed	Transitioned
24	LUX	Luxembourg	High Income	High Income	Developed	Developed	Developed
25	MEX	Mexico	Upper middle income	Upper middle income	Developed	Developed	Developed
26	NLD	Netherlands	High Income	High Income	Developed	Developed	Developed
27	NZL	New Zealand	High Income	High Income	Developed	Developed	Developed
28	NOR	Norway	High Income	High Income	Developed	Developed	Developed
29	POL	Poland	Lower middle income	High Income	Developing	Developed	Transitioned
30	PRT	Portugal	High Income	High Income	Developed	Developed	Developed
31	SVK	Slovak Republic	Lower middle income	High Income	Developing	Developed	Transitioned
32	SVN	Slovenia	Upper middle income	High Income	Developed	Developed	Developed
33	ESP	Spain	High Income	High Income	Developed	Developed	Developed
34	SWE	Sweden	High Income	High Income	Developed	Developed	Developed
35	CHE	Switzerland	High Income	High Income	Developed	Developed	Developed
36	TUR	Turkey	Lower middle income	Upper middle income	Developing	Developed	Transitioned
37	GBR	United Kingdom	High Income	High Income	Developed	Developed	Developed
38	USA	United States	High Income	High Income	Developed	Developed	Developed
39	ARG	Argentina	Upper middle income	Upper middle income	Developed	Developed	Developed
40	BRA	Brazil	Upper middle income	Upper middle income	Developed	Developed	Developed
41	BRN	Brunei Darussalam	High Income	High Income	Developed	Developed	Developed
42	BGR	Bulgaria	Lower middle income	Upper middle income	Developing	Developed	Transitioned
43	KHM	Cambodia	Low income	Lower middle income	Developing	Developing	Developing
44	CHN	China (People's Republic of)	Low income	Upper middle income	Developing	Developed	Transitioned
45	HRV	Croatia	Upper middle income	High Income	Developed	Developed	Developed
46	CYP	Cyprus2	High Income	High Income	Developed	Developed	Developed
47	IND	India	Low income	Lower middle income	Developing	Developing	Developing
48	IDN	Indonesia	Lower middle income	Lower middle income	Developing	Developing	Developing

49	HKG	Hong Kong, China	High Income	High Income	Developed	Developed	Developed
50	KAZ	Kazakhstan	Lower middle income	Upper middle income	Developing	Developed	Transitioned
51	LAO	Lao People's Democratic Republic	Low income	Lower middle income	Developing	Developing	Developing
52	MYS	Malaysia	Upper middle income	Upper middle income	Developed	Developed	Developed
53	MLT	Malta	Upper middle income	High Income	Developed	Developed	Developed
54	MAR	Morocco	Lower middle income	Lower middle income	Developing	Developing	Developing
55	MMR	Myanmar	Low income	Lower middle income	Developing	Developing	Developing
56	PER	Peru	Lower middle income	Upper middle income	Developing	Developed	Transitioned
57	PHL	Philippines	Lower middle income	Lower middle income	Developing	Developing	Developing
58	ROU	Romania	Lower middle income	Upper middle income	Developing	Developed	Transitioned
59	RUS	Russian Federation	Lower middle income	Upper middle income	Developing	Developed	Transitioned
60	SAU	Saudi Arabia	Upper middle income	High Income	Developed	Developed	Developed
61	SGP	Singapore	High Income	High Income	Developed	Developed	Developed
62	ZAF	South Africa	Upper middle income	Upper middle income	Developed	Developed	Developed
63	TWN	Chinese Taipei	Low income	High Income	Developing	Developed	Transitioned
64	THA	Thailand	Lower middle income	Upper middle income	Developing	Developed	Transitioned
65	TUN	Tunisia	Lower middle income	Lower middle income	Developing	Developing	Developing
66	VNM	Viet Nam	Low income	Lower middle income	Developing	Developing	Developing
Note: Although the OECD recognizes Chinese Taipei as a separate economy, the World Bank does not, resulting in Chinese Taipei's income group being classified according to China.							

