Appendices

Appendices

Appendix A – Technical note on the relationship between diversification and inequality

Chapter 3 outlines the results of an analysis of the relationship between diversification and inequality based on a sample of 182 countries over the period 1998 to 2018. The data used in this study was primarily collected from UNU-WIDER and UNCTAD. Inequality data was drawn from the UNU-WIDER WIID Companion, which provides the most comprehensive adjusted income inequality statistics covering 201 economies from 1960 to 2021.[1,2] Data covering 1998 to 2018 was considered based on the availability of export diversification and covariates data from UNCTAD. These covariates include GDP per capita (lagged term, in log), population size (in log), trade openness (expressed as the sum of imports and exports over GDP, in log), and human capital (expressed as a composite score, which captures the education, skills, and health conditions possessed by the population.

Appendix table A1 reports the regression results of the linear fixed effects model for the overall sample. The econometric analysis suggests a linear negative relationship between commodity dependence and income inequality, indicating that export diversification is associated with higher inequality. This suggests that diversification has adverse distributional effects on the population. This may be attributed to a more differentiated occupational structure, and wage differentials that arise with a more diversified economic structure. This relationship remains statistically significant across most different income inequality measures (Palma ratio and Theil's L index).

With respect to the effect of income, there is a statistically significant effect between GDP per capita (lagged term) and inequality, which is negative when considering the whole sample. This can proxy for economic development and implies that as incomes increase, inequality declines. Past income is used to reduce the effect of potential endogeneity between income and inequality. Indeed, the variable used measures income three years prior to current inequality, so it is a pre-determined variable. Trade openness is also negatively correlated with income inequality. This result is robust to the different specifications and dependent variables measuring inequality. This suggests that trade offers opportunities to different segments of the population, reducing the income gap.

Human capital appears to be positively correlated with income inequality measured by the Gini coefficient. This coefficient is also positive and statistically significant when considering the inter-decile ratio as the dependent variable. Population size is also significant and shows a negative coefficient. These findings remain robust when using the concentration index as the main regressor, which shows a significant negative association between income inequality (measured by the Gini coefficient) and export concentration (measured by the Finger-Kreinin similarity in trade indicator). Results also hold when considering the third export diversification measure (number of country product exports at the HS 6-digit level), which shows a positive association between export diversification and income inequality (measured by the Gini coefficient, the Palma ratio and Theil's L Index).

When disaggregating the sample by income and commodity dependence groups, table A2 unveils the following results. While there seem to be no statistically significant differences across income groups when measuring inequality with the Gini coefficient, there are differences when using the Palma ratio, the Theil's L index and the inter-decile ratio. These inequality measurements are more sensitive to changes in the tails of the income distribution and may provide additional information on the association between export diversification and income inequality. It seems that the positive relationship between diversification and inequality only holds in low and low-middle-income countries (and CDDCs), reflected by the significant coefficients in these specifications compared to high-income countries (non-CDDCs), where no diversification coefficient is statistically significant. The associations related to commodity exports highlighted in the low and low-middle-income subsamples remain statistically significant when using the Theil's L index and the inter-decile ratio as income inequality measures. This suggests that export diversification has negative distributional effects in lower-income countries. However, an alternative explanation could be that diversification in low-income and lower-middle-income countries is relatively limited and perhaps not extensive enough to create opportunities in all segments of the population. These results also suggest that trade openness decreases inequality in low and lower-middle-income countries. This is consistent with the Stolper-Samuelson theorem,[3] where an increase in trade in countries with relatively abundant low-skilled labour leads to lower inequality.

