Structural Transformation and the Climate Crisis

The Sluggish Global Industry Composition and Its Impact on Emissions, 1970–2025

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Abstract

Since emission intensities vary substantially across industries, a changing sector composition can play a key role in reducing global greenhouse gas emissions. To assess its historical impact, I compile a new dataset covering eight sectors across 57 countries and residual regions from 1970 to 2025, representing the global economy. In constant price measures, I find that the sector shares of agriculture, industry, and services have changed only modestly over the past 55 years. Counterfactual scenarios show that these limited changes reduced global emissions by just –2.4% between 2000 and 2022: minor compared to the effects of rising consumption per capita (+56%) and emission intensity improvements (–26.8%). Two novel features help explain the modest structural transformation observed. First, I focus on volume shares — decisive for environmental impacts — rather than employment or nominal GDP. As this accounts for the falling relative price of industrial sectors, their decline is much more limited than in nominal shares. Second, I take a global perspective, accounting for offshoring and the growing industrial share in low-income countries. These findings challenge the view that market-driven structural change under current trajectories will significantly reduce emissions and highlight the need for active policy to redirect the global economy away from high-emission sectors.

Keywords: Global Structural Transformation, Emission Decomposition
JEL Codes: Q56, L16, O44

*Master PPD at Paris School of Economics (PSE). Contact: moritz.odersky@gmx.de. First, I want to thank my supervisor, Thomas Piketty, who has always been available with insightful feedback and generous support on this thesis and beyond. I also thank Marc Fleurbaey for agreeing to be my referee. I'm grateful to the entire WIL team, where I felt welcome from the start, and especially Jonas, Nelly, and Anmol, for feedback and the fun time working together. Finally, I thank Lucie, who is sometimes far but always there. All remaining mistakes are my own.

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1 Introduction

Economists from different schools of thought suggest that changes in the sectoral composition of the economy could help address the climate crisis. On the one hand, proponents of "green growth" argue that market forces are already steering the economy away from high-emission industrial sectors toward lower-emission service sectors. For example, Aghion et al. (2025) state: *"the key mechanism in our theory is that, as economies grow and incomes rise, economic activity shifts from material production toward services."* They suggest that this shift reduces total greenhouse gas emissions, thereby allowing for continued economic growth. On the other hand, advocates of "degrowth" argue that deliberate policy interventions are necessary to shift the economy toward a service-oriented "care economy", while also limiting overall growth to stay within planetary boundaries (Greenford et al., 2020; Hickel et al., 2022).

Both positions rest on a shared idea: that service sectors emit fewer greenhouse gases (GHG) than industrial sectors. If this is true, then a shift in the economy's structure away from industry and toward services, commonly called structural transformation or structural change, would reduce total emissions. However, if no such shift occurs, achieving climate targets will require even faster decarbonization within sectors or stricter limits on overall economic activity.

Figure 1 illustrates that GHG emission intensities indeed vary significantly across sectors.[1] It plots final-demand-based emission intensities, measured in kilos of CO_2 equivalents emitted per euro of final demand. Final demand refers to the total demand for goods and services intended for end use rather than for further production. It includes household consumption, government spending, and investment. In final-demand-based accounting, all GHG emissions along global value chains are attributed to the sector delivering the final product.[2] This consumption-based accounting contrasts value-added-based measures such as gross domestic product (GDP), which capture each sector's contribution to the market value of goods and services. In production-based accounting, emissions are assigned to the sectors where they physically occur (see Appendix Figure 28 for value-added-based emission intensities).[3]

[1]Greenhouse gas emissions are gases released by human activity that contribute to global warming. Other greenhouse gases than CO_2, such as methane and nitrous oxide, are converted into CO_2 equivalents based on their global warming potential.

[2]The attribution is done using inter-country input-output (ICIO) tables, which track all the inputs required to produce a sector's final output. This is also known as consumption-based or upstream accounting (Hertwich and Wood, 2018) and is described in Appendix A.

[3]Production-based emissions are also known as direct, territorial, or scope 1 emissions (see Burq and Chancel (2021) for a detailed discussion on emission accounting).

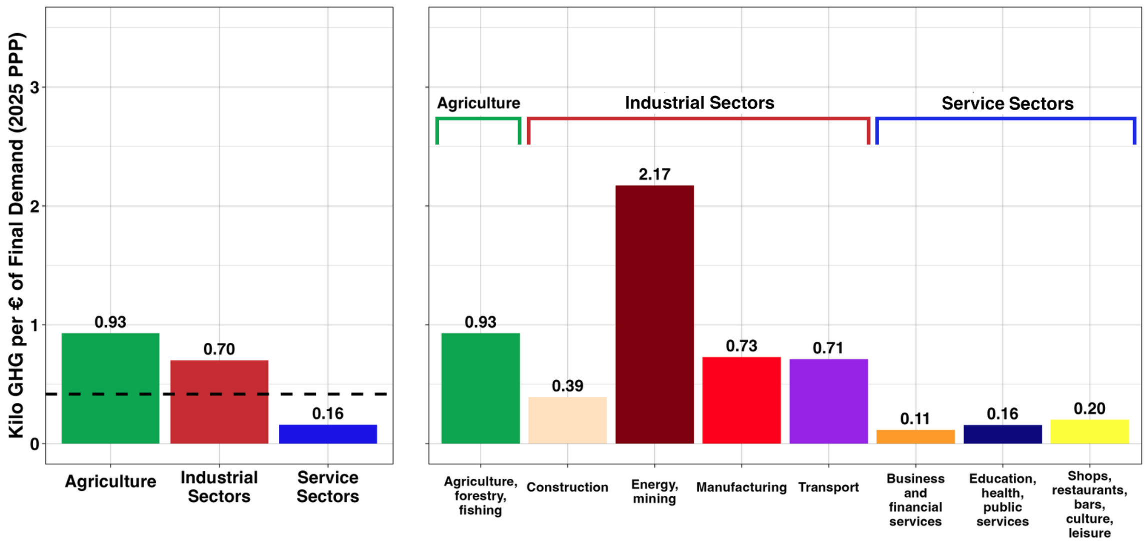


Figure 1. **Global Consumption-Based Emission Intensities in 2022**. CO_2 equivalents in kilos per euro of final demand (in 2025 PPP Euros). The eight sectors sum up to the three sectors. The three add up to the total economy, which is shown as the black dashed line (0.42 Kilos/Euro). On average, final demand of services causes around one-fifth of the emissions of industrial or agricultural final demand.

Given the potential for emission reduction through structural change, it is essential to understand how the sectoral composition of the global economy has evolved, and what forces have driven it. These insights can help to assess the potential of future structural transformation, whether market-driven or policy-induced.

However, the evolution of global sectoral shares of GDP and final demand in constant prices (i.e., volume terms) remains an open question in economics. Most empirical studies have either focused on employment and nominal GDP shares or limited their analysis to high-income countries. As a result, no clear global picture has emerged. Moreover, the main theoretical frameworks offer conflicting predictions: Baumol's theory suggests that rising productivity in industry and stagnant productivity in services lead to a price effect, causing a relative decline of services in volume terms. In contrast, Engel's law predicts that rising incomes shift consumption preferences toward services.

Therefore, this thesis aims to empirically answer the following question: **To what extent have changes in the industry composition of the world economy affected global greenhouse gas emissions between 1970 and 2025?**

Contribution. To answer this question, I have constructed a global eight-sector database covering 1970 to 2025. The database combines sector-level data on value-added, final demand, work hours, productivity, and prices, as well as GHG emissions since 2000. The global data consists of individual data points for 48 countries, with the remaining countries grouped into nine residual world regions. This enables a novel analysis of global structural transformation and its impact on GHG emissions through three main contributions.

First, studying the impact on emissions requires focusing on the sectoral composition in volume rather than value measures.[4] To that end, employment or nominal GDP shares are distorted by changes in sectoral productivity and relative prices. For instance, industry may appear to shrink as it becomes cheaper relative to services, even if output and emissions remain unchanged. To address this, I have harmonized sector-level price deflators and focus on value-added and final demand shares in volume terms.

Second, the global scope of the dataset enables the analysis of structural transformation in both high- and low-income countries. This also accounts for offshoring, where production and emissions shift from high-income to low-income countries, thereby lowering emissions in the former without reducing them globally.

Third, the dataset offers a consistent disaggregation into eight industries, going beyond the traditional classification into agriculture, industry, and services. This allows the study of heterogeneity within the industrial and service sectors.

Main Results. Between 1970 and 2025, the global final demand shares of agriculture, industry, and services remained remarkably stable in volume terms. Since 1970, the share of services in the global economy has only modestly increased by 4.3 percentage points. Conversely, the agricultural share has declined by 3 percentage points, and the industrial share was almost constant, reducing by 1.2 percentage points. Changes in value-added shares have been slightly larger, reflecting shifts in production structures, e.g., an increasing amount of services used as production inputs, in addition to changes in consumption patterns.

Decomposing global emission trends shows that changes in the final demand composition have reduced annual GHG emissions by only 2.3% between 2000 and 2022. In contrast, consumption per capita (+56%) and population (+30%) growth have led

[4] I use volume, real or constant prices to refer to variables, where year-on-year changes reflect quantity variations only. Similarly, value, nominal, or current prices refer to variables at prevailing prices, where changes over time reflect both price and quantity effects.

to a substantial increase in global emissions, which was somewhat slowed down by improvements in emission intensity (-27%).

These findings challenge common reports of rapid structural transformation, a difference that the study's two main novelties can explain: the focus on volume measures and the global coverage, which shows that industrial sector shares have declined in high-income countries but increased in low and middle-income countries over the past 55 years.

Roadmap. Section 2 reviews the Baumol and Engel theories and summarizes the empirical literature on structural transformation and its environmental impacts. Section 3 details the sources and methodology used to build the global dataset. Section 4 presents results on GDP and final demand shares. Section 5 examines measurement issues by comparing volume results to employment and nominal GDP shares. Section 6 explores economic drivers behind the observed stability. Finally, Section 7 quantifies the emission impact of sectoral composition changes and assesses the reduction potential from a more substantial transformation. Section 8 concludes.

2 Theory & Literature

There is a long-standing tradition in economics that seeks to understand if and how the sectoral composition of final demand and, by extension, the sectoral composition of value-added, changes over time. This section summarizes the existing theories and findings that serve as a benchmark for this study's results.

First, I introduce the two dominant economic theories on structural transformation. Named after the economists Baumol and Engel, these theories make conflicting predictions about changes in the composition of real final demand and value-added. Building on this, I next discuss the empirical literature on the two theories as well as on observed historical patterns of structural change. Finally, I provide an overview of existing environmental studies that assess the impact of the structural transformation on greenhouse gas emissions.

2.1 Baumol vs. Engel

There exist two widely discussed theories on structural change that describe opposing forces in the evolution of the sectoral composition of the economy: Baumol's theory focuses on a price effect, while Engel's theory rests on the idea of an income effect.

Baumol. William Baumol and his co-authors (Baumol and Bowen, 1965; Baumol, 1967; Baumol et al., 1985) argue that there exist both technologically progressive and stagnant sectors, where the former experience higher productivity growth than the latter. The technologically progressive sectors are typically industrial, while the stagnant sectors are services. Due to the differential productivity growth, technologically progressive sectors experience declining relative prices, and stagnant sectors become relatively more expensive.

In response to the productivity changes, labor relocates to the less productive sectors as fewer workers are needed in the progressive sectors. This results in a rising employment share of the stagnant sectors. Similarly, the share of the stagnant sectors increases in nominal value-added. However, Baumol argues that this is a pure denomination effect of changing prices. The lower prices in the progressive sectors potentially induce a price effect of higher consumption, and he predicts that the value-added shares in volume terms remain unchanged with income growth. As Baumol et al. (2012) states, *"it is reasonable to conclude that the manufacturing sector's share of the total 'physical' output of any given industrialized country has not changed very much."* This would imply that there is no long-term shift away from the emission-intensive sectors and no resulting emission reduction.

Engel. Baumol's hypothesis contradicts the idea of the "Engel curves", which predict that as people get richer, they change their consumption due to non-homothetic preferences (van Neuss, 2019). This effect is based on an idea of changing hierarchical needs. With additional income, people primarily purchase more services instead of additional agricultural or industrial goods, so that the sectoral composition of real quantities shifts toward services. Thus, with rising per capita income worldwide, the Engel theory expects continuously declining agricultural and industrial consumption shares.

While the predictions of the Engel and Baumol theories are similar regarding employment and nominal value-added shares, they diverge sharply in terms of sectoral value-added shares in volume terms. The changing prices in Baumol's theory could cause a price effect, leading to a higher consumption of industrial goods as people substitute services for these increasingly cheaper products. In contrast, the Engel theory predicts an income effect causing a rise in services and a decline in industrial sectors. The actual evolution of the sectoral composition will depend on which of the two effects dominates.

2.2 Drivers of Structural Transformation

In the classical multi-sector growth literature, changing relative prices and consumption preferences are still considered the two main drivers of structural transformation (van Neuss, 2019; Gangopadhyay and Mondal, 2021). There exists an extensive literature trying to estimate the relative importance of the two effects. Still, results are so far inconclusive, and depend on study period, country, number of sectors, and measurement (Dennis and İşcan, 2009; Herrendorf et al., 2013; Comin et al., 2021; Fukao and Paul, 2021). Theoretical models, which had at first focused on one of the two drivers, now incorporate both drivers into hybrid models to explain the observed empirical trends (Rogerson, 2008; Duarte and Restuccia, 2010).

Looking specifically at Baumol effects, the inverse relationship between sectoral productivity gains and relative price changes has been repeatedly confirmed in extensions to the original theory (see Ngai and Pissarides (2007); Alvarez-Cuadrado and Poschke (2011)). Empirically, Nordhaus (2008) analyzed the US from 1948 to 2001, and showed that sectors with slower productivity growth indeed experience rising relative prices. Since then, several studies on the US and other high-income countries have come to similar conclusions (see among others Duarte and Restuccia (2020); Gangopadhyay and Mondal (2021); Hartwig and Krämer (2023); Duernecker et al. (2024)). They have thereby highlighted the heterogeneity within the aggregate sector of services, within which one can find some of the most technologically progressive and stagnant subsectors (Baumol et al., 1985; Duarte, 2020; Duernecker and Sanchez-Martinez, 2023).

Production vs. Consumption. To understand the industry share developments better, Herrendorf et al. (2014b) highlight the importance of studying carefully the differences between variables. Importantly, value-added and final demand shares are impacted by different factors, such that studying the two can provide complementary insights.

Different trends in value-added and final demand shares can be explained either by changing input requirements or by outsourcing. Changing input requirements describe real economic changes. For example, when agriculture uses an increasing amount of industrial goods for a given output, this increases the share of industrial goods in value-added but not in final demand. These changes also have a tangible impact on the emissions that are produced in the economy.

Conversely, outsourcing is a measurement artifact that describes how firms outsource services that were previously conducted in-house. In the case of industrial firms, the value-added of the service activity was previously counted as industrial value-added (the main activity of the firm). After outsourcing, it is counted as value-added in the service sectors. The actual activities and emissions of the economy haven't changed, but value-added shares still adapt.

In both cases, final demand shares don't adjust, as the complete product value is assigned to the final producing sector. Studies have indeed reported a rise in the outsourcing of service jobs such as marketing or accounting, which could explain part of the growth in the value-added share of services (Yuskavage et al., 2008; Berlingieri, 2013; Miroudot, 2019; van Neuss, 2019). However, using occupation classifications, Duernecker and Herrendorf (2022) have recently argued that outsourcing is not a main driver of the observed labor reallocation to services.

Nonetheless, Herrendorf et al. (2014b) contend that there is a tendency in the general literature to overlook the differences between value-added, final demand, and other measures of structural change and argue that more work on these variations is warranted. Next, I will move from discussing the drivers of structural transformation to the observed patterns.

2.3 Structural Transformation Patterns

Many empirical studies have measured structural transformation in the three-sector decomposition between agriculture, industrial sectors, and service sectors (i.e., Duarte and Restuccia (2010); Duernecker and Sanchez-Martinez (2023)). The most common variables studied are employment shares. Real GDP and final demand are mostly discussed for countries in the Global North.

In a literature review, Herrendorf et al. (2014b) describe the general patterns that arise from historical studies on high-income countries across most variables: with income growth, the agricultural share declines, the services share rises, and industrial sectors show a reversed U-shape pattern.

The idea of a reversed U-shape pattern of the industrial sector value-added, i.a., emission-intensive sectors, corresponds to the concept of the environmental Kuznet curve (Kaika and Zervas, 2013). It describes the idea that with rising income, environmental impacts first increase and then fall. However, the theory has been repeatedly subject to criticism for being overly simplistic, for example, by studies showing that low-income countries also address environmental issues (Stern, 2004). Moreover, the development of the industrial sector share is contested in the literature on structural transformation and depends on the variable studied. For the US, Nordhaus (2008) actually observes a long-term increase in the real GDP share of the industrial sectors during the second half of the 20th century, driven by falling relative prices.

Outside high-income countries, studies have mainly analyzed changing employment shares. In the Global South, historically, there has been a transition from agriculture to industrial production (Timmer et al., 2015a). However, until today industrial levels remain low in many countries (McMillan et al., 2014). Further, there exists a debate on the possibility of a premature deindustrialization, meaning that the decline in the industry share starts at lower GDP per capita levels than in high-income countries (Rodrik, 2016; Atolia et al., 2020). Others have countered this and observed a "manufacturing renaissance" more recently after a temporary slowdown in the rise of the industrial sectors (Kruse et al., 2023).

Overall, there has not yet arisen a consensus on the evolution of the sectoral composition in volume terms. Insights from countries of the Global South are especially limited, so that the global pattern remains undiscovered. I will next present papers that quantify the impact of the observed structural transformation patterns on greenhouse gas emissions.

2.4 Impact on Emissions

Decomposition studies specifically analyze the impact of industry composition changes on greenhouse gas emissions. I will first summarize the literature arguing that in such analyses it is essential to use volume series and will then present the results of the historical emission decompositions.

Importance of Volumes. To study the environmental consequences of structural change, it is decisive to look at the evolution of GDP and final demand in constant prices. It is the composition of real volumes, i.e., describing real production outputs and consumption patterns, which matters for assessing the effect of structural change on GHG emissions (Kander, 2005). The monetary valuation does not directly affect emissions; only changes in the physical volume do. Henriques and Kander (2010) explain the importance of drawing conclusions on environmental effects only from shares in constant values but show that some previous studies have falsely used current price shares (e.g. Hamilton and Turton (2002); Schäfer (2005)). Thus, my main results will rely on GDP and final demand in constant prices, but I will also compare them to the trends in employment and nominal GDP.