Table A2: Description of all the variables

Variable	Unit	Description	Source
Direct Emissions	Million Tonnes	CO_2 emissions based on production.	OECD Trade in embodied CO2 (TeCO2) Database
Energy Consumption	terawatt-hours (TWh)	Total primary energy annual consumption.	Our World in Data
Output	USD (2018 prices)	Total output produced by the country. Converted to 2018 prices using GDP deflator.	Estimated using OECD ICIO Tables.
Value Added	USD (2018 prices)	Value added includes compensation for labour (or employees) and capital (i.e., gross operating surplus). It also includes taxes less subsidies on intermediate products Converted to 2018 prices using GDP deflator.	Estimated using OECD ICIO Tables.
Productivity	Ratio	Ratio of total output and total value added.	Estimated using OECD ICIO Tables.
Crude Birth Rate	persons	Birth per 1000 population.	United Nations - Population Division
Crude Death Rate	persons	Death per 1000 population.	United Nations - Population Division
Population	persons	De facto population in a country, area or region as of 1 July of the year indicated.	United Nations - Population Division
Net migration	persons	Net migration is the total number of immigrants (people moving into a given country) minus the number of emigrants (people moving out of the country).	United Nations - Population Division
GDP Deflator	Index	It shows change in GDP due to change in price level. The information is available for countries with different base year.	The World Bank, NASDAQ (Taiwan)
Consumer Price Index	Index	It measures the average change in price for a basket of goods and services over time compared to a base period. As the data was collected for different countries from different sources, therefore the base year varied for the countries.	OECD, UNECE Statistical Database, World Bank, Ycharts (Argentina), National Statistics Republic of China (Taiwan)
Note: (i) To estimate GDP deflator and CPI for the Rest of the World, the data for the two indicators was collected from the World Bank for the countries that are not included in the 66 countries considered in this paper and for whom the data was available for both the indicators. This comprised of 87 countries. As the base year was not the same for GDP deflator, the series for all the countries were rescaled to make 2010 as the			

base year. The CPI series already had 2010 as the base year. Additionally, data was extrapolated for GDP deflator information of Canada for the years 1995 and 1996.
(ii) As value for net migration for Taiwan was zero, therefore, for the purpose of the analysis the value is assumed to be 0.5 for both the years, so the when it is subtracted its value is equal to zero, consequently its contribution. However, when it is added, it does not impact the calculations of the other contributing factors.
(iii) Net migration values for Turkey are taken from United Nations - Population Division, United Nations Department of Economic and Social Affairs (UN DESA). UN DESA provides net migration measured over the previous five years and is expressed as the average annual net number of migrants. Therefore, for 2018, numbers for 2020 have been used.
(iv) Crude Birth Rate, Crude Death Rate and Population information for Turkey is taken from 'Our world in Data'.

Table A3: Contribution of decomposition factors to total CO_2 emissions change by country

Country	Development Trajectory	Total CO_2 emissions change	Carbonization contribution	Energy intensity contribution	Productivity contribution	Income per capita contribution	Natural population growth rate contribution	Net migration contribution
Australia	Developed	2530.50	1.93	-10.02	0.45	9.87	48.82	48.94
Austria	Developed	484.32	2.45	-7.04	2.79	4.26	48.75	48.79
Belgium	Developed	726.32	-1.24	-5.98	0.76	3.99	51.25	51.22
Canada	Developed	3489.59	3.51	-12.15	0.44	10.66	48.75	48.79
Chile	Developed	452.77	6.81	5.07	0.40	3.80	41.71	42.21
Colombia	Transitioned	548.45	-6.75	16.51	2.32	-15.16	51.09	51.98
Costa Rica	Transitioned	69.94	-23.63	28.34	-2.31	-16.60	56.76	57.44
Czech Republic - Czechia	Developed	775.34	-8.27	-21.55	2.00	19.22	54.37	54.22
Denmark	Developed	469.55	7.17	-12.32	1.28	3.85	50.04	49.97
Estonia	Transitioned	110.60	0.48	-12.06	-0.64	19.10	46.47	46.66
Finland	Developed	415.30	6.52	-9.22	0.88	6.72	47.51	47.59
France	Developed	2466.31	3.53	-8.38	0.96	3.87	49.94	50.08
Germany	Developed	5107.06	-2.07	-7.70	1.83	4.14	52.04	51.75