Table A1 Fixed effects coefficients (Linear, full sample)

Variables	(1) Gini	(2) Palma ratio	(3) Theil's L Index	(4) Inter-decile ratio
Commodity exports (% total merchandise exports, in log)	**-0.655***	**-0.197***	**-1.860***	-1.476
	(0.380)	(0.118)	(1.067)	(0.950)
Lagged term of GDP per capita (in log)	-2.127**	-0.134	-3.016*	-1.919
	(1.064)	(0.170)	(1.795)	(1.524)
Trade openness (in log)	-1.007**	-0.277**	-2.646**	-2.339*
	(0.449)	(0.122)	(1.216)	(1.336)
Population (in log)	-3.263**	-0.693*	-6.790*	-2.077
	(1.414)	(0.354)	(3.489)	(3.147)
Human capital index	0.0988*	0.00738	0.195	0.242**
	(0.0560)	(0.0128)	(0.119)	(0.108)
Constant	89.70***	10.73***	123.0***	43.17
	(13.60)	(3.146)	(31.50)	(31.78)
Observations	1,109	1,109	1,109	1,109
R-squared	0.149	0.077	0.102	0.026
Number of countries	182	182	182	182

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: UNCTAD.

Similar results are observed in the subsample comprising CDDCs, which indicates that the benefits of diversification may be constrained to a specific portion of the population in these countries. Nonetheless, as outlined previously, another interpretation could be that the limited diversification happening in these countries in the first place generates little benefits that cannot be spread out among the population. By contrast, most variables in the subsample containing non-CDDCs are statistically non-significant.

Table A2 Fixed effects coefficients (Linear, subsamples)

	Dependent variable: Gini				Dependent variable: Palma ratio			
Variables	(1) Low- and Low-middle-income	(2) High income	(3) CDDCs	(4) Non-CDDCs	(5) Low- and Low-middle-income	(6) High income	(7) CDDCs	(8) Non-CDDCs
Commodity exports (% total merchandise exports, in log)	-0.764	-0.462	-1.847	-0.625	**-0.399****	-0.0474	**-1.193***	-0.1
	(0.528)	(0.585)	(0.437)	(0.696)	(0.181)	(0.0523)	(0.147)	(0.0509)
L.GDP per capita (in log)	-1.173	-0.0636	-2.320**	-1.257	-0.0293	0.0243	-0.143	-0.134
	(1.200)	(1.466)	(1.159)	(2.119)	(0.305)	(0.121)	(0.195)	(0.151)
Trade openness (in log)	-1.153	0.624	-1.411***	0.772	-0.322*	0.0604	-0.350**	0.0487
	(0.703)	(0.450)	(0.505)	(0.764)	(0.187)	(0.0445)	(0.145)	(0.0599)
Population (in log)	-4.899	-1.184	-2.138	2.198	-1.074*	-0.128**	-0.445	0.196
	(2.960)	(0.721)	(1.403)	(2.685)	(0.634)	(0.0558)	(0.335)	(0.191)
Human capital index	0.159	-0.0165	0.0695	0.0292	0.0191	-0.00189	-0.00200	0.00158
	(0.110)	(0.0491)	(0.0723)	(0.0535)	(0.0308)	(0.00377)	(0.0187)	(0.00394)
Constant	98.82***	44.02***	86.68***	19.53	13.67**	2.239**	9.634***	0.503
	(26.42)	(13.73)	(13.55)	(27.02)	(5.867)	(1.071)	(2.996)	(1.855)
Observations	578	259	855	254	578	259	855	254
R-squared	0.119	0.031	0.188	0.032	0.074	0.035	0.09	0.03
Number of countries	105	48	136	46	105	48	136	46

Table A2 Fixed effects coefficients (Linear, subsamples) [Continued]