Emission Decomposition. To move beyond simply analyzing trends in industry shares and to estimate the impact of sectoral composition changes on emissions exactly, studies have decomposed total emission trends into their drivers. As sector composition changes in real terms are modest in many countries, studies have correspondingly found limited effects on emissions (Kander, 2005; Henriques and Kander, 2010; Mulder et al., 2014; Artan et al., 2024). Much larger effects are observed for the scale factors of population and per capita consumption growth, which cause large emission increases, as well as the partial mitigation through reductions in emission intensities (i.e., Hamilton and Turton (2002); Henriques and Borowiecki (2017)).

After the publication of the WIOD database in 2014, which provides inter-country input-output tables for around 35 countries and which I also use as one data source, several decomposition studies emerged. Schymura and Voigt (2014) find a small negative effect of structural change on emissions and a somewhat larger negative emission intensity effect. Voigt et al. (2014) and Arto and Dietzenbacher (2014) similarly observe a small composition effect, but much larger reductions due to improvements in emission intensity. Country-level analyses for China and Brazil find similar patterns (Peters et al., 2007; Ribeiro et al., 2023).

At the country level, emissions can also be influenced by the offshoring of emission-intensive industries. Hardt et al. (2018) find it to be one of the biggest drivers of falling energy consumption in the UK, and Houseman et al. (2011) observe an increasing import share of material-intensive goods in the US. A global perspective naturally accounts for these patterns.

After summarizing the existing literature on structural transformation and environmental consequences, I will next present the data used in the thesis.

3 Measurement & Data

By collecting and harmonizing approximately twenty national accounts, input-output, and environmental data sources, I construct an eight-sector database spanning 1970 to 2025. It covers 48 individual countries and nine residual regions, which include all remaining countries. The eight sectors always add to the total economy values, and the sum of the 57 countries and regions equals the global totals. The database provides sector-level data on GDP, deflators, consumption, investment, work hours, and productivity. From 2000 onward, these national accounting variables are complemented by sectoral greenhouse gas emissions for all 57 countries and regions.

The database uses a consistent sectoral disaggregation into eight industries across all variables. Figure 2 shows the eight industries and their correspondence to the ISIC Rev. 3 and Rev. 4 standards (not all sources follow ISIC 3 or ISIC 4, see Appendix Table 4 for a detailed conversion table).

In the remainder of the section, I provide an overview of the data sources, the harmonization, and extrapolation (more details can be found in the Appendix Section B). In addition, I discuss the concepts and methods used to construct consistent sectoral deflators to measure volumes.

Sector	ISIC 3 Code	ISIC 4 Code
Agriculture, forestry, fishing	A+B	A
Business and financial services	J+K	K+L+M+N
Construction	F	F
Education, health, public services	L+M+N	O+P+Q
Energy and mining	C + E	B+D+E
Manufacturing	D	C
Shops, restaurants, bars, culture, leisure	G+H+O+P	G+J+I+R+S+T
Transport	I	H

Figure 2. **Sector Correspondence**. Eight sectors of the new database and their correspondence to the ISIC Rev. 3 and 4 classifications.

3.1 Sources & Data

Even though cross-country sources are available, the large number of variables and country-sector-year combinations required meticulous data collection and harmonization efforts.

To harmonize the sources, I apply growth-rate-based harmonization for each variable to build consistent time series from 1970 to 2025. The source priority is determined based on data quality and coverage; outliers are treated individually by comparing the country-variable series across the different sources. Whenever there are harmonized total economy values available for all countries, I ensure consistency by multiplying the newly created sector shares with the absolute values. After harmonization, the dataset covers over 90% of the global total values across all variables.

To fill gaps and ensure completeness, I use extrapolation based on regional averages for countries with limited data and linear extrapolation for shorter missing periods. For the nine residual regions, I first create a series for all 216 countries and then aggregate them. Appendix B.2 describes the detailed harmonization and extrapolation procedure.

Figure 3 summarizes the main data sources by variable. For each variable group, I will now describe the primary sources and highlight key challenges in the construction of the harmonized series. More detailed information on source coverage by country and variable can be found in the tables in Appendix B.1.

Sources for Historical Database on Sectoral Structure of World Economy

Variables	Description	Sources
Sectoral GDP & Relative Prices	Total Economy GDP and Deflator from *Nievas & Piketty (2025)*, industry-level newly created for 216 countries.	Nievas & Piketty, 2025 (World Inequality Database) World Input-Output Database Long-run WIOD Economic Transformation Database ETD Transition Economies African Sector Database 10-Sector Database UN Data: National Accounts Official Country Data (Tables 2.1 - 2.4) UN Data: National Accounts Estimates of Main Aggregates
Sectoral Working Hours	Total Economy from *Andreescu et al. (2025)*, industry-level newly created for all 56 countries and residual regions.	Andreescu et al., 2025 (World Inequality Database) Economic Transformation Database ETD Transition Economies African Sector Database 10-Sector Database ILOSTAT: mean weekly hours ILO Modelled Estimates
Sectoral Final Demand, Consumption & Investment	Total and industry-level final demand and its subcomponents (consumption and investment) newly harmonized for all 56 countries and regions.	OECD Inter-Country Input-Output Tables FIGARO World Input-Output Database Long-run WIOD
Population	Population Series from *Gomez-Carrera et al. (2024)*.	Gomez-Carrera et al., (2024) (World Inequality Database; based on UN World Population Prospects)
A-matrix & T-matrix	Inter-country Input-Output matrices	FIGARO World Input-Output Database Long-run WIOD
Sectoral GHG Emissions	Totals from the Global Carbon Project, sectoral-level newly harmonized for 56 cuntries and regions.	Global Carbon Project FIGARO World Input-Output Database Environmental Accounts

Figure 3. **Overview of the Main Sources by Variable Group.** Eight-sector database covering 48 countries and nine regions from 1970 to 2025, together summing to world aggregates. All sources harmonized to eight equivalent industry sectors, which add up to the economy totals. Sources are listed in order of harmonization priority, and if sectoral values are matched to totals, the source of the aggregates is indicated in the description column.

GDP & Deflators. Total economy GDP values in current and constant prices, along with total economy deflators, are drawn from Nievas and Piketty (2025), who provide updated data for the 216 countries included in the World Inequality Database (WID). The aggregate values are then broken up into eight sectors by using sector GDP shares in current and constant prices from various sources.

Where available, I used the World Input-Output Database (WIOD) and the long-run WIOD from the Groningen Growth and Development Center (Timmer et al., 2015b; Woltjer et al., 2021). Up until 2014, they provide input-output tables for around 35 countries in both current and previous-year prices, which I convert into constant prices using chain-linking. Country and year coverage, especially in the Global South, is extended by using the Economic Transformation Database (ETD) and its extension, the ETD Transition Economies, the African Sector Database (ASD), and the Ten-Sector Database (TSD) (Kruse et al., 2023; Hamilton and de Vries, 2025; de Vries et al., 2015; Timmer et al., 2015a). I also incorporate UN Official Country data, using only country-year entries with full industry coverage. Finally, where necessary, I rely on the UN Main Aggregates, which cover 219 territories but use a 7-sector classification. However, due to its partial harmonization and limited sectoral resolution, I only use it if no other source is available. This is the case primarily for some small, low-income economies.

Overall, data availability for sectoral GDP shares is strong, so that I have sectoral data points for all 216 WID countries. By combining the sectoral current and constant shares with the total GDP values, I obtain absolute values and calculate sectoral GDP deflators, which are consistent with the total economy deflators.

Work Hours & Productivity. For the construction of sectoral work hours, I first compute sectoral employment shares, which I then combine with data on annual hours worked per employee to derive work hour shares. Work hours provide a more accurate measure of labor input than employment figures, which ignore sectoral differences in working time (Herrendorf et al., 2014a; van Neuss, 2019).

Employment shares primarily come from the ETD, the ETD Transition Economies, the ASD, and the TSD, sources that I have already used for GDP. For countries not covered by those data sets, I use the ILO Modelled Estimates, which provide data for all countries disaggregated into 14 sectors that map well to my classification. However, similar to the UN Main Aggregates, the ILO data is extrapolated for some nations, so I only use it when no other source is available.

After harmonizing employment shares for all 216 economies, I use ILOSTAT data on sectoral mean weekly hours to adjust for sectoral differences in the hours worked per employee. Similar to GDP, the work hour shares are combined with the economy totals created by Andreescu et al. (2025) to obtain absolute values. Combining GDP and work hours yields sectoral labor productivity (GDP per hour worked), which I refer to simply as productivity throughout the paper.

Final Demand. Final demand reflects a consumption perspective, counting all expenditure on goods and services not used for further production. Globally, around one-fourth of final demand is investment and three-fourths is consumption; the shares have been broadly stable since 1970 (see Appendix Figure 29). As any good that is not used within one year is counted as an investment in national accounting, including items such as residential housing, I use aggregate final demand to discuss the consumption perspective. At the sector level, final demand is assigned to the industry of completion, that is, the last industry before it is consumed. Exceptions are made for trade and transport margins: only their value-added is counted as final demand of those sectors, while the remaining value is attributed to the industry that last modified the product (Lequiller and Blades, 2014).

Comparable cross-country data for consumption is generally less available than for value-added (Herrendorf et al., 2014a). I rely on data from four different inter-country input-output tables (ICIO), which gives me a substantial country-year coverage. ICIO tables distinguish between intermediate inputs and final demand components and also detail cross-border flows, making it possible to observe sectoral consumption and investment. ICIOs usually have a given number of countries and a "Rest of the World" residual, which is usually extrapolated and therefore not used in this study. Instead, I combine several sources to maximize coverage and then create my own nine residual regions based on actual country observations.

To harmonize, I divide all variables by the total economy GDP from the same source, and then harmonize the shares. Afterwards, absolute values are recreated by multiplying the harmonized shares with the harmonized GDP values. Among the sources, priority is given to the OECD inter-country input-output table, which covers 76 countries from 1995 to 2020. Most historical data comes from the WIOD and long-run WIOD, with further countries added via the EU's FIGARO database. During harmonization, I ensure that subcomponents sum to aggregates. In case of inconsistencies, I give priority to the aggregates as they usually have higher data quality. Thereby, I ensure that accounting identities hold, for example, that consumption components add up to total consumption.

Greenhouse Gas Emissions. In addition to the national accounting variables, the database also includes sectoral emissions data. Emissions are mapped based on the same sector classification as the national accounting items. Due to data limitations, coverage only starts in 2000, from which year the WIOD environmental satellite accounts provide sectoral CO_2 emissions data (Corsatea et al., 2019). This is combined with sectoral greenhouse gas (GHG) emissions post-2010 from FIGARO, which covers all greenhouse gases. Between 2000 and 2009, I transform the CO_2 series into GHG bseries based on total economy GHG values from the Global Carbon Project and the observed CO_2e-GHG-ratios by sector in 2010.

Population. The population series by country and on the global level are taken from Gomez-Carrera et al. (2024). During the period under study from 1970 until 2025, the dataset mostly relies on the 2024 updated UN World Population Prospects (WPP).

A-Matrices. Finally, in addition to the newly created eight-sector database, I use historic A-matrices from the WIOD and FIGARO input-output tables to calculate final-demand-based emissions. A-matrices show how much input from each industry is required to produce one unit of output in every other industry.

3.2 Measuring Volumes

This study requires the measurement of real quantities, that is, the actual volumes of goods and services produced by each sector. However, in practice, sectoral shares are typically reported in nominal terms, which conflate price and quantity changes. To recover volume changes, I use purchasing power parities (PPPs) and sector-specific deflators. This section explains the use of these concepts in more detail and discusses general challenges associated with measuring volumes.

Purchasing Power Parity. Cross-country price level differences imply that a given nominal income can buy different consumption levels in different countries. These differences are mainly due to lower prices for non-tradable goods in lower-income countries, driven by lower wage levels (Blanchet, 2017). Market exchange rates do not capture these discrepancies, thereby overstating consumption gaps between high- and low-income countries. To address this, I use PPP exchange rates from the World Inequality Database that equalize the real value of a given monetary amount across countries (Alvaredo et al., 2020). All series in the study's dataset, both in current and constant prices, are expressed in PPP-adjusted Euros.

Price Indices. To isolate volume changes over time, price indices are required. While total economy deflators (e.g., GDP deflators) are readily available and sufficient for aggregate analyses, they do not account for changes in relative prices between sectors. Applying a uniform deflator to all sectors assumes identical price dynamics, which biases volume estimates. In sectors with falling relative prices, volume growth is underestimated, and in sectors with rising relative prices, volume growth is overestimated. Figure 4 illustrates how deflating by total versus sector-specific deflators affects the prices in which the series are nominated, depending on whether one studies the total or sector level.

	Current Price	Total-Economy Deflated	Sector-Deflated
Total Economy	Value Series	Volume Series	Volume Series
Sectoral Absolute Values	Value Series	Volume Total * Value Share	Volume Series
Sectoral Shares	Value Shares	Value Shares	Volume Shares

Figure 4. **Illustration of Current Price, Total-Economy Deflated, and Sector-Deflated.** Boxes with the same color have the same values. In value series, year-on-year differences can be caused by both quantity and price changes, while in volume series, year-on-year differences show pure quantity changes. The main focus of the study lies on sector-deflated series.

Current-price series remain relevant for analyzing expenditure and income-related questions, e.g., how much households spend on a sector or the sectoral distribution of income. At the total economy level, general deflators suffice to derive real growth trends. However, to assess physical production or emissions at the sector level, sector-deflated series are required. The "sectoral absolute values" obtained by applying a total economy deflator are not true volume series. Instead, they represent total output in constant prices multiplied by current-price sector shares, which is not easily interpretable. In Figure 4, I label this construct "Volume Total * Value Shares". Because the same factor deflates all sectors, the evolution of the sector shares is the same as with current-price data. For the remainder of this paper, references to "volumes," “constant-price series,” or “real sectoral shares” always refer to sector-deflated series.

Potential Biases. Building price indices and volume series is complex, and several biases can arise. The core problems are how to deal with new products that are not in the price index basket (”new good bias”), changing product quality (”quality bias”), and the adaptation of consumers to price changes (”substitution bias”). These issues are well documented in the literature (Deaton, 1998; Blanchet, 2017). National statistical agencies adopt various methods to address them. In this study, I rely on these official data sources and do not attempt to correct these biases myself.

Non-market Output. For sectoral analyses, it is also important to measure changes in non-market production. For example, in many countries, a substantial part of the education, health, and public services sector is provided free or at non-economically significant prices, so-called ”non-market output” (EUROSTAT, 2016). The convention is that these outputs are valued by the sum of production costs (International Monetary Fund, 2009). While this is clearly an important limitation, Gethin (2023) shows that public spending in these sectors is correlated with output-relevant outcomes.

Deflating these services to obtain volume series is especially difficult. Historically, the dominant method was input deflation, which implies zero productivity growth (Atkinson, 2005). More recently, national accounting institutions in many countries have adopted output-based measures using the price indices of comparable market goods or use direct output indicators such as student numbers or standardized test scores (OECD, 2022).[5] While I observe some productivity gains in these sectors, I cannot assess the accuracy of the deflators and rely on the national accounting sources.

Deflating Final Demand and Other Variables. The deflators that I create are GDP deflators, thus tracking price changes of sectoral value-added. However, I also apply them to other items such as final demand. This is necessary because, as of now, there exists no inter-country input-output table in constant prices covering recent years.[6] Applying a GDP deflator to other variables is suboptimal because it rests on the assumption that prices of a sector have developed the same regardless of its final use. For example, if final demand uses a subset of manufacturing goods that

[5] OECD (2022) discuss the different methods used by OECD countries.

[6] OECD and FIGARO both state that they are currently working on providing complete ICIO in previous-year prices.

has different price dynamics than the total manufacturing output, ideally, one would deflate by the final demand's specific price index. In the absence of more granular deflators, I assume homogeneous within-sector price developments.

After these measurement clarifications, the next part presents the core results of the data analysis.

4 Results: Global Structural Transformation

This section presents the global structural transformation over the past 55 years, measured both in volume GDP and volume final demand. For each variable, I will first analyze changes at the three-sector level, addressing the classic literature on structural transformation, and then use the eight-sector decomposition to explore heterogeneity within the industrial and service sectors.

Absolute value-added and final demand, as well as per-capita levels, have grown significantly in all sectors between 1970 and 2025. However, varying sectoral growth rates have altered their relative shares. Global volume GDP has undergone a modest shift away from agriculture and industrial sectors towards services. Final demand reveals an even more stable three-sector composition with only a very limited shift towards services. In both variables, changes have been more substantial at the eight-sector level but partly offset each other when aggregated to the three sectors. While GDP shares are determined both by changing consumption and investment patterns as well as evolving production input structures, final demand reflects only changes in the consumption and investment composition by sector.

4.1 Real GDP Shares

Over the past 55 years, the service sector's GDP share has increased by 8.9 percentage points, while both agriculture and manufacturing decreased their share in roughly equal parts (see Figure 5). Services today make up almost 60% of global GDP, up from around 50% in 1970 when measured in today's prices. The agricultural GDP share has nearly halved from around 11.6% in 1970 to 5.8% today.

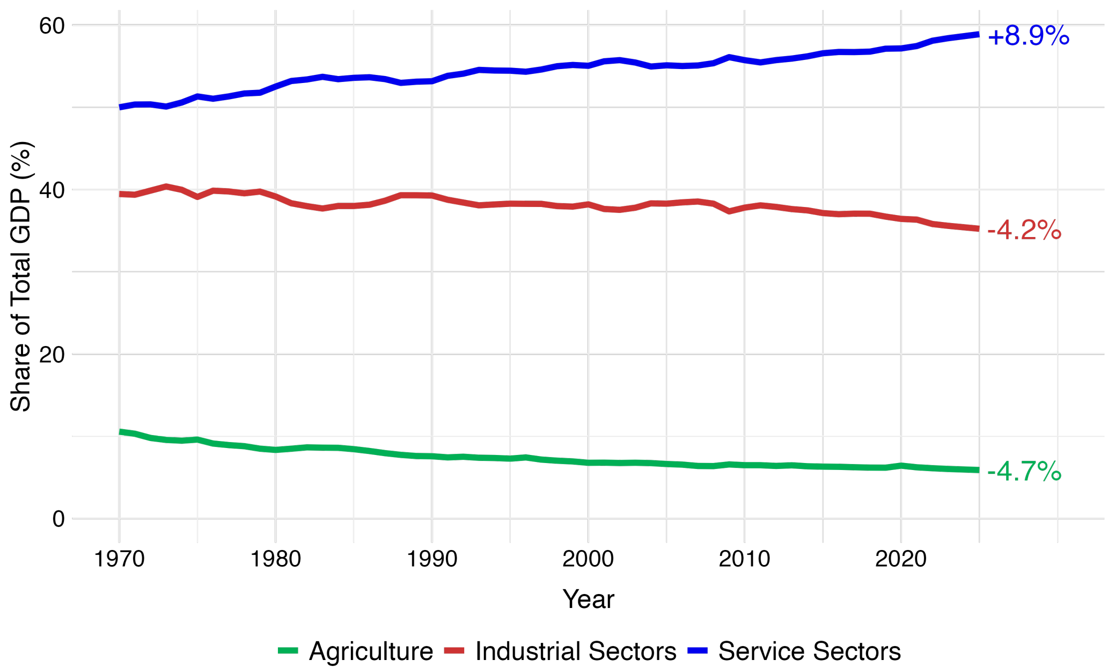


Figure 5. **Global GDP Shares in Volume Terms by Three Sectors (2025 PPP Euros).** Agriculture includes 'agriculture, forestry, fishing'; the industrial sectors include 'construction', 'manufacturing', 'energy, mining', and 'transport'; services include 'business and financial services', 'education, health, public services', and 'shops, restaurants, bars, culture, leisure'. Percentages show difference between 1970 and 2025 shares.