Greece	Developed	591.78	-3.27	2.25	-0.82	-1.04	51.59	51.29
Hungary	Developed	317.24	-3.22	3.36	0.48	-3.85	51.74	51.48
Iceland	Developed	33.84	-14.20	14.64	1.28	1.76	47.96	48.56
Ireland	Developed	318.13	7.44	-16.87	-2.29	19.66	46.00	46.06
Israel	Developed	451.84	1.15	-6.59	-1.26	7.02	49.73	49.95
Italy	Developed	2373.16	0.88	-4.80	0.65	1.75	50.79	50.73
Japan	Developed	8927.77	0.87	-4.70	0.88	0.44	51.21	51.29
Korea	Developed	4507.37	-9.71	-0.78	2.26	11.93	47.82	48.50
Latvia	Transitioned	78.49	1.89	-17.38	0.23	22.10	46.55	46.61
Lithuania	Transitioned	190.55	14.33	-27.26	-2.71	27.95	43.73	43.95
Luxembourg	Developed	78.47	9.95	-18.73	12.93	4.60	45.74	45.50
Mexico	Developed	2783.84	-5.50	22.26	0.50	-20.03	50.84	51.93
Netherlands	Developed	1214.39	2.24	-9.10	1.65	5.00	50.08	50.13
New Zealand	Developed	242.67	6.65	-10.74	-0.88	9.45	47.74	47.78
Norway	Developed	389.23	10.51	-3.14	-0.35	0.73	46.08	46.17
Poland	Transitioned	2030.11	-8.19	-13.20	1.97	13.63	52.82	52.96
Portugal	Developed	363.64	-3.75	3.06	-1.91	4.06	49.33	49.21
Slovak Republic	Transitioned	345.02	-7.55	-28.52	0.92	25.52	54.77	54.87
Slovenia	Developed	83.85	-4.58	0.71	-0.07	0.54	51.69	51.71
Spain	Developed	1706.85	-3.33	-2.16	0.43	5.05	50.09	49.92
Sweden	Developed	434.47	6.72	-9.17	-1.11	5.65	48.99	48.92
Switzerland	Developed	457.80	9.63	-16.81	0.60	10.58	48.02	47.98
Turkey	Transitioned	84105.68	-59.76	74.80	5.03	-73.71	76.75	76.90
United Kingdom	Developed	2810.03	-0.99	-11.65	0.40	4.17	54.02	54.05
United States	Developed	33431.40	-2.95	-12.09	-0.24	9.02	53.14	53.12
Argentina	Developed	4643.14	26.72	33.62	1.16	-33.25	35.65	36.10
Brazil	Developed	2988.93	2.24	28.86	0.30	-23.88	45.92	46.56

Brunei Darussalam	Developed	40.93	-0.73	18.49	0.81	-5.08	42.99	43.52
Bulgaria	Transitioned	1497.92	-22.83	49.82	4.40	-51.45	60.15	59.92
Cambodia	Developing	54.56	-10.73	17.96	0.73	15.17	38.03	38.84
China (People's Republic of)	Transitioned	70102.25	4.29	-17.57	0.29	31.67	40.47	40.84
Croatia	Developed	110.56	-5.79	-2.62	-2.12	10.89	49.53	50.11
Cyprus	Developed	48.74	-4.81	-5.59	-0.12	3.18	53.79	53.55
India	Developing	12112.76	-2.34	6.76	1.75	8.33	42.40	43.10
Indonesia	Developing	4992.29	-1.45	35.60	0.59	-27.66	46.13	46.78
Hong Kong, China	Developed	787.97	-9.35	3.73	-4.75	13.33	48.47	48.56
Kazakhstan	Transitioned	1195.36	3.92	26.78	-5.35	-18.70	45.93	47.41
Lao People's Democratic Republic	Developing	416.20	-43.65	58.63	-1.18	-32.89	58.81	60.28
Malaysia	Developed	1064.43	-1.88	13.03	-2.43	3.17	43.76	44.36
Malta	Developed	27.93	-23.28	9.15	2.36	14.99	48.37	48.40
Morocco	Developing	297.82	-6.61	-0.67	-0.63	14.02	46.50	47.40
Myanmar	Developing	480.13	-30.89	44.73	4.01	-25.70	53.53	54.31
Peru	Transitioned	255.01	-3.24	7.19	-0.96	7.84	44.15	45.02
Philippines	Developing	823.13	0.96	7.32	1.35	-1.25	45.32	46.31
Romania	Transitioned	1623.11	-12.99	44.75	-2.28	-46.09	58.25	58.37
Russian Federation	Transitioned	22583.43	-3.45	40.35	-0.51	-39.05	51.58	51.08
Saudi Arabia	Developed	1622.56	11.86	7.05	-0.32	0.78	39.97	40.67
Singapore	Developed	783.92	-4.39	-6.38	-0.10	16.58	47.30	47.00
South Africa	Developed	2754.19	9.54	19.00	0.91	-20.17	44.96	45.77

Chinese Taipei	Transitioned	1769.38	-6.21	-4.93	-0.27	15.62	47.61	48.17
Thailand	Transitioned	1483.02	-11.00	8.27	1.53	7.23	46.77	47.20
Tunisia	Developing	139.21	-1.72	19.75	-0.09	-11.02	46.18	46.90
Viet Nam	Developing	828.39	-1.95	15.08	7.99	8.91	34.75	35.23