	Dependent variable: Theil's L index				Dependent variable: Inter-decile ratio			
Variables	(9) Low- and Low-middle-income	(10) High income	(11) CDDCs	(12) Non-CDDCs	(13) Low- and Low-middle-income	(14) High income	(15) CDDCs	(16) Non-CDDCs
Commodity exports (% total merchandise exports, in log)	**-3.196****	-0.636	**-8.219***	-1.400	**-3.122****	-0.202	**-9.200***	-0.934
	(1.587)	(0.822)	(4.924)	(1.028)	(1.437)	(0.418)	(5.376)	(0.775)
L.GDP per capita (in log)	-2.304	-0.123	-3.245	-2.022	-2.283	-0.202	-2.106	-0.524
	(3.030)	(2.174)	(2.301)	(1.788)	(2.666)	(0.909)	(2.122)	(1.143)
Trade openness (in log)	-2.987	1.136	-3.570**	0.579	-2.916	0.425	-3.212	-0.203
	(1.892)	(0.728)	(1.711)	(1.260)	(1.865)	(0.383)	(2.081)	(1.026)
Population (in log)	-10.56	-1.786*	-1.823	-12.37***	-5.007	-0.470	0.425	-4.504**
	(7.265)	(1.061)	(3.572)	(3.851)	(6.906)	(0.471)	(2.880)	(2.183)
Human capital index	0.369	-0.00553	0.0116	0.186	0.495*	0.0190	0.179	0.181*
	(0.289)	(0.0719)	(0.219)	(0.128)	(0.265)	(0.0308)	(0.198)	(0.107)
Constant	152.0**	34.43*	95.74***	148.1***	66.33	9.974	30.21	44.96**
	(65.11)	(19.40)	(34.47)	(34.09)	(66.29)	(7.633)	(33.01)	(20.36)
Observations	578	259	623	486	578	259	623	486
R-squared	0.090	0.029	0.111	0.107	0.028	0.023	0.033	0.055
Number of countries	105	48	114	99	105	48	114	99

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: UNCTAD.

Table A3 Countries included in the analysis

Afghanistan
Albania
Algeria
Andorra
Angola
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahamas
Bahrain
Bangladesh
Barbados
Belarus
Belize
Benin
Bhutan
Bolivia (Plurinational State of)
Bosnia and Herzegovina
Botswana
Brazil
Brunei Darussalam
Bulgaria
Burkina Faso
Burundi
Cabo Verde
Cambodia
Cameroon
Canada
Central African Republic
Chad
Chile
China
Colombia
Comoros
Congo
Democratic Republic of the Congo
Costa Rica
Côte d'Ivoire
Croatia
Cuba
Cyprus
Czechia
Denmark
Djibouti
Dominica
Dominican Republic
Ecuador
Egypt
El Salvador
Equatorial Guinea
Eritrea
Estonia
Eswatini
Ethiopia
Fiji
Finland
France
Gabon
Gambia
Georgia
Germany
Ghana
Greece
Grenada
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
Hungary
Iceland
India
Indonesia
Iran (Islamic Republic of)
Iraq
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Kiribati
Republic of Korea
Kuwait
Kyrgyzstan
Lao People's Democratic Republic
Latvia
Lebanon
Lesotho
Liberia
Libya
Lithuania
Luxembourg
Madagascar
Malawi
Maldives
Mali
Malta
Marshall Islands
Mauritania
Mauritius
Mexico
Republic of Moldova
Mongolia
Montenegro
Morocco
Mozambique
Myanmar
Namibia
Nepal
Kingdom of the Netherlands
New Zealand
Nicaragua
Niger
Nigeria
North Macedonia
Norway
Oman
Pakistan
Palau
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Russian Federation
Rwanda
Saint Lucia
Saint Vincent and the Grenadines
Samoa
Sao Tome and Principe
Saudi Arabia
Senegal
Serbia
Seychelles
Sierra Leone
Slovakia
Slovenia
Solomon Islands
Somalia
South Africa
South Sudan
Spain
Sri Lanka
Sudan
Suriname
Sweden
Switzerland, Liechtenstein*
Syrian Arab Republic
Tajikistan
Tanzania, United Republic of
Thailand
Timor-Leste
Togo
Tonga
Trinidad and Tobago
Tunisia
Turkmenistan
Türkiye
Tuvalu
Uganda
Ukraine
United Arab Emirates
United Kingdom of Great Britain and Northern Ireland
United States of America
Uruguay
Uzbekistan
Vanuatu
Venezuela (Bolivarian Republic of)
Viet Nam
Yemen
Zambia
Zimbabwe

Note: Commodity-dependent developing countries are marked in bold; the standard font is for non-CDDCs. Grouping countries into CDDCs and non-CDDCs is derived from the UNCTAD definition of commodity export dependence, when more than 60 per cent of its total merchandise exports are composed of commodities, in line with the *State of Commodity Dependence 2021*.

* This grouping is based on the UNCTAD target economies classification, available at https://unctadstat.unctad.org/EN/Classifications/DimCountries_TargetEconomies_Classification.pdf. For the purposes of this *study*, they are counted as a single country.