Eight-sector decomposition. Looking at absolute volumes shows that value-added has increased substantially across all eight industries during the past 55 years (see Figure 6). Total global GDP has grown sixfold since 1970. Accounting for population growth, per capita GDP has still increased by a factor of 2.5 (see Appendix Figure 30). All sectors at least tripled their GDP volume, with particularly strong growth in business and financial services as well as in transport, though the latter still represents a small absolute share. In general, one can see that growth was heterogeneous across sectors, leading to a changing industry composition. Importantly, not only service sectors but also manufacturing and transport grew above average, illustrating the heterogeneity within the service and industrial sectors.

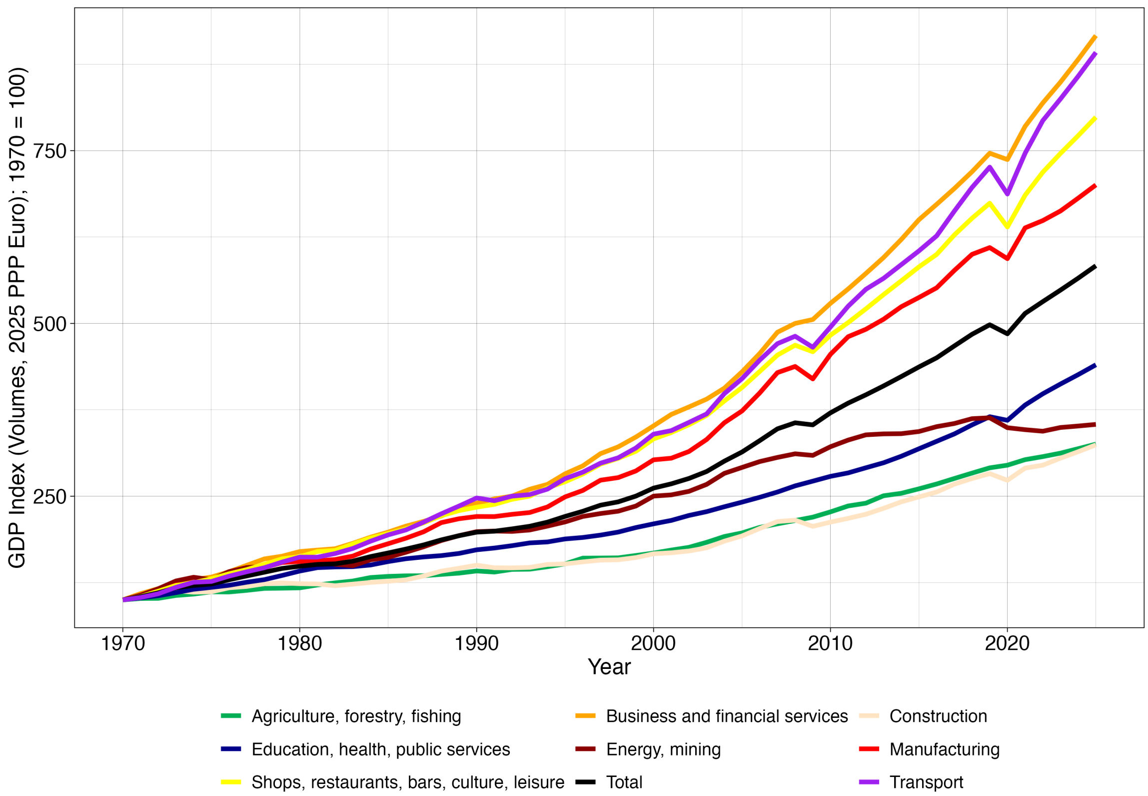


Figure 6. **Index of Global Sectoral GDP Growth in Volume Terms (2025 PPP Euros, 1970 = 100).** Total GDP in 2025 is around six times larger than in 1970. GDP of sectors above the black line grew above economy average, sectors below grew below economy average.

The differential growth rates lead to the composition changes shown in Figure 7. Today, business and financial services make up 8.7 percentage points more of global GDP than in 1970, driving most of the service sector's increase. The decline in the industrial sectors is driven by decreasing shares of construction and energy and mining. Manufacturing, which captures typical industrial production, has in fact expanded its volume share, contradicting ideas of a global industrial decline.

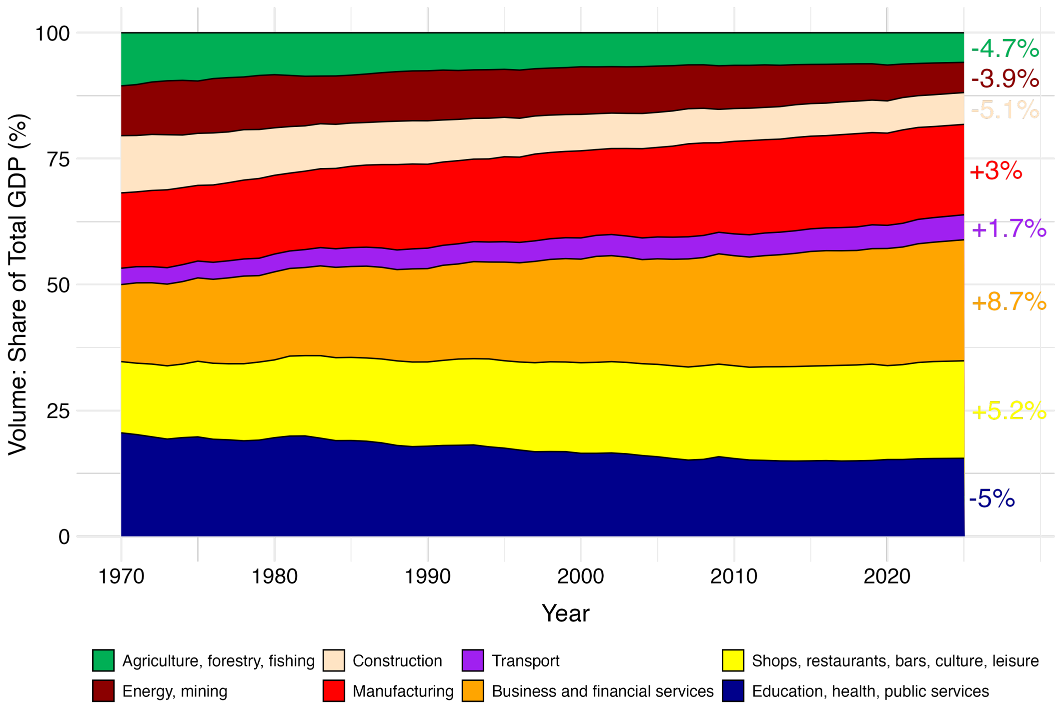


Figure 7. **Global GDP Shares in Volume Terms by Eight Sectors (2025 PPP Euros)**. Agricultural share decreased between 1970 and 2025. Both in the material sectors and in the service sectors, some sectors increased their share and others decreased it.

Regional differences. The global trends are reflected across most world regions (Appendix Figure 31 shows three-sector decomposition by nine world regions). Services increase their share in GDP in all nine world regions. The agricultural share declines substantially in the Global South and is roughly stable at low levels in North America, Oceania, and Europe since 1970.

The industrial share decreases in most regions, but has grown in East Asia and South/South East Asia. The regional eight-sector decomposition in Appendix Figure 32 shows that this is primarily due to a rise in the manufacturing share, which has increased by 12.3 percentage points since 1970 in East Asia and 6.1 points in South and South East Asia. These changes outweigh the manufacturing decline in the Global North, resulting in the total 3 percentage points rise in the global manufacturing share.

In summary, sectors with both high and low emission intensity are found among the growing and shrinking industries. This already suggests that the impact of structural change on emissions since 1970 is limited.

From value-added data alone, however, I cannot differentiate whether the observed change is driven by changing consumption preferences or by changing input structures. To disentangle these underlying factors, I next analyze the development of final demand shares in volume terms.

4.2 Real Final Demand Shares

Final demand reveals a remarkably stable global composition of agriculture, industrial sectors, and service sectors. Over 55 years, agriculture's share declined from 7.4% to 4.4%. The industrial sectors have a roughly stable share around 40%, decreasing only slightly by 1.2 percentage points since 1970 (Figure 9). Services increased somewhat from 45% to 48%. Thus, looking at final demand data, I observe less structural change than in the value-added data.

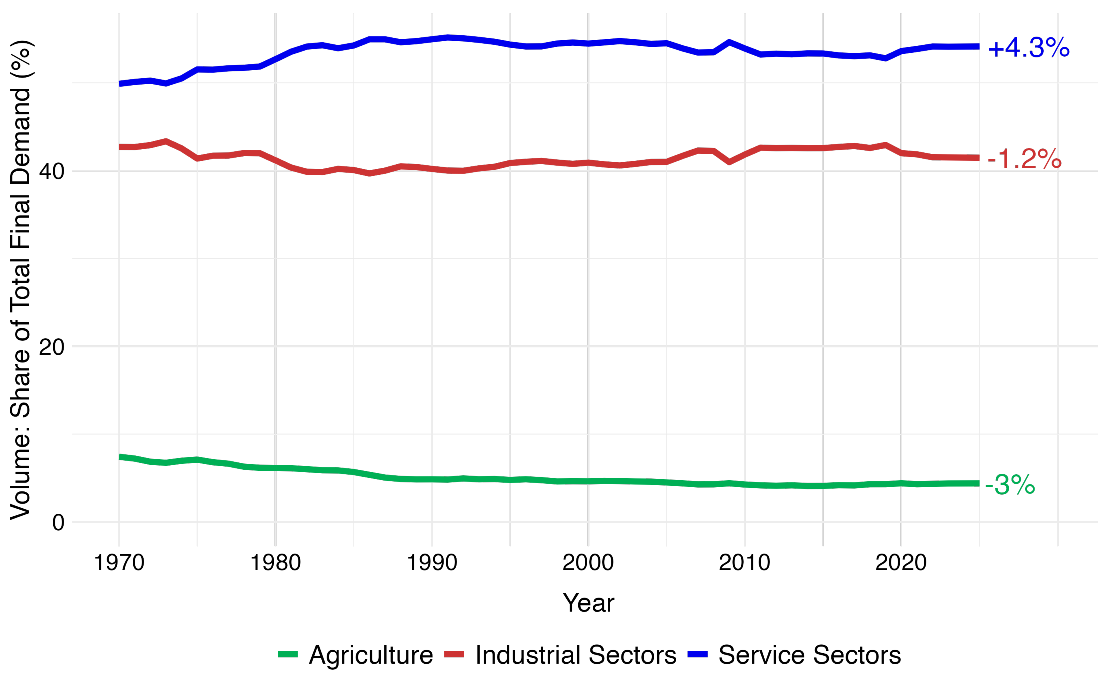


Figure 8. **Global FD Shares in Volume Terms by Three Sectors (2025 PPP Euros).** Agriculture includes 'agriculture, forestry, fishing'; the industrial sectors include 'construction', 'manufacturing', 'energy, mining', and 'transport'; services include 'business and financial services', 'education, health, public services', and 'shops, restaurants, bars, culture, leisure'. Percentages show the difference between the 1970 and 2025 shares.

Eight-sector decomposition. Looking at the individual industries, patterns are similar to the volume GDP but at slightly lower magnitudes (see Figure 9). A smaller increase in the business and financial services and hospitality/leisure shares drives the more moderate growth in services. The larger increase in these services in GDP could be due to an increased use of these services as production inputs or due to outsourcing. Similarly, I find a substantially smaller decline in the energy and mining share (-1 percentage point compared to -3.9 percentage points in value-added), which suggests improvements in the energy efficiency of production. Finally, I also observe a larger increase in manufacturing and a larger decline in construction. While speculative, this could reflect a shift in investment from traditional infrastructure toward high-tech capital goods (Hasni, 2025).

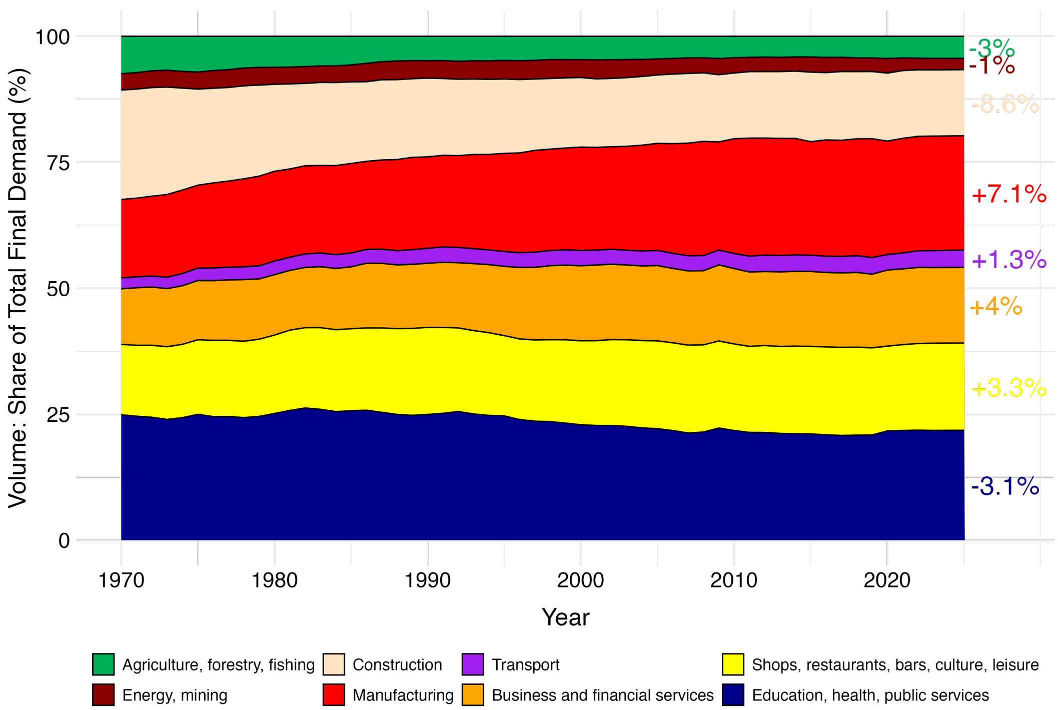


Figure 9. **Global FD Shares in Volume Terms (2025 PPP Euros)**. Agricultural and manufacturing share decreased slightly between 1970 and 2025. Overall, there is a very limited transition towards services.

Regional differences. Despite relative global stability, regional trends reveal significant heterogeneity (see Appendix Figure 33). The sub-global analysis suggests that the three-sector changes depend on the country's income level, a relationship I further explore in Section 6. Agricultural final demand share declined rapidly in countries of the Global South (-30 percentage points in South/South-East Asia and -28 percentage points in Sub-Saharan Africa). It remained stable at very low levels in high-income countries. It is important to note that food processed or prepared outside the household is classified under manufacturing and services. While households reduce their expenditure share on food with income, the rise of processed food consumption likely plays an additional role (Banerjee and Duflo, 2007; Timmer et al., 2015b). Service shares have risen in all world regions, while manufacturing shows a mixed picture. It increases in some regions but falls in the Global North. However, the decline in the high-income countries is smaller than in value-added, suggesting the presence of offshoring.

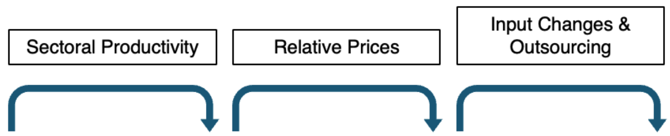
The global analysis reveals that structural transformation is modest in both value-added and final-demand shares in constant prices. The increase in services and decline in industrial sectors have been more pronounced in value-added, indicating that services are making up an increasing share of production inputs, or the rise in outsourcing of service activities.

In the following two sections, I discuss why I observe such a stable industry composition. First, I focus on measurement reasons, i.e., that this study looks at volume instead of employment or nominal GDP shares. Second, I focus on the economic drivers that influence the sector shares and show that Baumol and Engel effects acted in opposing directions, leading to the overall balanced trend.

5 Different Measures: Role of Sectoral Productivity and Price

Why do I observe such limited structural change? A first reason is the volume measurement, contrasting most existing studies on structural transformation, which commonly look at employment or nominal GDP shares. To understand if my data is contradicting the previous results, this section analyses employment and nominal GDP and compares them to the previous results in volumes. Figure 10 gives an overview of the observed changes in the three-sector decomposition across the four different measures. Indeed, in employment and nominal GDP shares, I also find a substantial structural transformation towards services.

These shares are influenced by sectoral productivity and price changes. As visible in the figure, correcting for sectoral productivity and sectoral prices, appropriate for the study of environmental consequences, reduces the magnitude of the transformation substantially. In the remainder of the section, I show how sectoral productivity and prices vary over time and how employment and nominal GDP shares change in response.



Global, 1970 - 2025	Working Hours	Nominal GDP	Real GDP	Real FD
Agriculture	- 23 %	- 6 %	- 5 %	- 3 %
Industrial Sectors	+ 3 %	- 8 %	- 4 %	- 1 %
Service Sectors	+ 20 %	+ 14 %	+ 9 %	+ 4 %

Figure 10. **Comparison of Global Shares by Three Sectors (1970-2025 Change).** Percentages show differences between 1970 and 2025 shares. The boxes above indicate possible explanations for the increasingly stable sector composition across variables.

5.1 Sectoral Productivity and Price Changes

Industrial sectors and agriculture have, on average, experienced larger productivity growth than the service sectors (see left plot in Figure 11). Since 1970, agriculture has seen a 1.7 times larger growth in productivity than the service sectors and industrial sectors 1.3 times larger.

According to Baumol's inverse relationship, this should lead to a falling relative price of the two sectors compared to the services. Indeed, the right plot shows that relative to services, industrial and agricultural outputs are, on average, around 20 percent cheaper today than in 1970 (Appendix Figure 34 shows productivity and Appendix Figure 35 shows relative prices on the eight-sector level).

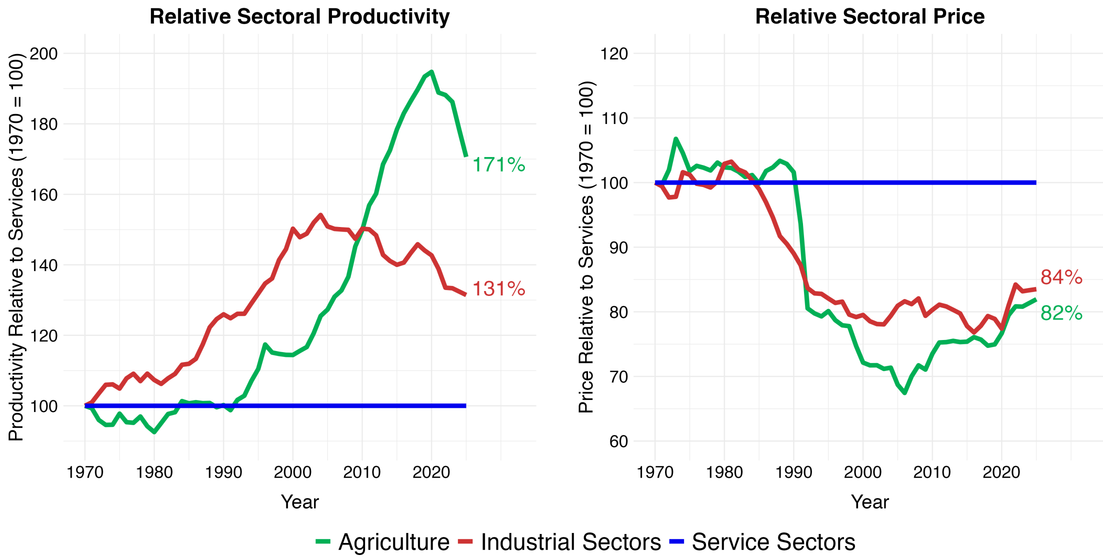


Figure 11. **Productivity and Price of Agriculture and Industrial Sectors Relative to Service Sectors (1970-2025).** Evolution of productivity and price levels relative to the service sector. All prices indexed to 100 in 1970 and normalized to average service sectors' price level.

5.2 Working Hours Shares

Working hours are highly affected by changes in the sectoral productivity. As productivity gains were largest in agriculture and lowest in services, global employment has shifted markedly from agriculture to services over the last 55 years (see Figure 12). At the same time, the industrial sector's share remained roughly stable at the global level. In 1970, agriculture accounted for nearly half of global working hours. By 2025, agriculture's share had fallen to 26%. Over the same period, the service sectors expanded from 22% to 43% of global working hours. The service rise and agricultural decline are by far the largest transformations observed across the four different measures. In contrast, the industrial sector saw only a slight increase from 29% to 32%.

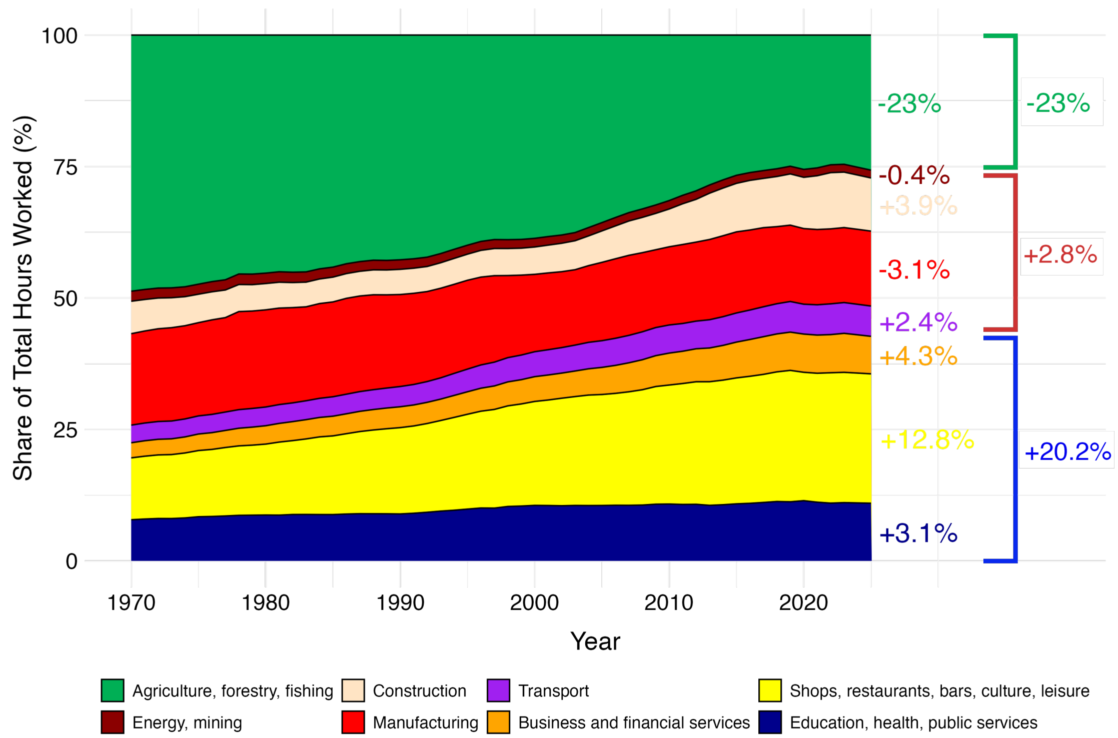


Figure 12. **Global Working Hour Shares by Eight and Three Industries.** Percentages show the differences in shares between 1970 and 2025. On the very right, the change for the three aggregate sectors is shown.

All service sectors substantially increase their employment share, above all the hospitality and leisure sector, resulting in the above-discussed substantial increase in total service employment. While business and financial services have seen the most significant growth, globally, still only around 7% work in this sector.

In the industrial sectors, the development of the subsectors is more heterogeneous. Working hours in sectors with above-average productivity gains (manufacturing, energy, mining, and agriculture) have grown more slowly than the total economy average. By contrast, the more labor-intensive and productivity-stagnating sectors of construction and transport have seen their work hours share increase. Jointly, this results in an almost stable share of the industrial sectors (+2.8%).

Overall, employment shares have seen the most significant changes in the three-sector composition, with a substantial increase in services and a decline in agriculture. The industrial sectors have experienced a slight increase in the work hour share, driven by the productivity-stagnant transport and construction industries.

5.3 Nominal GDP Shares

Nominal shares, reported in current-year prices, reflect the commonly perceived industry composition of GDP. Changes in these shares are not only influenced by volume shifts but also by the relative price changes.

At the global level, I find that the decline in agriculture's share and the rise of services are substantial, though less pronounced than in the hours worked measure. The increase in the services is driven by all three subcategories, with the largest rise in business and financial services. The industrial sector declines from 43% to 35%, driven by the falling relative prices of its output. Within the industrial sector, the share of manufacturing has dropped sharply from 26% to 18%, accounting for nearly the entire decline in the secondary sector, while other industrial sectors remain relatively stable. This makes sense as manufacturing has also seen the largest reduction in its relative price across all sectors (see Appendix Figure 35). The magnitude of all three changes is larger than in volume terms, reflecting the additional price effect.

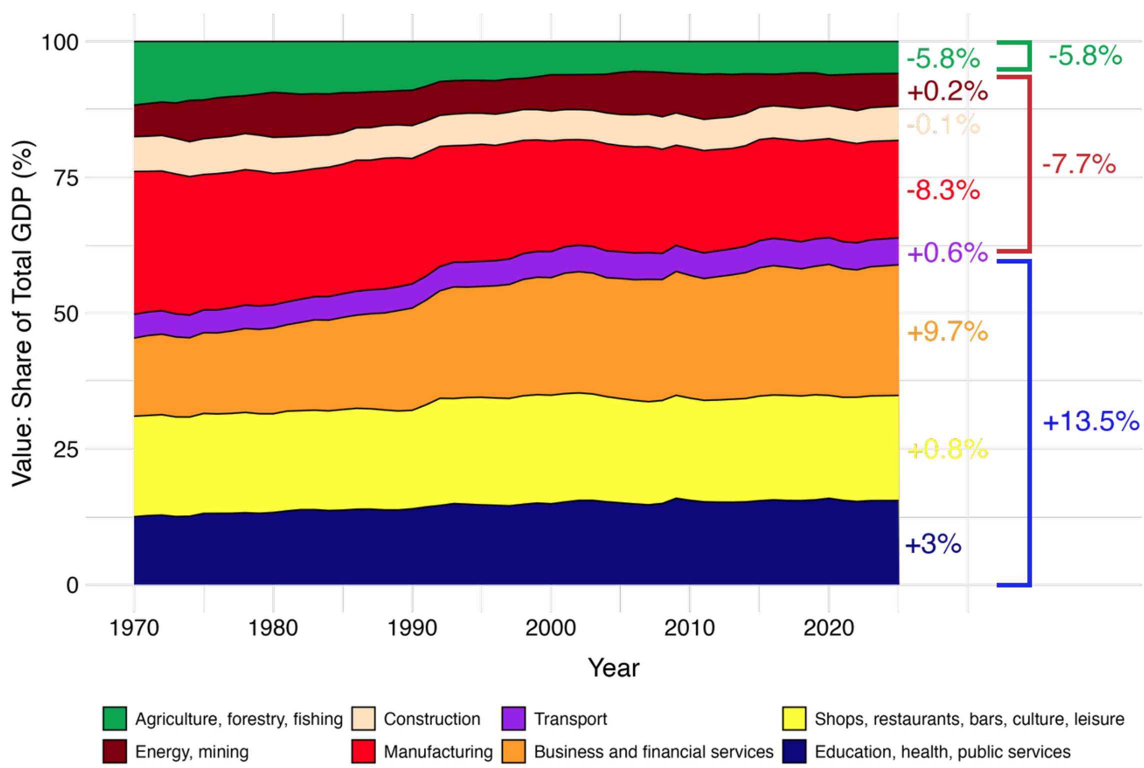


Figure 13. **Global GDP Shares in Current Prices by Eight and Three Industries.** Percentages show the differences in shares between 1970 and 2025. On the very right, the change for the three aggregate sectors is shown.

This section showed that looking at employment and nominal GDP shares, the new dataset also indicates substantial changes in the industry composition. As it also covers low-income countries, the magnitudes are still partly smaller than in the previous literature, but trends for the Global North are comparable to existing estimates (i.e., Duarte and Restuccia (2010); Duernecker and Sanchez-Martinez (2023)). This shows that the finding of a stable industry composition is not primarily driven by the exceptionality of the data but rather by the focus on volume measures and the global coverage. The following section, therefore, moves beyond comparing different measures and discusses the economic drivers that can explain the stable composition in volume terms.

6 Reasons for Slow Transformation

After showing how large the differences are across measures, I now return to the primary economic drivers of structural transformation – Baumol and Engel effects - and show how their opposing forces led to the remarkably stable sector composition in volume terms.

Regarding Baumol effects, I observe that differential productivity growth indeed leads to changing relative prices, making agriculture and the industrial sectors continuously cheaper compared to services. At the eight-sector level, the relative price changes are notably larger. However, the heterogeneity in price developments within the industrial and service sectors limits the overall price effect for the three aggregate sectors.

On Engel effects, I find a substantial decline in agriculture and a rise in services with growing income levels. Looking at the share of industrial sectors across national income levels, I indeed find a reversed U-shape pattern in both value-added and final demand, resonating with the existing literature on the historical trends in the Global North. The changes are of lower magnitude in final demand. Nonetheless, there is still a pattern of a rising industrial sector share until a GDP per capita level of around 8000 Euros and a decline afterwards. While many high-income countries experienced a declining industrial share during the past 55 years, many other countries have been on the increasing part of the curve, leading to the almost stable global industrial sector share.

6.1 Baumol: Industrial Sectors Continuously Get Cheaper

Baumol's prediction of higher productivity growth in the industrial sectors leading to a relative price decline compared to services also holds at the eight-sector level. The disaggregate analysis shows more pronounced Baumol effects, which are hidden in the previously discussed three-sector aggregate. Nonetheless, overall, agriculture and industrial sectors have still become continuously cheaper, so that a price effect toward these more emission-intensive sectors can be expected.

Sectoral Inverse Relationship. Figure 14 shows productivity and price series relative to the total economy for all eight sectors, indicating strong Baumol effects across almost all sectors between 1970 and 2025. The global results are in line with previous studies, mainly on high-income countries or product-specific analyses (Dennis and İşcan, 2009; Duernecker and Herrendorf, 2022; Duernecker and Sanchez-Martinez, 2023; Hartwig and Krämer, 2023).

The strongest contrast exists between manufacturing and education, health, public services. Manufacturing has seen the most substantial productivity increase of all sectors as its value-added per hour rose 46% faster than the total economy, while its relative price fell by 44%. Education, health, public services have experienced 47% slower productivity growth and a 64% quicker price rise than average, nearly a mirror image.

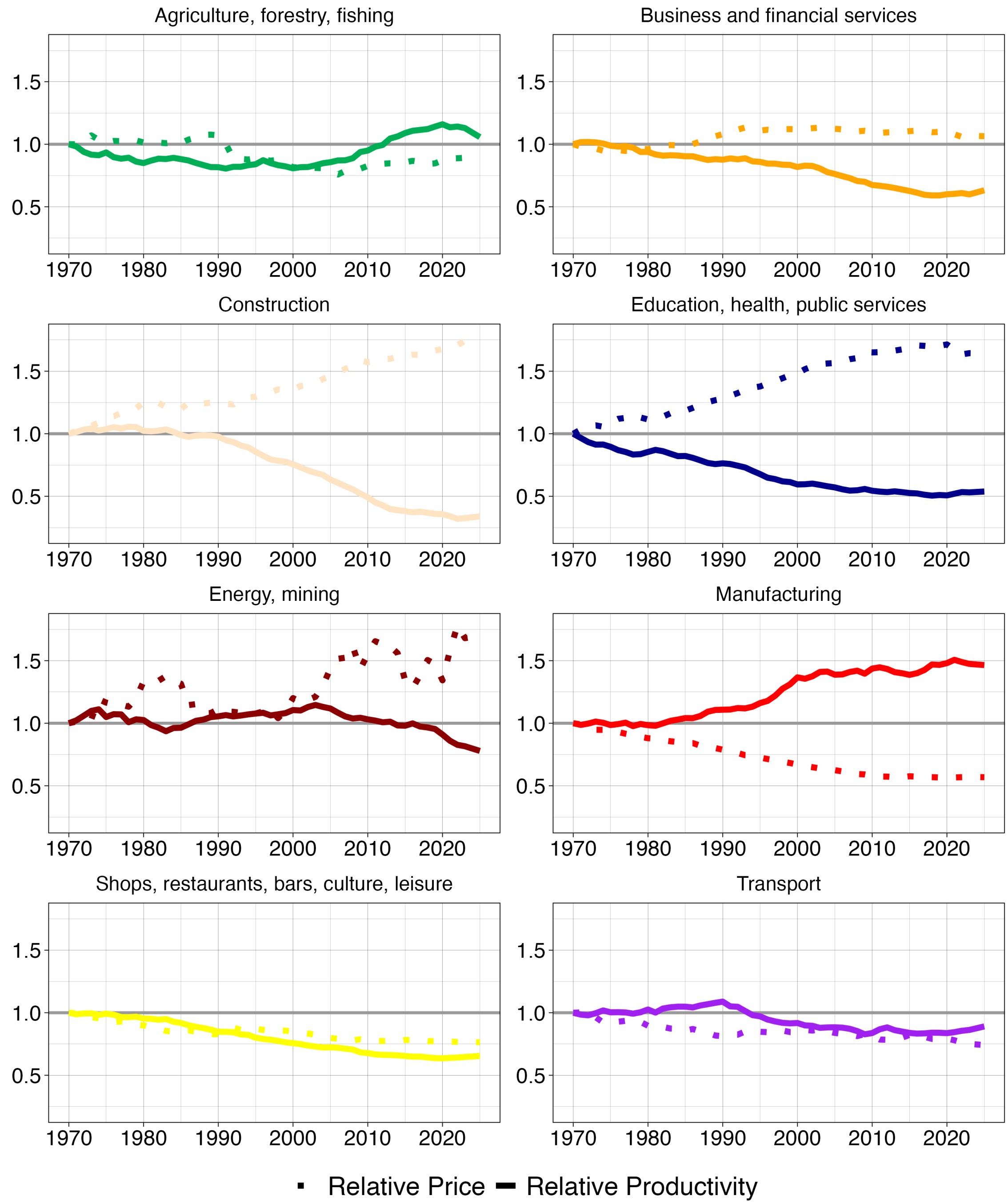


Figure 14. **Relationship Between Sectoral Relative Productivity and Relative Prices.** Indexed to 1 in 1970. The relative manufacturing productivity reached around 1.5 by 1970, indicating that the productivity growth in manufacturing was around 50% higher than the economic average. Generally, a rise in relative productivity is associated with a fall in relative prices, and vice versa.

Sector Specificities. The small productivity growth of education, health, public services could partly reflect the problems of measuring non-market output (see Section 3). However, I find that countries using direct output-based methods do not show significantly higher productivity growth, even though these methods should, in principle, allow for productivity gains (OECD, 2022). Moreover, the other service sectors, which are largely provided privately, have also shown similar below-average productivity gains.

Construction is classified as an industrial sector but is unusual as its productivity growth is substantially below average and has, since 1970, declined in absolute terms (see Appendix Figure 34). This is partially due to shifts in regional labor composition as regions with a lower absolute productivity now account for a greater share of global construction hours and GDP (Appendix Figure 36). Still, even within some individual countries, such as in the United States, productivity has declined. The declining US construction productivity was already observed in previous studies (D'Amico et al., 2024). Between 1970 and 2000, Goolsbee and Syverson (2023) finds a 40% fall in US construction productivity, and my data shows a very similar US decline of 43% over the same period.

The energy and mining sector is a notable exception to the inverse relationship predicted by Baumol and also shows especially volatile prices. This largely reflects oil price fluctuations. Appendix Figure 39 shows a close correspondence between the energy and mining deflator and real oil prices. Since annual changes in the oil prices are shaped by geopolitical shocks and supply constraints rather than productivity changes, this example illustrates that non-productivity factors also influence sectoral prices.

Across Time and Regions. The inverse relationship between relative productivity holds across time and income levels (see Appendix Figures 37 and 38). On the regional level, it is most pronounced in Europe, East Asia, North America/Oceania, possibly due to better price data quality. In all regions, manufacturing exhibits higher productivity growth and a relative price decline compared to the service sectors.

Plotted by decade, the relationship is present in most periods but less pronounced than in the long run, which indicates that short-term price movements are more influenced by factors beyond productivity, such as policy changes, supply shocks, or demand fluctuations.