Appendix B – Estimating the cyclical and trend components of output-elasticities of emissions

Following (Cohen et al., 2018) and (Jalles and Ge, 2020), this report uses the Hodrick-Prescott (HP) filter to decompose real GDP per capita and GHG emissions series into their trend and cyclical components.[4] Despite its limitations, the HP filter has been widely used in the literature, so this report follows past practice. The cyclical component reflects the relationship between output and emissions due to the business cycle, and the trend component captures the long-run, structural relationship between output and emissions.[5] These decompositions were carried out for 186 countries classified as CDDCs, diversified developing countries (DDCs) or developed countries, over the period 1980-2018.

Data on real output (in 2010 United States dollars) are from the World Bank's World Development Indicators. Data on greenhouse gas emissions come from the Emissions Database for Global Atmospheric Research (EDGAR) which contains data sets covering the three direct greenhouse gases – carbon dioxide, nitrous oxide and methane aggregated by country and sector, using the IPCC 2006 sector designations.[6] For the historical analysis focusing on the five major industrialized economies, data for real GDP is from the Maddison Project, and data for historical carbon dioxide emissions are from the Carbon Dioxide Information and Analysis Center (CDIAC).[7] Total CO_2 emissions are the sum of fossil fuel emissions for solid, liquid, and gas fuels, as well as gas flaring and cement production. Combined GDP and CO_2 emissions data for each country is available as follows: United States (1800–2017), United Kingdom (1751–2017), Germany (1850–2017), France (1820–2017), and Japan (1870–2017).

The cyclical relationship between emissions and output is established by estimating the following fixed effects specification:[8]

$$e_{ti}^{c} = \beta^{c} y_{ti}^{c} + \gamma_{i} + \epsilon_{ti}^{c} \qquad (1)$$

where e_{ti}^{c} and y_{ti}^{c} are respectively the cyclical components of the log of emissions and log of real output for each country in the group, β^{c} is the estimated cyclical elasticity of emissions with respect to output, γ_i captures country-fixed effects and ϵ_{ti}^{c} is a random error term.

The trend elasticity is estimated as follows:

$$e_{ti}^{\tau} = \beta_0 + \beta^{\tau} y_{ti}^{\tau} + \gamma_i + \epsilon_{ti}^{\tau} \qquad (2)$$

Where e_{ti}^{τ} and y_{ti}^{τ} are the trend components of the log of emissions and the log of real output, β^{τ} is the estimated trend elasticity of emissions with respect to output and ϵ_{ti}^{τ} is a random error term. An intercept is included to account for differing initial levels of output and emissions.

In both specifications, γ_i are the country-specific fixed effects and ϵ_{t}^{τ} and ϵ_{ti}^{τ} are the error terms.

For individual countries, the cyclical and trend output elasticities of emissions are estimated using OLS regressions as follows:

$$e_{t}^{c} = \beta^{c} y_{t}^{c} + \epsilon_{t}^{c} \qquad (3)$$

$$e_{t}^{\tau} = \beta^{0} + \beta^{\tau} y_{t}^{\tau} + \epsilon_{t}^{\tau} \qquad (4)$$

where e_t^c and e_t^τ are the cyclical and trend components of the log emissions series for each country, y_t^c and y_t^τ are the cyclical and trend component of log GDP, and β^c and β^τ are the trend and cyclical elasticities.

Typically, the cyclical (trend) component of the log of emissions is regressed on the cyclical (trend) component of the log of real GDP for a country in a given year. The estimated coefficient beta is the cyclical (trend) elasticity of emissions with respect to output, accounting for country-fixed effects.

In addition, to provide a longer-term context about how these elasticities evolve, the same decompositions are conducted for much longer time periods – starting from the mid-18th or mid-19th centuries – for five major developed countries: France, Germany, Japan, the United Kingdom and the United States. These decomposed series are then divided into 30-year periods for each country, and elasticities are estimated on these shorter periods to better reflect changes in output-elasticities of emissions for these countries at different stages of their industrial development.

Furthermore, the time-series properties of the variables are analysed to ensure that the relationships are not spurious. For each country with adequate data, Augmented Dicky-Fuller tests are conducted to test for the presence of a unit root of the individual series before estimating the relevant elasticities. The results are presented for different country groups. Pickbourn et al. (2022) provides more information about country-level elasticities. Nevertheless, more in-depth country analyses might be needed to properly account for country specificities.

Empirical results – output-elasticities of emissions:

Table B1 shows the cyclical and trend elasticities for CDDCs, DDCs and developed countries. In general, these results are similar to those obtained for individual countries by Cohen et al. (2018) and Jalles and Ge (2020). These empirical results confirm the information in appendix table B2: higher trend elasticities for both CDDCs and DDCs suggest that emissions are more sensitive to changes in output in the long run than in the short run. A pairwise comparison of the means test confirms that while the trend elasticities for CDDCs and DDCs are not statistically different between them, both values are highly statistically different from the elasticity for developed countries.

Table B1 Trend and cycle elasticities by country status (fixed-effects estimates)

Country category	Trend elasticity	Trend p-value	Cycle elasticity	Cycle p-value
CDDC	0.67	0.00	0.23	0.00
DDC	0.65	0.00	0.39	0.00
Developed countries	0.30	0.00	0.63	0.00

Source: UNCTAD.

Disaggregating the group of CDDCs by type of commodity dependence reveals some heterogeneity within the group: trend elasticities are higher for CDDCs that depend on agricultural and fuel exports than among mineral exporters (Appendix Table B3). Analysis at the country level reveals even more heterogeneity within these groups (see Appendix Table A3 in Pickbourn et al. (2022)).

Table B2 Trend and cycle elasticities for CDDCs by type of commodity export

Country category	Trend elasticity	Trend SE	Trend p-value	Cycle coefficient	Cycle SE	Cycle p-value
Agricultural CDDC	0.72	0.03	0.00	0.25	0.05	0.00
Fuel CDDC	0.71	0.02	0.00	0.20	0.08	0.01
Mineral CDDC	0.53	0.02	0.00	0.27	0.07	0.00

Source: UNCTAD.

The differences among CDDCs are more striking when the elasticities are analysed by income (Table B3). How rich or poor a CDDC is clearly has some bearing on the sensitivity of emissions to output in that country: the trend output-elasticity of emissions in low-income CDDCs is 0.6, the same as in middle-income countries and 1.1 among high-income CDDCs. Again, elasticity estimates at the country level reveal considerable heterogeneity within these income groups.

Table B3 Trend and cycle elasticities for CDDCs by income group (fixed-effects estimates)

Income level (World Bank classification)	Trend coefficient	Trend p-value	Cycle coefficient	Cycle p-value
High	1.12	0.00	0.39	0.00
Low	0.60	0.00	0.11	0.00
Lower middle	0.62	0.00	0.23	0.00
Upper middle	0.60	0.00	0.27	0.01

Source: UNCTAD.

Note: See income group thresholds in Table 3.1.

Table B4 Elasticities of CDDCs by region (fixed-effects estimates)

Region	Trend coefficient	Trend p-value	Cycle coefficient	Cycle p-value
East Asia and the Pacific	0.48	0.00	0.23	0.09
Latin America and the Caribbean	0.73	0.00	0.61	0.00
Middle East and North Africa	1.04	0.00	0.18	0.08
Sub-Saharan Africa	0.62	0.00	0.16	0.01

Source: UNCTAD.

Regional analysis also reveals some important differences (Table B4). The long-run output-elasticity of emissions is highest in the Middle East and North Africa, which is rich in hydrocarbons, and considerably lower in East Asia and the Pacific, as well as in sub-Saharan Africa. A pairwise comparison of means reveals that compared with Europe and Central Asia, long-run elasticities are statistically higher in the Middle East and North Africa, sub-Saharan Africa, Latin America and the Caribbean. Emissions are also the least pro-cyclical in sub-Saharan Africa and more procyclical in Latin America and the Caribbean. These regional differences are likely due to differences in types of commodity dependence and production processes across regions. Within each region, there is again considerable heterogeneity among countries.