6.2 Engel: Heterogeneity across Income Levels

The development of the industrial sector's share is correlated with income levels as predicted by Engel's theory. Figure 15 shows the share of the industrial sectors in real GDP and real final demand across log GDP per capita levels. It first increases with rising national income levels and then declines at higher income levels. At the global level, this pattern has largely balanced out across the last 55 years, as countries were on both the rising and falling sides of the curve. I focus on the industrial sector share as its evolution with income growth is most contested, and it emits a large proportion of total emissions.

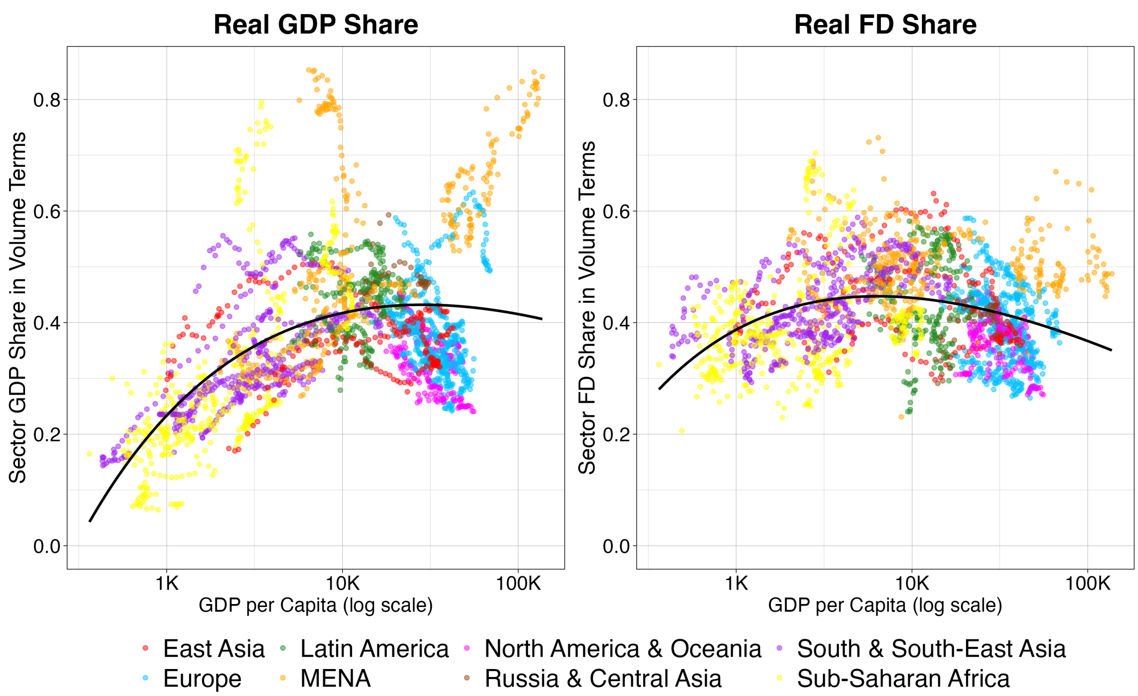


Figure 15. **Industrial Sector Shares in GDP and Final Demand across GDP per Capita (Log)**. The share of industrial sectors (construction, energy and mining, manufacturing, transport) first rises with GDP per capita and then falls. Each dot represents a country-year observation, with colors indicating the world region. The pattern is more pronounced in value added than in final demand.

Despite substantial heterogeneity across countries, a clear reversed U-shape pattern is visible in Figure 15: the industrial share increases up to a GDP per capita level of around 8000 Euros and then starts declining. This pattern is present in both GDP and final demand, although the curve is flatter in final demand, possibly due to outsourcing or offshoring of material production. A notable exception is oil countries in the MENA region, which have very large industrial sector shares in value-added due to the energy sector, but also have a larger share in final demand. The reversed U-shape pattern is also evident in three of the four industrial subsectors (manufacturing, transport, and construction). At the same time, the energy production share is highly heterogeneous, and the energy consumption share shows a slightly increasing linear trend (see Appendix Figures 42 to 45).

In the Appendix, Figures 40 and 41 show the agriculture and service share across income levels. Agricultural shares are declining, with the most rapid changes happening already at comparatively low income levels. However, agriculture only makes up a small part of the total economy, and many countries have already been on a stable, low level since the 1970s. Thus, the change in its total economy share is limited. Services show a continuously growing share with rising national income levels.

These patterns help explain the modest structural change observed globally and the almost stable final demand share of the industrial sectors. In the next section, I attempt to estimate the relative importance of the Engel and Baumol effects on the observed sectoral final demand trends.

6.3 Baumol vs. Engel

The previous sections have suggested that both Baumol and Engel effects exist and affect sectoral shares in opposing directions. Based on a simple framework, this section shows global counterfactual compositions if only Baumol or Engel effects had been present. I observe that all three sectors were affected by both effects. Relative to their size, the Engel effects have had a stronger impact on agriculture and the services than on the industrial sectors. This is in line with the observed patterns across GDP per capita levels, where the direction of the income effect on the industrial sector depends on the country's income level and is thus more limited at the global scale.

Framework. While I have previously shown how Baumol effects cause sectoral relative prices to diverge, I now obtain price elasticities to assess the impact of these relative price changes on the final demand volumes. Price elasticities are calculated using country-level data and running a long-difference regression of the 5-year change in country-sector final demand on the 5-year change in the country-sector relative price, controlling for GDP growth and year fixed effects (see C for the regression specification and the observed price elasticities). For all three sectors, I observe price elasticities between -1 and -0.5, which seems reasonable but should be treated with caution as they are not causally identified.[7]

Combining the observed evolution of relative prices and sectoral price elasticities, I create a counterfactual final demand composition affected only by Baumol effects, so assuming no income growth. I then derive the Engel-only counterfactual as the residual component explaining the gap between the observed trend and the Baumol-only trend. Clearly, this simple framework has substantial limitations, and results should be viewed as "back-of-the-envelope" calculations. Nonetheless, the counterfactual trends shown in Figure 16 reveal insights consistent with previous observations.

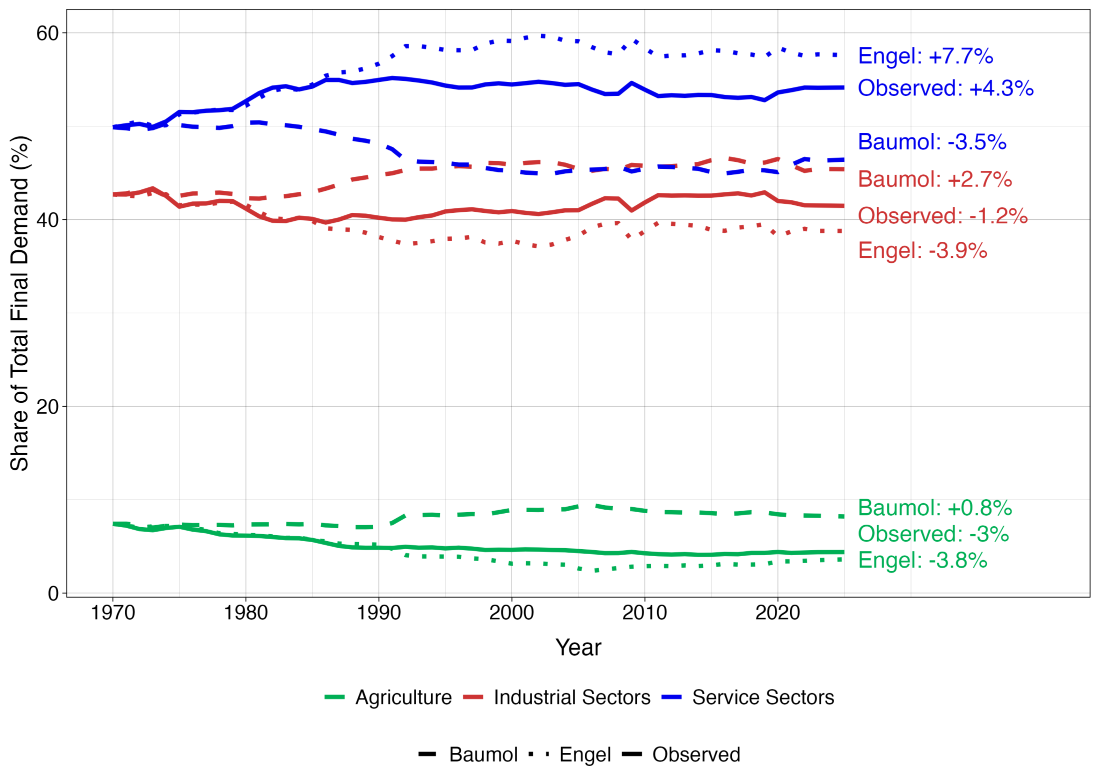


Figure 16. **Simple Estimation of Baumol and Engel Effects on Three Sectors**. All three trends start at the observed 1970 shares. The "Baumol" counterfactual shows the evolution of the shares when only the relative prices change, impacting final demand through price elasticities. The "Engel" counterfactual is the residual between the observed and Baumol trends.

[7] As both variables are expressed in logs, the elasticities show the percentage change in sectoral final demand (-1 to - 0.5) that is associated with a one-percent increase in the relative price.

Results. As all price elasticities are negative, Baumol effects cause an increase in the agriculture and industrial sector shares and a fall in the service share, in line with their relative price developments. The Baumol effect on the three aggregate sector shares is sizable but not very large. This is because, in aggregate, agriculture and industrial goods became only about 20 percent cheaper than services over 55 years. The magnitude of the effect also depends on the price elasticities. As I observe the smallest elasticity for the industrial sectors, this might partly explain the smaller Baumol effect, which would be greater under a larger elasticity.

The decomposition shows a strong Engel effect for agriculture. Compared to its size in 1970, the Engel effect more than halved the agricultural share from 7.4% to 3.6%. This suggests that the large decline in the agricultural share is strongly driven by Engel effects, a finding consistent with the continued decline in agricultural shares with rising GDP per capita (as discussed earlier and plotted in Appendix Figure 40). Similarly, I observe a strong Engel effect in services, increasing the service share by 7.7 percentage points since 1970, or by about 16% relative to its 1970 size. This corresponds to the observed rise in services with increasing income (Figure 41), where the service sector grows continuously, though more heterogeneously and more slowly than the agricultural decline. The positive Engel effect on services is partly offset by the Baumol effect, limiting the overall observed increase.

Finally, the Engel effect on the industrial sector is smallest relative to its size. This reflects the reversed U-shape pattern of the industrial share across national income levels, where the global Engel effect combines rising shares at low income levels and declining shares at high levels. As a result, the global Engel effect on industrial sectors is the weakest among the three aggregate sectors. Together with the Baumol effect this leads to an almost stable industrial share over time.

Overall, I observe that Baumol and Engel effects act in opposing directions across all three aggregate sectors. While Engel effects dominate, driving the shift from agriculture and industry to services, Baumol-based price effects slow this structural transformation. Before turning to the implications for GHG emissions, I briefly discuss how these two forces might evolve in the future and what this implies for the likely trajectory of sectoral composition.

6.4 Future of Structural Transformation

While the historic trends revealed a modest structural transformation, this does not necessarily imply that it will develop similarly in the future. Thus, I will discuss what the past patterns suggest regarding the future impact of Baumol and Engel effects on the structural transformation. This is obviously based on many insecurities and, for now, abstracts from policy action that might be taken in light of the climate crisis. Nonetheless, discussing the possible future structural change provides a backdrop for analyzing its potential for emission reductions that I will analyze in Section 7.

Future of Baumol. As Baumol effects hold at all income levels and there have been continuously larger productivity gains in industrial sectors, the best current estimate is that these more emission-intensive sectors will continue to become cheaper relative to services. Thus, Baumol effects likely continue to slow down the structural transformation away from agricultural and industrial products.

Some authors suggest that sectoral productivity trends could be altered by the adoption of artificial intelligence (AI). There is an ongoing debate about the magnitude of AI's productivity impact, with some authors proposing aggregate productivity gains of several percentage points per year. In contrast, others project a much more limited potential (Bick et al., 2024; Acemoglu, 2025). Regardless of the magnitude, AI-driven productivity gains are expected to affect some sectors more than others, potentially modifying Baumol effects. Filippucci et al. (2025) argue that manual tasks such as agriculture, fishing, and personal services see the smallest gains, while ICT, finance, and professional services are expected to experience the largest productivity increases. Some of the low-potential and high-potential sectors are within both the services and industrial sectors. As other sources of productivity gains, such as automation, are also progressing, the overall impact at the three-sector level might therefore be limited.

Future of Engel. If the observed reversed U-shape pattern remains stable in the future, as the world becomes richer, a stronger reduction in the global industrial sector share should happen. Figure 17 shows the fitted line for the FD shares and the global population distribution of 1970 and 2025 across GDP per capita. In 1970, a larger share of the population was in the rising part of the curve than today. Nevertheless, the fitted line still predicts a rising industrial sector share for many countries in the Global South, regions also expected to see the largest population growth.

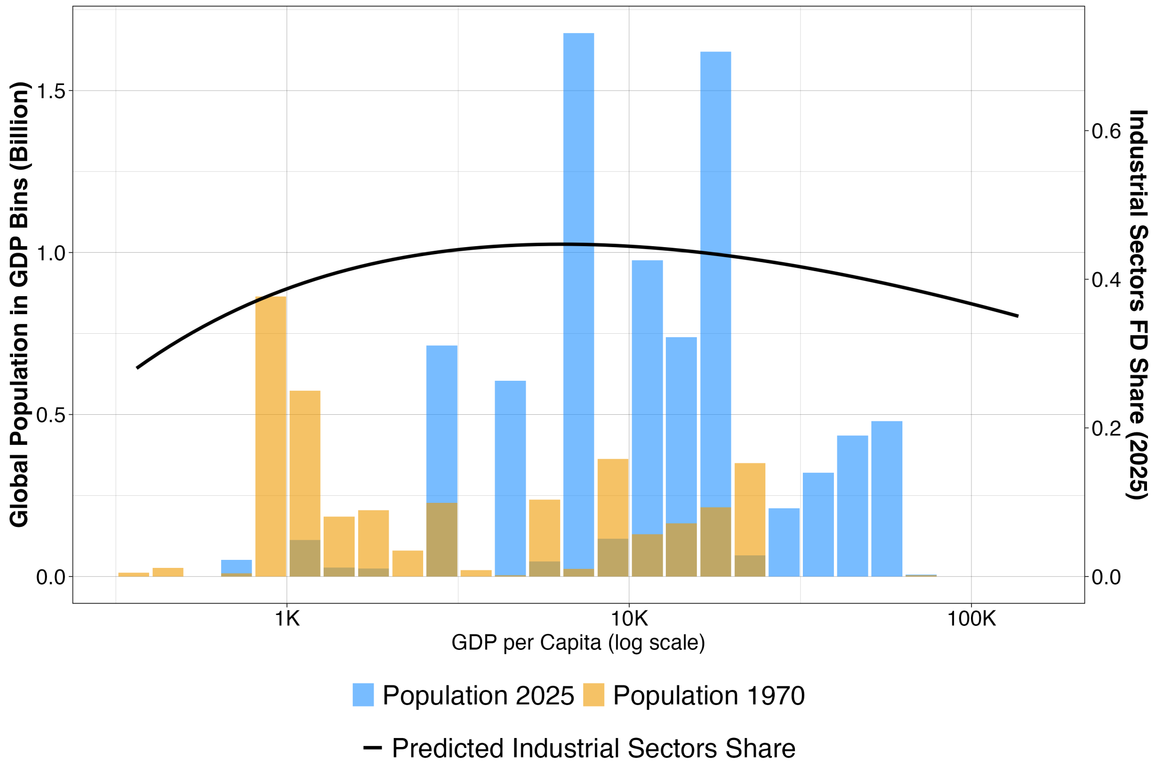


Figure 17. **Predicted FD Industrial Sector Shares and World Population Bins (1970 and 2025) by Log GDP per Capita.** The figure shows the stylized reversed U-shape pattern of the final demand share of industrial sectors observed in Figure 15. In addition, it displays the global population (binned) across log GDP per capita levels. Today, a majority lives near the peak or on the declining side of the curve.

In summary, over the past 55 years, falling prices in the industrial sector due to Baumol effects made emission-intensive goods relatively cheap, which likely shifted consumption and production inputs towards these sectors. Engel effects countered this: at higher incomes, the demand for agricultural and industrial goods falls. However, while there is a trend away from industrial sectors in rich countries, lower-income countries increased their industrial final demand share. This led to a limited Engel effect on the industrial sector share and a remarkably stable total composition. In the next section, I will quantify the effect that this modest structural transformation had on greenhouse gas emissions and will also show the potential for emissions reduction of a larger change in the final demand composition.

7 Impact on Emissions

The preceding sections showed that the global sectoral composition of final demand has changed only modestly over the past 55 years. In this section, I quantify the impact of those limited changes on global emissions, focusing on the 2000–2022 period for which global sector-level emissions data is available. I first decompose observed emission changes into the four key drivers and then explore the mitigation potential of a hypothetical, faster structural shift away from emission-intensive sectors.

7.1 Emission Decomposition

The Kaya identity expresses total greenhouse gas (GHG) emissions as the product of population, GDP per capita, and emission intensity (Kaya et al., 1997). On the global economy level, GDP per capita is equivalent to final demand (FD) per capita:

$$E_t = \underbrace{P_t}_{\text{Population}} \cdot \underbrace{\left(\frac{F_t}{P_t}\right)}_{\text{FD per Capita}} \cdot \underbrace{\left(\frac{E_t}{F_t}\right)}_{\text{FD Emission Intensity}}$$

In a sectoral framework, emissions can be further disaggregated as the sum of the sectoral emissions. On the sector level, it is more appropriate to use final demand shares and emission intensities, since a value-added approach may conflate intensity improvements with shifts in composition. The formula below shows the extended Kaya identity with i indicating the individual sectors:

$$E_t = \underbrace{P_t}_{\text{Population}} \cdot \underbrace{\left(\frac{F_t}{P_t}\right)}_{\text{FD per Capita}} \cdot \sum_i \underbrace{s_{i,t}}_{\text{Sector FD Share}} \cdot \underbrace{\left(\frac{E_{i,t}}{F_{i,t}}\right)}_{\text{FD Emission Intensity}}$$

To isolate each factor's contribution, I simulate counterfactual scenarios in which one factor evolves as observed while the other three remain fixed at their 2000 levels. I then calculate annual counterfactual GHG emissions, which are plotted in Figure 18.