Long-run elasticities for early industrializers

Given the time that countries need to fully diversify their economies, it is important to take a long-term perspective. In this regard, the elasticities discussed in the previous section are compared with the historical elasticities of more developed countries. The trend growth-emissions elasticities are analysed for the five major developed economies since the middle of the 18th century. It is particularly interesting to consider these countries' elasticities in the early stages of industrial development, which is the stage where most CDDCs currently are. To do this, the full-time series of the five countries are split up into 30-year periods. The trend elasticity equations are estimated on each of these 30-year sub-periods. The results are plotted in Appendix A. The findings could inform the following argument that is frequently made: since today's developed countries are responsible for most of the accumulated stock of GHG emissions and currently have higher emissions than developing countries, should the latter not be allowed a greater share of the global carbon budget, at least until they have put in place the basic capabilities needed to fully engage and take advantage of the green transition? This debate is important in defining paths to the industrialization and diversification of CDDCs. Note that this analysis focuses only on CO_2 emissions, but as noted earlier, other emissions represent a marginal share of the total.[9]

Overall, the major industrialized economies appear to have followed highly carbon-intensive industrial growth paths, with a levelling-out of emissions growth in the late 20th century and ending with some modest attempts to reduce emissions.[10] Output growth in the early periods of industrialization led to more than proportionate increases in emissions, with trend elasticities greater than 2 in the mid to late 19th century for all the countries (Table A1). Each subsequent period generally witnesses a decline in the output elasticity of emissions. In their final period, they are at or near zero elasticity, suggesting most early industrializers have reached a state of relative decoupling. As earlier noted, this needs more investigation as this apparent decoupling might reflect the ability of the United States and Europe to outsource their most polluting productive activities to other regions, particularly East Asia, so that consumption in these countries embodies substantially more emissions than production (see Gough (2017), page 73; Pitron (2018); Jalles and Ge (2020)). The results show that these countries reached output-elasticities of emissions lower than one several decades after setting up their industrialization.

Country results show that generally, developing countries – both CDDCs and DDCs – have output-elasticities of emissions comparable to (and in several cases, less than) those of early industrializers when the latter were mostly well past a century of industrialization. The elasticities of several developing countries are at about the levels that the early industrializers reached in the mid-20th century (Pickbourn et al., 2022).

Endnotes

[1] UNU-WIDER, 2022. UNU-WIDER: World Income Inequality Database - WIID [WWW Document]. UNU-WIDER. URL https://www.wider.unu.edu/database/world-income-inequality-database-wiid (accessed 4.27.23).

[2] See WIDER Technical Notes for further information on the construction of the WIID Companion datasets (https://www.wider.unu.edu/publications?f%5b%5d=biblio_type:Technical+Note&query=WIID&order=desc&sort=string_date).

[3] Stolper-Samuelson, 1941.

[4] The Hodrick-Prescott Filter is a data-smoothing technique that minimizes the function where is a given series, is the trend component, is the cyclical component, and is the error component Hodrick and Prescott (1997). Following Cohen et al. (2019) and Jalles and Ge (2019), the smoothing parameter is used.

[5] The values for the aggregate series are initially calculated by using the unweighted mean. For robustness, the series was also aggregated using population weights.

[6] The IPCC sectors are defined as follows: energy industries comprises emissions from fuels combusted by the fuel extraction or energy-producing industries; manufacturing industries are emissions from combustion of fuels in industry, and includes combustion for the generation of electricity and heat for own use in these industries; transportation sector refers to emissions from the combustion and evaporation of fuel for all transport activity excluding military transport); manufacturing non-energy) covers emissions from industrial processes and product use, excluding those related to energy combustion. See the IPCC guidelines for further details.

[7] This dataset provides country-level time-series estimates of CO_2 emissions from fossil fuel combustion and cement manufacture going back to 1751, and include emissions from solid fuel consumption, liquid fuel consumption, gas fuel consumption, cement production, and gas flaring https://data.ess-dive.lbl.gov/view/doi:10.15485/1712447)

[8] For more details on the methodology, refer to the Pickbourn et al. (2022).

[9] As shown previously, CO_2 dominates GHG emissions so limiting the analysis to this type of gas does not affect the general view about GHG emissions.

[10] The trend-cycle decompositions for these five countries over the entire timespan are available upon request.

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