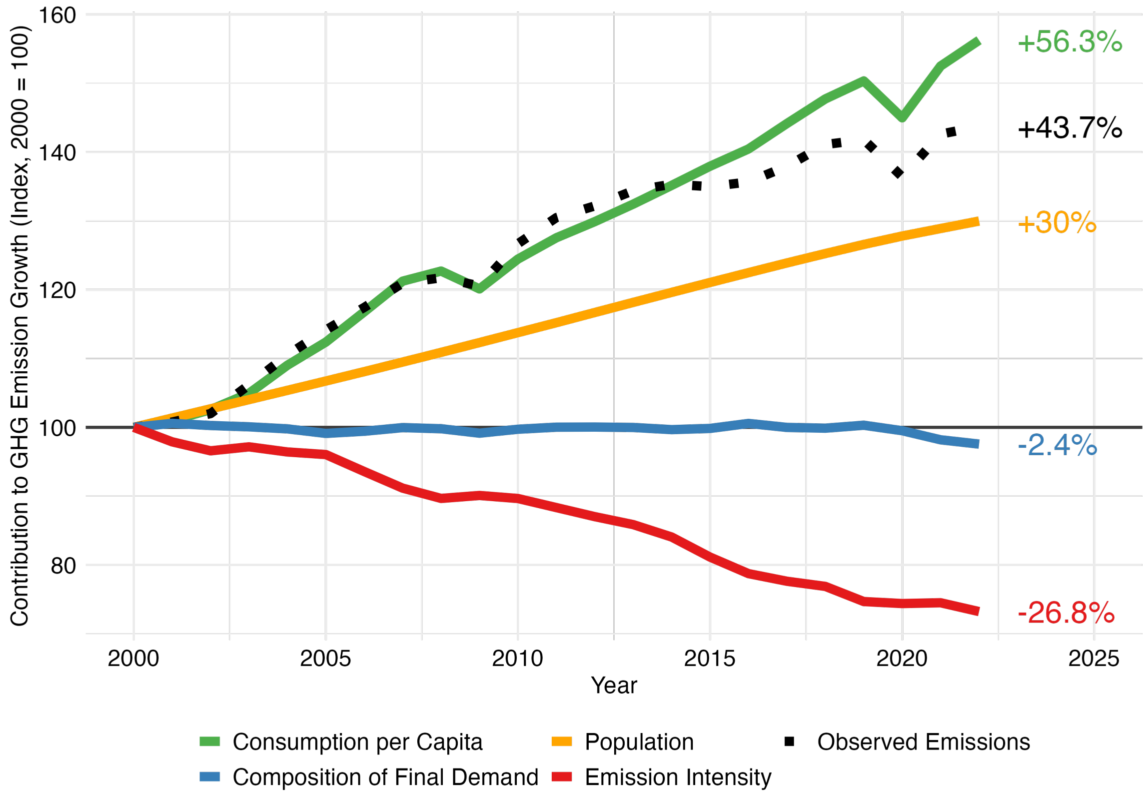


Figure 18. **Decomposition of Change in Global Annual GHG Emissions (2000-2022).** In each counterfactual scenario, only one factor evolves over time, while the others remain fixed at 2000 values. Percentages are not additive due to differing baselines, as each counterfactual holds different terms constant.

Emission Effects. Annual global GHG emissions have grown from 36 Gt CO_2e in 2000 to 51 Gt in 2022, a 43.7% rise. The growth was primarily driven by rising per capita consumption and population. If only per capita consumption had changed, emissions would have increased by 56.3%. The population rose by 30% during the period, leading to a corresponding emission increase, all else equal. At the same time, emission intensity improved and decreased global annual emissions by 28.6%. This includes changes in the input requirements of production as well as carbon efficiency improvements. By contrast, the effect of the changing final demand composition was modest, decreasing emissions by only 2.4%. Since 2020, the global consumption basket has become slightly less emission-intensive, but the effect is negligible compared to the other factors. Despite large differences in sectoral emission intensities, the relative stability in the final demand structure muted any substantial composition effect over the 22-year period.

Appendix Figure 46 disaggregated the small total composition effect into individual sector effects by not only holding three out of four aggregate factors but also seven out of eight sectors fixed. The small negative effect was driven by a declining final demand share of energy and mining, the most emission-intensive sector, which reduced global emissions by 4.3%. This was partly offset by a rising share of manufacturing, which added 2% to emissions. Other sectors had effects between -1% and 1%.

Literature Comparison. These results broadly align with previous studies, which have typically focused on shorter time frames or limited country samples. Schymura and Voigt (2014), covering 40 countries from 1995 to 2009, find a structural effect of around -7% and a somewhat larger negative emission intensity effect. Voigt et al. (2014), analyzing energy use in the same countries and time period, find only a 4% reduction from structural changes but a 20% decline due to technological improvements. Similarly, Arto and Dietzenbacher (2014) observe the effect of emission intensity to be about eight times that of the final demand composition.

In summary, structural change has in the recent past played a marginal role in shaping emissions compared to the scale effects of population and consumption per capita, and the reducing effect of emission intensity. Nonetheless, the significant differences in sectoral emission intensities suggest that future structural shifts could make a meaningful contribution to emission mitigation.

7.2 Potential of Structural Transformation

To explore this potential, I simulate a hypothetical scenario in which global final demand shifts more decisively away from emission-intensive industrial sectors toward agriculture and less emission-intensive services between 2000 and 2022. To determine the alternative composition, I apply a carbon price on industrial sectors that alters their relative price trajectories. I observe sectoral price elasticities from my dataset to estimate the effect of these price changes on final demand. Even if one perceives the not causally identified elasticities between sectoral price and final demand as implausible, the alternative final demand composition still illustrates the potential of structural change.

Alternative Composition. To obtain a hypothetical, less emission-intensive final demand composition, I assume the introduction of a gradually increasing global carbon price on industrial sectors (see Appendix Section D for more detail). The carbon price starts at €10 per ton CO_2e in 2001 and increases by €10 annually, reaching €220 in 2022. This is at the upper end of carbon prices suggested in the social cost of carbon literature based on local temperature variation, but remains far below the approximately 1100€ per ton proposed by Bilal and Känzig (2024), who exploit global temperature variation for their estimation. In my framework, all tax revenues are used to subsidize services and agriculture, thereby amplifying the relative price effect. For the industrial sector, the price increase depends on the emission intensity. As a result, energy and mining are particularly affected and experience substantial additional price increases between 2000 and 2022 (see Appendix Figure 25). While real carbon pricing would also affect emission intensities through technological change and changes in the input structure of the economy, I focus solely on the change in the final demand composition. To obtain the hypothetical final demand composition shown in Figures 19 and 20, I again use sectoral price elasticities estimated from my dataset via a country-level, five-year long-difference regression of sectoral final demand on sectoral prices (see Appendix Section C for details).

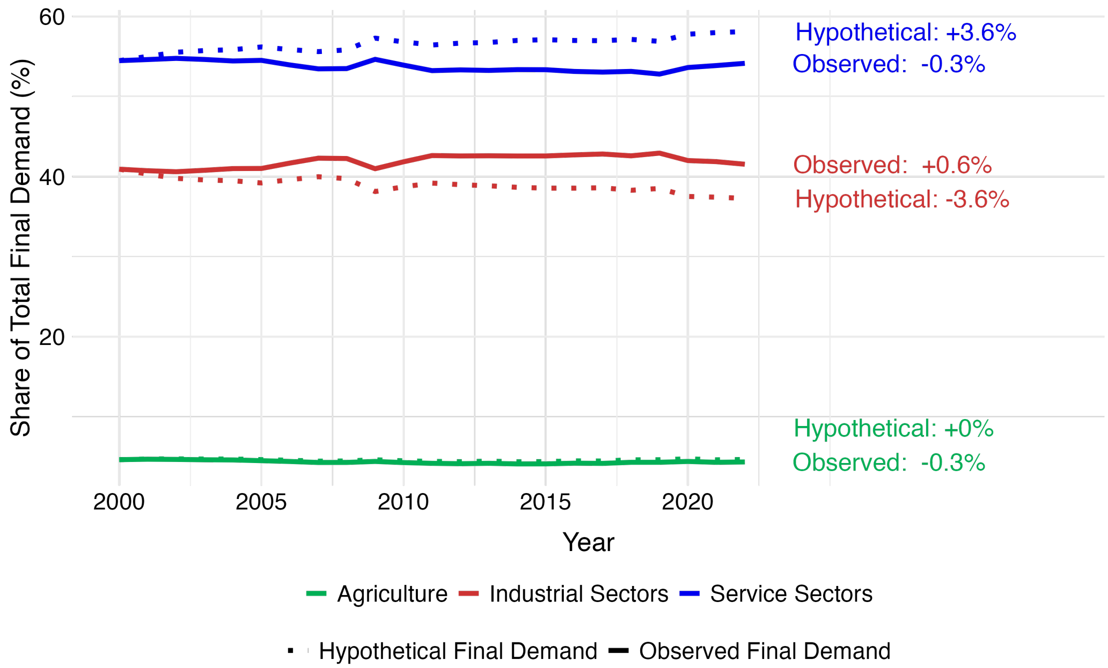


Figure 19. **Hypothetical Final Demand Changes by Three Sectors (2000-2022).** Within the service and agricultural sectors, the increase is proportional to the sectors' size; within the industrial sectors, it depends on emission intensity, so that the decrease is larger for more emission-intensive sectors.

Under the hypothetical scenario, the industrial sector's share in 2022 is about four percentage points smaller, while services are four points larger (Figure 19). In 2022, final demand per capita of the service sectors would be around 8900 Euro PPP instead of 8600 Euro PPP, and agricultural demand would be 710 Euro instead of 690. Conversely, industrial sectors' per capita demand decreases from approximately 6600 Euro to 6300. Thus, on the aggregate level, this hypothetical final demand vector only changes consumption patterns slightly.

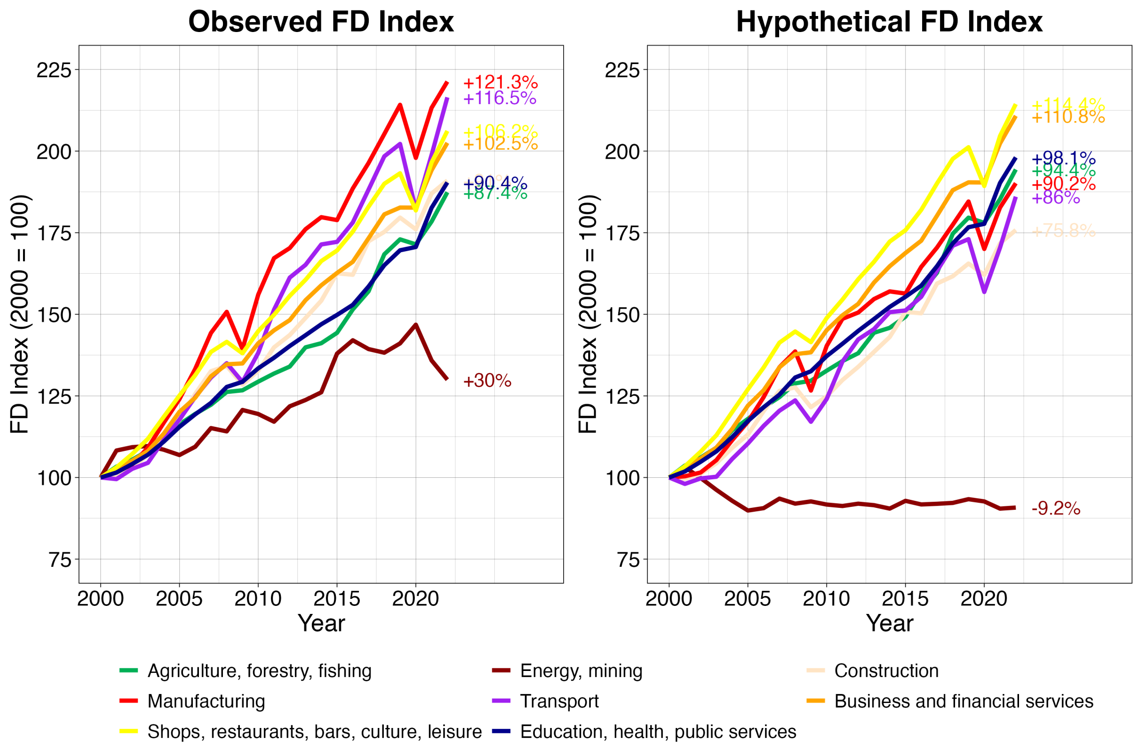


Figure 20. **Observed and Hypothetical Final Demand Indices by Eight Sectors (2000-2022).** Decrease in the industrial sector depends on emission intensity; thus, a slight absolute decline in energy, mining.

Since the reduction is proportional to sectoral final demand emission intensity, the energy and mining sector declines in absolute terms (Figure 20). This results in a stronger mitigation effect than a uniform reduction across all industrial sectors, as the most polluting sector is reduced the most. However, energy used for production remains unchanged in this framework.

Apart from energy and mining, all other sectors still see an almost doubling in final demand volumes under the carbon price from 2000 to 2022. However, under the hypothetical scenario, the fastest-growing sectors are no longer manufacturing and transport but the three service sectors.

Emission Effects. This hypothetical final demand composition would have limited the annual emission growth by about one-quarter. Figure 21 compares observed emissions to the hypothetical scenario, letting population, consumption per capita, and emission intensity grow as observed. In 2022, emissions would be 48 Gt under the hypothetical final demand instead of 51.7 Gt with the real final demand composition.

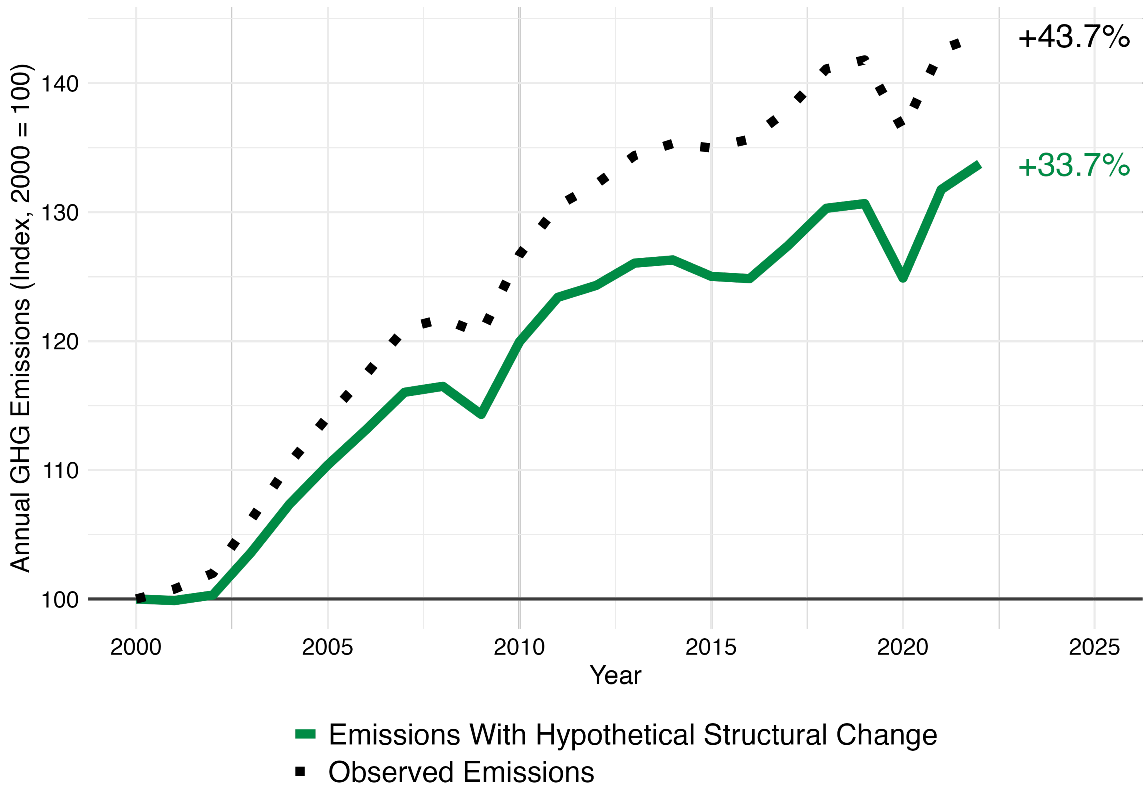


Figure 21. **Annual Emissions with Hypothetical vs. Observed FD (2000-2022).** All other variables vary as observed; only the FD vector is replaced with the hypothetical carbon price scenario.

Clearly, this scenario has many limitations. First, it assumes structural change occurs without affecting overall growth or technology. A higher share of services, which tend to grow more slowly, could reduce total growth. Sectoral income shifts could also influence investment and thereby affect emission intensity. Moreover, reducing energy consumption while the population grows could have detrimental human consequences. Second, the assumed link between carbon pricing and structural change relies on homogeneous price elasticities derived from a simple country-level regression without addressing endogeneity. This ignores heterogeneity in elasticities across countries and time, and does not account for diminishing marginal responses.

Nonetheless, the scenario demonstrates that, given the large differences in emission intensities across sectors, a significant structural shift can have substantial emission mitigation effects. However, since all sectors have positive emission intensities and industrial consumption cannot be eliminated entirely, the potential impact of structural change is limited. Thus, it must be combined with limits on overall volume growth and substantial improvements in within-sector emission intensities. Carbon pricing is one possible tool to accelerate structural transformation, but alternatives such as industrial consumption quotas in high-income countries could also be considered.

8 Conclusion

This thesis has shown that there has been only a limited structural transformation away from the emission-intensive agriculture and industrial sectors toward the less emission-intensive services between 1970 and 2025. The changing sectoral final demand composition has therefore had a minimal effect in reducing annual greenhouse gas emissions since 2000.

This finding contrasts existing accounts of a substantial structural shift away from material sectors. The discrepancy can be explained by the novel contribution of this thesis, which analyzes the global sector composition using volume measures. In line with the previous literature, I found a more pronounced transition toward services in employment and nominal GDP shares.

Several factors explain the slow transformation in volume terms. First, the decomposition into eight industries revealed substantial heterogeneity within the broad sectors of agriculture, industry, and services. Among both industrial and service sectors, some industries increased and others decreased their GDP and final demand shares, leading to smaller aggregate effects. Second, agriculture and industry have become relatively cheaper over the past 55 years, likely inducing a price-based substitution toward these sectors. Third, the development of the industrial share varies across income levels, following a reversed U-shape pattern: it declined in high-income countries, especially in production, while it rose in low- and middle-income countries, resulting in a nearly stable global share.

Limitations & Possible Extensions. The findings are based on descriptive historical trends and are thus constrained. This section outlines key limitations and possible extensions to strengthen the analysis in the future.

While greenhouse gas emissions are the most salient environmental issue today, the analysis could be extended to other challenges such as land use, waste, or raw material consumption. Although ecological intensities differ, the historically stable aggregate sector composition suggests similarly limited structural transformation effects on these indicators.

The analysis of Engel and Baumol effects relies on aggregate historical trends, but these could be better quantified using exogenous supply and demand shocks. Sectoral Engel effects, for instance, could be analyzed in response to exogenous income changes. For Baumol effects, future research could estimate the magnitude of the substitution effect caused by the changing relative prices.

Limited availability of international input-output tables in constant prices constrained the analysis of evolving production structures and outsourcing. To move beyond comparisons between GDP and final demand, future research should examine historical changes in sector-specific input requirements and investigate offshoring patterns across regions once constant-price input-output tables become available.

Finally, to inform efforts against the worsening climate crisis, historical trends should be used to model future developments. Well-identified Engel and Baumol effects could support projections of the future structural transformation under business-as-usual scenarios or policy-driven pathways. Analyzing the emission reduction potential of a more ambitious structural transformation could help clarify how quickly within-sector decarbonization must proceed and what constraints on growth might be necessary. The final part aims to provide a bridge from the historical work of this thesis to a potential analysis on the future.

Future Outlook. Changes in the industry composition have considerable potential for emission reduction in the future. On average, agriculture and industry emit about five times more per unit consumed than services. However, over the past 55 years, all sectors have grown in both total and per capita volumes. Composition shifts can still occur even as all sectors grow, echoing Fressoz (2024), who shows that in absolute terms new energy sources historically added to, rather than replaced, existing forms of energy. Whether declining sector shares also imply falling volumes depends on the overall growth rate and the extent of the composition change.

Structural transformation alone is insufficient to address the climate crisis. In addition, several changes must likely be pursued. First, emission intensities within sectors must fall sharply. Second, production processes must become less material-intensive. Third, total consumption must be limited and more equitably distributed, which probably implies a reduction for high-consumption groups.

Nonetheless, these large-scale changes do not necessarily imply generally lower living standards. On the contrary, they can foster a more livable and equitable future.

For example, beyond mitigating the climate crisis, a shift toward services offers additional benefits: improved education levels, less local pollution, and more fulfilling, less physically demanding jobs. We should, therefore, envision the structural transformation not just as a necessity, but as an opportunity to build a more sustainable and prosperous future.

A Accounting

A.1 Input-Output Accounting

Sectoral output can be subdivided from either a production or a consumption perspective. Similarly, emissions can be assigned to sectors using either production-based or consumption-based accounting. This appendix section provides more details on the concepts of final demand and value-added, and explains the corresponding accounting methods for emissions. To illustrate these ideas, I rely on input-output concepts pioneered by Leontief (1936).

Consumption Perspective. From a consumption perspective, sectoral output is either used as intermediate consumption or consumed as final demand. Intermediate consumption is goods and services used in production processes, while final demand refers to products consumed by households, governments, or non-profit institutions (NPISH), or invested as gross fixed capital formation (GFCF) or inventory changes.[8] Thus, the total output of a sector can be expressed as the sum of its own intermediate input requirements, the intermediate input needs of other sectors, and the final demand for its products.

$$x_1 = \overbrace{a_{11}x_1}^{\text{Input for same sector}} + \overbrace{\cdots + a_{1i}x_i + \cdots + a_{1n}x_n}^{\text{Input for other sectors}} + \overbrace{f_1}^{\text{Final Demand}}$$

Where a_{ij} are technical coefficients showing the amount of output from sector i needed to produce the output of sector j. This equation applies to all sectors, so that the following matrix explains the complete output of the economy and its use:

[8] The distinction between consumption and investment is based on when the goods or services are "used up". Products consumed within the same year are counted as consumption. By convention, all household purchases except for dwellings are counted as consumption, even if they are used beyond the accounting year (e.g., a car). All dwellings and major renovations count as investments. Firm purchases used within the same year are intermediate consumption, all products still used afterwards are counted as investment (see Lequiller and Blades (2014)).

$$
\begin{aligned}
x_1 &= a_{11}x_1 + \cdots + a_{1i}x_i + \cdots + a_{1n}x_n + f_1 \\
&\vdots \\
x_i &= a_{i1}x_1 + \cdots + a_{ii}x_i + \cdots + a_{in}x_n + f_i \\
&\vdots \\
x_n &= a_{n1}x_1 + \cdots + a_{ni}x_i + \cdots + a_{nn}x_n + f_n
\end{aligned}
$$

Using matrix notation following the input-output literature, this system can be expressed as $x = Ax + f$, where capital letters denote matrices and lowercase letters are vectors. Solving for the output vector x using the identity matrix I yields:

$$x = (I - A)^{-1} f$$

The output vector is thus determined by final demand f and the Leontief inverse $L = (I - A)^{-1}$, which is also called the total requirements matrix and shows how output responds to changes in final demand given the technical coefficients.

Production Perspective. From a production perspective, sectoral output is the sum of sectoral value-added (v) and intermediate inputs used from other sectors (Ax):

$$x = Ax + v$$

Production-based Emissions. Every sector produces greenhouse gases during production, which can be expressed as the vector of direct emissions (in metric tons of CO_2 equivalent).

$$e_i^{\text{prod}} = \begin{bmatrix} e_1^{\text{prod}} & e_2^{\text{prod}} & \ldots & e_n^{\text{prod}} \end{bmatrix}$$

These correspond to production-based emissions, meaning emissions are attributed to the sector and country in which they physically occur (**?**). To express them as sectoral emission-intensities, the sectoral emissions are divided elementwise either by the sectoral output or by the sectoral value-added:

$$\varepsilon_i^{\text{VA}} = \frac{e_i^{\text{prod}}}{v_i}$$

Consumption-based Emissions. Using the Leontief inverse, one can reassign production-based emissions to the sectors where final demand occurs. While total emissions remain unchanged at the aggregate level, this reallocation reveals the emissions embodied in final demand, often referred to as indirect emissions.

The sectoral emission intensities (emissions per unit of output) are reassigned to final demand according to the total requirements matrix.[9]

$$e^{\text{fd}} = \hat{\varepsilon} \cdot L \cdot f$$

This approach traces the full supply chain emissions resulting from consumption and investment in a given sector. To express consumption-based emissions as intensities per unit of final demand (ε^{FD}), sectoral emissions are divided by the sectoral final demand.

A.2 Determinants of Emissions

In this sectoral perspective, total emissions are the sum of sectoral emissions, each determined by sectoral final demand and final-demand-based emission intensity:

$$E_t = \sum_i E_{i,t} = \sum_i f_{i,t} \cdot \varepsilon_{i,t}^{\text{FD}}$$

This can be integrated with the Kaya identity, which expresses emissions as a product of population, consumption per capita, and aggregate emission intensity (Kaya et al., 1997):

$$E_t = \underbrace{P_t}_{\text{Population}} \cdot \underbrace{\left(\frac{F_t}{P_t}\right)}_{\text{FD per Capita}} \cdot \underbrace{\varepsilon_t^{\text{FD}}}_{\text{FD Emission Intensity}}$$

Emission intensities of final demand are a function of the output emission-intensities and the Leontief matrix showing the input requirements. Thus, it should be highlighted that both technological changes leading to emission intensity improvements and changes in the input requirements can affect final-demand based emission intensities:

[9] Specifically, the emission intensities are placed along the diagonal of a matrix $\hat{\varepsilon}$, then multiplied by the Leontief inverse $L = (I - A)^{-1}$ and the final demand vector f.

$$E_t = \underbrace{P_t}_{\text{Population}} \cdot \underbrace{\left(\frac{F_t}{P_t}\right)}_{\text{FD per Capita}} \cdot \underbrace{\varepsilon_t^{\text{output}}}_{\text{Output Emission Intensity}} \cdot \underbrace{L_t}_{\text{Leontief Matrix}}$$

When we combine the Kaya identity and the input-output emission identity, total emissions are determined by the total population, consumption per capita, as well as the sectoral emission intensity and the final demand shares. It should be noted that in the consumption-based framework, emission intensity is influenced not only by production-side intensity improvements but also by changes in input structures.

$$E_t = \underbrace{P_t}_{\text{Population}} \cdot \underbrace{\left(\frac{F_t}{P_t}\right)}_{\text{FD per Capita}} \cdot \sum_i \underbrace{s_{i,t}}_{\text{Sector FD Share}} \cdot \underbrace{\varepsilon_{i,t}^{\text{FD}}}_{\text{FD Emission Intensity}}$$

This formulation allows for an analysis of the drivers behind overall emission trends, which I use in the final section of the analysis (see Section 7).

B Data

B.1 Sources

This section shows the sources used per country for GDP shares and the corresponding sectoral deflators, employment shares, and final demand. For each country, it lists the yearly ranges for which a given source or extrapolation is used. The lists are restricted to the 48 main countries to limit the size of the tables, even though individual country series for all 216 WID countries were created before aggregating the other countries to the residual regions. The data for other variables such as work hours, population, and GHG emissions are coming from the same source for all countries and are therefore not shown by country (see description in Section 3 for source details). After presenting the sources, I describe how they have been combined using a growth-based harmonization.

Table 1. **GDP and Deflator Sources by Country and Year.** The eight residual regions are aggregate of individual country series, so that for a given year, there are many sources depending on the country (not shown in this table). Between sources, growth-rate harmonization is applied according to the priority order.

Country	**Sources**
Algeria	1970–2023: UN Main
Argentina	1970–1972: UN Main; 1973–1989: TSD; 1990–2018: ETD; 2019–2023: UN Main

Country	Sources
Australia	1970–2014: WIOD; 2015–2023: UN Main
Bangladesh	1970–1989: UN Main; 1990–2018: ETD; 2019–2023: UN Main
Brazil	1970–2014: WIOD; 2015–2018: ETD; 2019–2023: UN Main
Canada	1970–2014: WIOD; 2015–2023: UN Main
Chile	1970–1989: UN Main; 1990–2018: ETD; 2019–2023: UN Main
China	1970–1989: TSD; 1990–2018: ETD; 2019–2023: Extrapolated
Colombia	1970–1989: UN Main; 1990–2018: ETD; 2019–2023: UN Main
Cote d'Ivoire	1970–2023: UN Main
DR Congo	1970–2018: Imputed; 2019–2023: Extrapolated
Denmark	1970–2014: WIOD; 2015–2023: UN Main
Egypt	1970–1981: UN Main; 1982–1989: TSD; 1990–2018: ETD; 2019–2023: UN Main
Ethiopia	1970–1989: ASD; 1990–2018: ETD; 2019–2023: UN Main
France	1970–2014: WIOD; 2015–2023: UN Main
Germany	1970–2014: WIOD; 2015–2023: UN Main
India	1970–2014: WIOD; 2015–2018: ETD; 2019–2023: UN Main
Indonesia	1970–1989: TSD; 1990–1999: ETD; 2000–2014: WIOD; 2015–2018: ETD; 2019–2023: UN Main
Iran	1970–2023: UN Main
Italy	1970–2014: WIOD; 2015–2023: UN Main
Japan	1970–2014: WIOD; 2015–2018: ETD; 2019–2023: UN Main
Kenya	1970–1989: ASD; 1990–2018: ETD; 2019–2023: UN Main
Korea	1970–2014: WIOD; 2015–2018: ETD; 2019–2023: UN Main
Mali	1970–2023: UN Main
Mexico	1970–2014: WIOD; 2015–2018: ETD; 2019–2023: UN Main
Morocco	1970–1989: TSD; 1990–2018: ETD; 2019–2023: UN Main
Myanmar	1970–1989: UN Main; 1990–2018: ETD; 2019–2023: UN Main
Netherlands	1970–2014: WIOD; 2015–2023: UN Main
New Zealand	1970–2023: UN Main
Niger	1970–1999: UN Main; 2000–2017: UN Country - ISIC3; 2018–2023: UN Main
Nigeria	1970–1989: ASD; 1990–2018: ETD; 2019–2023: UN Country - ISIC4
Norway	1970–1999: UN Country - ISIC3; 2000–2014: WIOD; 2015–2023: UN Main
Pakistan	1970–1989: UN Main; 1990–2018: ETD; 2019–2023: UN Country - ISIC4
Philippines	1970: UN Main; 1971–1989: TSD; 1990–2018: ETD; 2019–2023: UN Country - ISIC4
Russian Federation	1970–1989: Imputed; 1990–1994: UN Main; 1995–1999: ETD; 2000–2014: WIOD; 2015–2019: ETD; 2020–2023: UN Main
Rwanda	1970–1989: UN Main; 1990–2018: ETD; 2019–2023: UN Main
Saudi Arabia	1970–2023: UN Main
South Africa	1970–1989: ASD; 1990–2018: ETD; 2019–2023: UN Main
Spain	1970–2014: WIOD; 2015–2023: UN Main
Sudan	1970–1994: Imputed; 1995–2006: UN Country - ISIC3; 2007–2018: Imputed; 2019–2023: Extrapolated
Sweden	1970–2014: WIOD; 2015–2023: UN Main
Taiwan	1970–2014: WIOD; 2015–2018: ETD; 2019–2023: Extrapolated
Thailand	1970–1989: TSD; 1990–2018: ETD; 2019–2023: UN Main
Turkey	1970–1989: UN Main; 1990–1999: ETD; 2000–2014: WIOD; 2015–2018: ETD; 2019–2023: UN Main
USA	1970–2014: WIOD; 2015–2023: UN Main
United Arab Emirates	1970–2023: UN Main
United Kingdom	1970–2014: WIOD; 2015–2023: UN Main

Country	Sources
Viet Nam	1970–1989: UN Main; 1990–2018: ETD; 2019–2023: UN Main

Table 2. **Employment Sources by Country and Year.** These are the sources of the employment shares, which are then adjusted to reflect work hour shares by the ILOSTAT mean weekly hours data for all countries.

Country	Sources
Algeria	1971–1990: Extrapolated; 1991–2023: ILO
Argentina	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Australia	1971–1990: Extrapolated; 1991–2023: ILO
Bangladesh	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Brazil	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Canada	1971–1990: Extrapolated; 1991–2023: ILO
Chile	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
China	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Colombia	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Cote d'Ivoire	1971–1990: Extrapolated; 1991–2023: ILO
DR Congo	1971–1990: Extrapolated; 1991–2023: ILO
Denmark	1971–2011: TSD; 2012–2023: ILO
Egypt	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Ethiopia	1971–1989: ASD; 1990–2018: ETD; 2019–2023: ILO
France	1971–2011: TSD; 2012–2023: ILO
Germany	1971–1991: TSD; 1992–2023: ILO
India	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Indonesia	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Iran	1971–1990: Extrapolated; 1991–2023: ILO
Italy	1971–2011: TSD; 2012–2023: ILO
Japan	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Kenya	1971–1989: ASD; 1990–2018: ETD; 2019–2023: ILO
Korea	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Mali	1971–1990: Extrapolated; 1991–2023: ILO
Mexico	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Morocco	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Myanmar	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Netherlands	1971–2011: TSD; 2012–2023: ILO
New Zealand	1971–1990: Extrapolated; 1991–2023: ILO
Niger	1971–1990: Extrapolated; 1991–2023: ILO
Nigeria	1971–1989: ASD; 1990–2018: ETD; 2019–2023: ILO
Norway	1971–1990: Extrapolated; 1991–2023: ILO
Pakistan	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Philippines	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Russian Federation	1971–1989: Extrapolated; 1990–2019: ETD; 2020–2023: ILO
Rwanda	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
Saudi Arabia	1971–1990: Extrapolated; 1991–2023: ILO
South Africa	1971–1989: ASD; 1990–2018: ETD; 2019–2023: ILO
Spain	1971–2011: TSD; 2012–2023: ILO
Sudan	1971–1990: Extrapolated; 1991–2022: ILO; 2023: Extrapolated

Country	Sources
Sweden	1971–2011: TSD; 2012–2023: ILO
Taiwan	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Thailand	1971–1989: TSD; 1990–2018: ETD; 2019–2023: ILO
Turkey	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO
USA	1971–2010: TSD; 2011–2023: ILO
United Arab Emirates	1971–1990: Extrapolated; 1991–2023: ILO
United Kingdom	1971–2011: TSD; 2012–2023: ILO
Viet Nam	1971–1989: Extrapolated; 1990–2018: ETD; 2019–2023: ILO

Table 3. **Final Demand Source Coverage by Country and Year.** Final Demand coverage mostly comes from ICIO tables and is more limited than the other sources. However, the largest economies are covered for the entire study period.

Country	Sources
Algeria	1970–2020: Imputed
Argentina	1970–1994: Imputed; 1995–2020: OECD; 2021–2022: FIGARO
Australia	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Bangladesh	1970–1994: Imputed; 1995–2020: OECD
Brazil	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Canada	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Chile	1970–1994: Imputed; 1995–2020: OECD
China	1970–1999: WIOD Long-Run; 2000–2014: WIOD; 2015–2022: FIGARO
Colombia	1970–1994: Imputed; 1995–2020: OECD
Cote d'Ivoire	1970–1994: Imputed; 1995–2020: OECD
DR Congo	1970–2020: Imputed
Denmark	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Egypt	1970–1994: Imputed; 1995–2020: OECD
Ethiopia	1970–2020: Imputed
France	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Germany	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
India	1970–1999: WIOD Long-Run; 2000–2014: WIOD; 2015–2022: FIGARO
Indonesia	1970–1994: Imputed; 1995–2020: OECD; 2021–2022: FIGARO
Iran	1970–2020: Imputed
Italy	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Japan	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Kenya	1970–2020: Imputed
Korea	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Mali	1970–2020: Imputed
Mexico	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Morocco	1970–1994: Imputed; 1995–2020: OECD
Myanmar	1970–1994: Imputed; 1995–2020: OECD
Netherlands	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
New Zealand	1970–1994: Imputed; 1995–2020: OECD
Niger	1970–2020: Imputed
Nigeria	1970–1994: Imputed; 1995–2020: OECD
Norway	1970–1994: Imputed; 1995–2020: OECD; 2021–2022: FIGARO
Pakistan	1970–1994: Imputed; 1995–2020: OECD

Country	Sources
Philippines	1970–1994: Imputed; 1995–2020: OECD
Russian Federation	1970–1994: Imputed; 1995–2020: OECD; 2021–2022: FIGARO
Rwanda	1970–2020: Imputed
Saudi Arabia	1970–1994: Imputed; 1995–2020: OECD; 2021–2022: FIGARO
South Africa	1970–1994: Imputed; 1995–2020: OECD; 2021–2022: FIGARO
Spain	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Sudan	1970–2020: Imputed
Sweden	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Taiwan	1970–1994: WIOD Long-Run; 1995–2020: OECD
Thailand	1970–1994: Imputed; 1995–2020: OECD
Turkey	1970–1994: Imputed; 1995–2020: OECD; 2021–2022: FIGARO
USA	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
United Arab Emirates	1970–2020: Imputed
United Kingdom	1970–1994: WIOD Long-Run; 1995–2020: OECD; 2021–2022: FIGARO
Viet Nam	1970–1994: Imputed; 1995–2020: OECD

B.2 Harmonization & Extrapolation

Harmonization. Essential for the new dataset is the consistent definition of the eight sectors. For each source, I inspected sectoral codes and descriptions and matched them to the eight sectors. Table 4 shows the sector correspondence for most main sources. Sources not included in the detailed table follow the ISIC 3 or 4 standard, which I match at the aggregate letter-level to the eight sectors (see Figure 2). For each data source, all industries are matched according to the correspondence table and values are added up to eight sectors. This is done for each source individually and before the growth-rate harmonization is applied on the eight-sector level.

I apply growth-rate-based harmonization for each variable to build consistent time series from 1970 to 2025. For each variable, I assign a source priority order based on data quality and coverage. The level of the series for each country is based on the highest-priority source available. For remaining sources, I compute year-on-year growth rates. Whenever the data with the highest priority ends, I extend the series by applying the annual growth rate of the source with the next highest priority. This prevents abrupt jumps in the final series due to statistical discrepancies or methodological differences across sources. Additionally, I individually inspect both the level and trend of all sources per country and variable, excluding outliers and adapting the source selection where needed. In ambiguous cases, I consult additional sources.

Some important exceptions are sources that do not break up certain sectors sufficiently to match the eight-sector classification. The long-run WIOD does not differentiate between the sectors of ”shops, restaurants, bars, culture, leisure” and ”education, health, public services" (see LtQ in the correspondence table). Thus, the combined sector is broken up based on the earliest WIOD shares available. "Education, health, public services" then is based backward on the trend of the aggregate sector. "Shops, restaurants, bars, culture, leisure" follows a composite trend of the aggregate sector and the other remaining industries which are separately available in the long-run WIOD and assigned to the leisure sector (e.g. H, I). Similarly, the UN Main Aggregates provides only seven sectors and again do not differentiate between the leisure and public services (see NA in table). The source therefore has the lowest priority and is only used for some low-income countries where no other source is available. In these countries, the sector is split by a two-third leisure and one-third public services split which approximates the average split in low-income countries for which other data is available.

Table 4. **Detailed Sector Conversion of Main Sources.** For each column, the table shows the sector codes used in the sources and how they correspond to the eight sectors.

Sector	FIGARO	WIOD	WIOD LR	OECD	ILO Model	ILO Hours	ILO Main	TSD / ASD	ETD	UN Main
Agriculture, forestry, fishing	A01	A01	AtB	A01 02	A	A	A	AtB	A	A-B
Agriculture, forestry, fishing	A02	A02	AtB	A01 02	A	A	A	AtB	A	A-B
Agriculture, forestry, fishing	A03	A03	AtB	A03	A	A	B	AtB	A	A-B
Energy, mining	B	B	C	B05 06	B	B	C	C	B	C, E
Energy, mining	B	B	C	B07 08	B	B	C	C	B	C, E
Energy, mining	B	B	C	B09	B	B	C	C	B	C, E
Manufacturing	C10T12	C10-C12	D15t16	C10T12	C	C	D	D	C	D
Manufacturing	C13T15	C13-C15	D17t19	C13T15	C	C	D	D	C	D
Manufacturing	C16	C16	D21t22	C16	C	C	D	D	C	D
Manufacturing	C17	C17	D21t22	C17 18	C	C	D	D	C	D
Manufacturing	C18	C18	D21t22	C17 18	C	C	D	D	C	D
Manufacturing	C19	C19	D23	C19	C	C	D	D	C	D
Manufacturing	C20	C20	D24	C20	C	C	D	D	C	D
Manufacturing	C21	C21	D24	C21	C	C	D	D	C	D
Manufacturing	C22	C22	D25	C22	C	C	D	D	C	D
Manufacturing	C23	C23	D26	C23	C	C	D	D	C	D
Manufacturing	C24	C24	D27t28	C24	C	C	D	D	C	D
Manufacturing	C25	C25	D27t28	C25	C	C	D	D	C	D
Manufacturing	C26	C26	D30t33	C26	C	C	D	D	C	D
Manufacturing	C27	C27	D30t33	C27	C	C	D	D	C	D
Manufacturing	C28	C28	D29	C28	C	C	D	D	C	D
Manufacturing	C29	C29	D34t35	C29	C	C	D	D	C	D
Manufacturing	C30	C30	D34t35	C30	C	C	D	D	C	D
Manufacturing	C31 32	C31 C32	Dnec	C31T33	C	C	D	D	C	D
Manufacturing	C33	C33	D29	C31T33	C	C	D	D	C	D

Sector	FIGARO	WIOD	WIOD LR	OECD	ILO Model	ILO Hours	ILO Main	TSD / ASD	ETD	UN Main
Energy, mining	D35	D35	E	D	D; E	D	E	E	D+E	C, E
Energy, mining	E36	E36	E	D	D; E	E	E	E	D+E	C, E
Energy, mining	E37T39	E37-E39	E	E	D; E	E	E	E	D+E	C, E
Construction	F	F	F	F	F	F	F	F	F	F
Shops, restaurants, bars, culture, leisure	G45	G45	G	G	G	G	G	GtH	G+I	G,H
Shops, restaurants, bars, culture, leisure	G46	G46	G	G	G	G	G	GtH	G+I	G,H
Shops, restaurants, bars, culture, leisure	G47	G47	G	G	G	G	H	GtH	G+I	G,H
Transport	H49	H49	I60t63	H49	H; J	H	I	I	H	I
Transport	H50	H50	I60t63	H50	H; J	H	I	I	H	I
Transport	H51	H51	I60t63	H51	H; J	H	I	I	H	I
Transport	H52	H52	I60t63	H52	H; J	H	I	I	H	I
Shops, restaurants, bars, culture, leisure	H53	H53	I64	H53	I	I	H	GtH	G+I	G,H
Shops, restaurants, bars, culture, leisure	I	I	H	I	I	I	H	GtH	G+I	G,H
Shops, restaurants, bars, culture, leisure	J58	J58	D21t22	J58T60	I	J	H	GtH	G+I	G,H
Shops, restaurants, bars, culture, leisure	J59 60	J59 J60	D21t22	J58T60	I	J	H	GtH	G+I	G,H
Shops, restaurants, bars, culture, leisure	J61	J61	I64	J61	I	J	H	GtH	G+I	G,H
Business and financial services	J62 63	J62 J63	J	J62 63	I	J	J	JtK	K	NA
Business and financial services	K64	K64	J	K	K	K	J	JtK	K	NA
Business and financial services	K65	K65	J	K	K	K	J	JtK	K	NA
Business and financial services	K66	K66	J	K	K	K	J	JtK	K	NA
Business and financial services	L	L68	K	L	L; M; N	L	K	JtK	L	NA
Business and financial services	M69 70	M69 M70	K	M	L; M; N	M	K	JtK	J+M+N	NA
Business and financial services	M71	M71	K	M	L; M; N	M	K	JtK	J+M+N	NA
Business and financial services	M72	M72	K	M	L; M; N	M	K	JtK	J+M+N	NA
Business and financial services	M73	M73	K	M	L; M; N	M	K	JtK	J+M+N	NA
Business and financial services	M74 75	M74 M75	K	M	L; M; N	M	K	JtK	J+M+N	NA
Business and financial services	N77	N	K	N	L; M; N	N	K	JtK	J+M+N	NA
Business and financial services	N78	N	K	N	L; M; N	N	K	JtK	J+M+N	NA
Business and financial services	N79	N	K	N	L; M; N	N	K	JtK	J+M+N	NA
Business and financial services	N80T82	N	K	N	L; M; N	N	K	JtK	J+M+N	NA
Education, health, public services	O84	O84	LtQ	O	O	O	L	LtN	O+P+Q	NA
Education, health, public services	P85	P85	LtQ	P	P	P	M	LtN	O+P+Q	NA
Education, health, public services	Q86	Q	LtQ	Q	Q	Q	N	LtN	O+P+Q	NA
Education, health, public services	Q87 88	Q	LtQ	Q	Q	Q	N	LtN	O+P+Q	NA

Sector	FIGARO	WIOD	WIOD LR	OECD	ILO Model	ILO Hours	ILO Main	TSD / ASD	ETD	UN Main
Shops, restaurants, bars, culture, leisure	R90T92	R S	LtQ	R	R; S; T; U	R	O	OtP	R+S+T+U	NA
Shops, restaurants, bars, culture, leisure	R93	R S	LtQ	R	R; S; T; U	R	O	OtP	R+S+T+U	NA
Shops, restaurants, bars, culture, leisure	S94	R S	LtQ	S	R; S; T; U	S	O	OtP	R+S+T+U	NA
Shops, restaurants, bars, culture, leisure	S95	R S	LtQ	S	R; S; T; U	S	O	OtP	R+S+T+U	NA
Shops, restaurants, bars, culture, leisure	S96	R S	LtQ	S	R; S; T; U	S	O	OtP	R+S+T+U	NA
Shops, restaurants, bars, culture, leisure	T	T	LtQ	T	R; S; T; U	T	P	OtP	R+S+T+U	NA
Shops, restaurants, bars, culture, leisure	U	U	LtQ	T	R; S; T; U	U	Q	OtP	R+S+T+U	NA

Extrapolation. Thanks to the large number of integrated sources, long-run series for most countries require minimal extrapolation. Data coverage is most limited for final demand which is derived from inter-country input-output tables. However, I still cover 90% of global demand or trade for most years without extrapolation (see data coverage).

To get a balanced panel that adds up to the global totals and has information on all 57 countries and regions, I use a three-step extrapolation method. First, for countries lacking sectoral data over long periods (e.g., pre-1995) or who have no data at all, I assign values using regional average shares weighted by each country's national aggregates (on level of the nine world regions). I apply these values for some benchmark years (e.g., 1970, 1995, and 2020) and apply linear growth between assigned benchmark years and observed real data points. The assigned shares are then multiplied by observed country totals. If I do not have a separate source for country totals (e.g., final demand components), I harmonize and extrapolate the sectoral variables relative to national GDP and then multiply with the observed country GDP.

Second, for series where only a few years are missing at the beginning or the end of the time period, I estimate average annual growth rates over the first or last ten years of observed data and apply them to extend the series. This method is also applied to extrapolate the two most recent years, which, in the future, will need to be updated if this project continues. The data files report the data source or extrapolation method for each individual observation.

The nine residual regions aggregate data from countries not individually listed, e.g. "Other Western Europe". I first harmonize and extrapolate series for all 216 countries and then aggregate them to the nine regions. As for the individual countries, I also ensure that sectoral values sum to the economy totals of the region by multiplying the observed total values by the newly created shares. Where necessary, I also ensure that national accounting identities hold by adjusting subcomponents (e.g., consumption items) to match their aggregates, with the latter taking precedence.

C Price and Income Elasticities

To determine sectoral price elasticities, which I use in sections 6 and 7, I rely on the collected country-level eight-sector data.

To determine the elasticities I run a regression. I first exclude all aggregate regions and extrapolated values from the dataset. The unit of observation is country-sector-year prices and final demand volumes. With this, I want to identify the association between a within-country-sector price change and the change in the country-sector final demand volume. With the inclusion of the change in total economy GDP level, I control for total economy growth and can proxy income effects on the sectoral final demand volumes. As I do not exploit any exogenous shocks to prices or total income, the estimates should be interpreted with caution.

My main specification to estimate price and income elasticities is the following two-way fixed effects model with sector interaction terms. For different sections, I run the regression both on the three and eight sector level, where the number of industries is n. I present the respective results below.

$$
\begin{aligned}
\Delta^5 \log(\text{Sector FD}_{cst}) = & \sum_{s=1}^{n} \beta_s \cdot \Delta^5 \log(\text{Relative Price}_{cst}) \times \text{Sector}_s \\
& + \sum_{s=1}^{n} \gamma_s \cdot \Delta^5 \log(\text{Total GDP}_{ct}) \times \text{Sector}_s \\
& + \delta_t + \varepsilon_{cst}
\end{aligned}
\tag{1}
$$

where:

- $\Delta^5 \log(\text{Sector FD}_{cst})$ is the 5-year log-difference in real final demand for sector s in country c at time t,
- $\Delta^5 \log(\text{ Relative Price}_{cst})$ is the 5-year log-difference in relative price,
- $\Delta^5 \log(\text{Total GDP}_{ct})$ is the 5-year log-difference in total real GDP of the country at time t (as proxy for income level),

- Sector_s is a set of dummy variables for the eight sectors,
- β_s and γ_s are sector-specific elasticities with respect to relative prices and aggregate GDP, respectively,
- δ_t are year fixed effects accounting for global time-specific shocks,
- ε_{cst} is the error term.

Three-Sector Level. The price elasticities on the three-sector level shown in Figure 22 are used for the decomposition fo Baumol and Engel effects in Section 6. The income effects are printed for illustration and act as controls for GDP changes in the regression, but are not further used in the analysis.

All three price elasticities are between -1 and -0.5, showing that a one-percent increase in the relative price of one of the three aggregate sectors is associated with a percentage decline in the sectoral final demand between 0.5 and 1. Surprisingly, industrial sectors show the smallest price elasticity, which could be driven by the heterogeneity of the sector and that substitution is primarily within the aggregate sector. The eight-sector price elasticities are possibly more insightful and I discuss them in more detail.

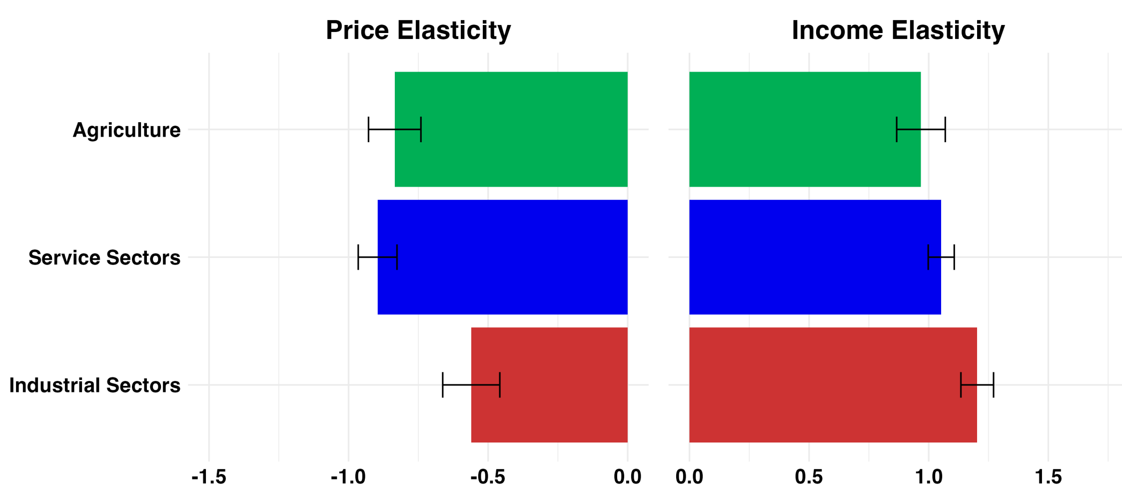


Figure 22. **Income and Price Elasticities of Sectoral Final Demand by Three Sectors**. Percentage change in sectoral volume FD associated with a one-percent increase in the sector's relative price (price elasticity) and the percentage change associated with a one-percent increase in the total country's GDP.

Eight-Sector Level. The eight-sector specification identifies the price and income elasticities in Figure 23, from which I use the price elasticities for the hypothetical final demand composition in Section 7.2.

The sectoral price elasticities are slightly above minus one, which would indicate that a one percent increase in the relative price is associated with a one percent decrease in the sectoral final demand volume. The elasticities are generally similar across sectors and mostly not statistically significantly different at the 5-percent level. Agriculture shows the smallest elasticity, which can be explained because it mainly provides necessities. The income elasticities are around plus one, which makes sense as it implies that a one percent increase in total GDP is associated on average with a one percent increase in final demand. Again, agriculture shows the smallest estimate in magnitude, which supports the Engel prediction that agricultural demand grows less with income growth than other sectors' demand. There is no clear pattern in the industrial sectors and services, with subsectors of each group below and above one. The magnitude of the elasticities is generally in line with the existing literature but more homogeneous, which might be explained by the large sector categories where substitution across sectors is limited (Duarte and Restuccia, 2020).

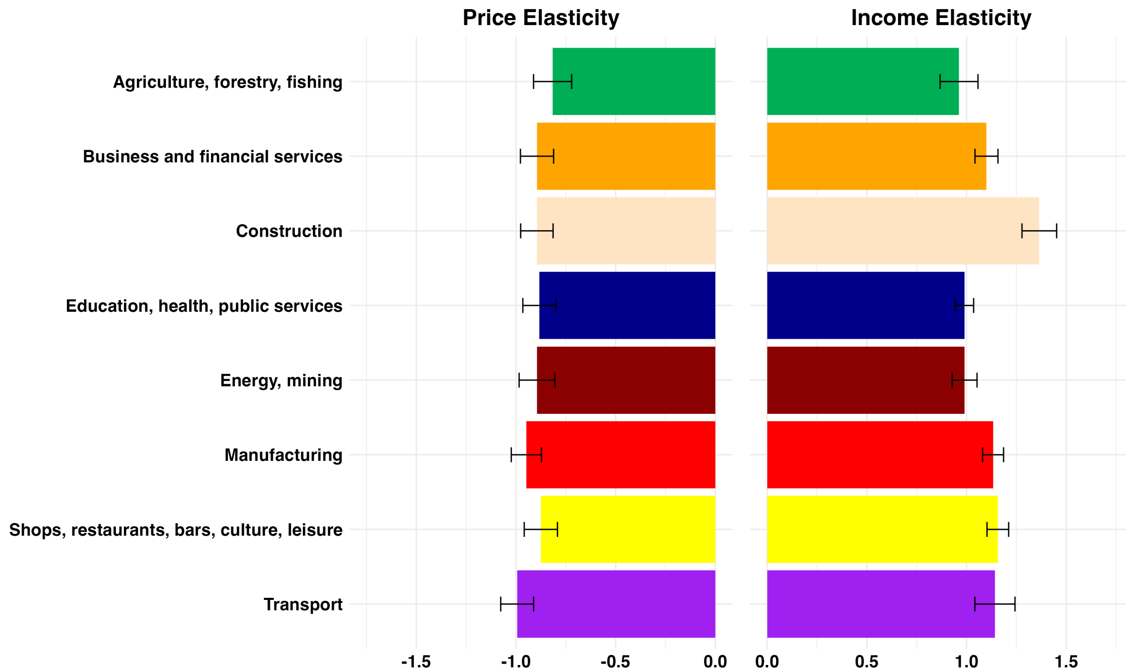


Figure 23. **Income and Price Elasticities of Sectoral Final Demand by Eight Sectors**. Percentage change in sectoral volume FD associated with a one-percent increase in the sector's relative price (price elasticity) and the percentage change associated with a one-percent increase in the total country's GDP.

Next to this main specification, I run the regression with varying length of long-differences, price elasticity estimates are shown below in Figure 24. Estimates do also not substantially change when I sub-set the data frame only to countries of the Global North.

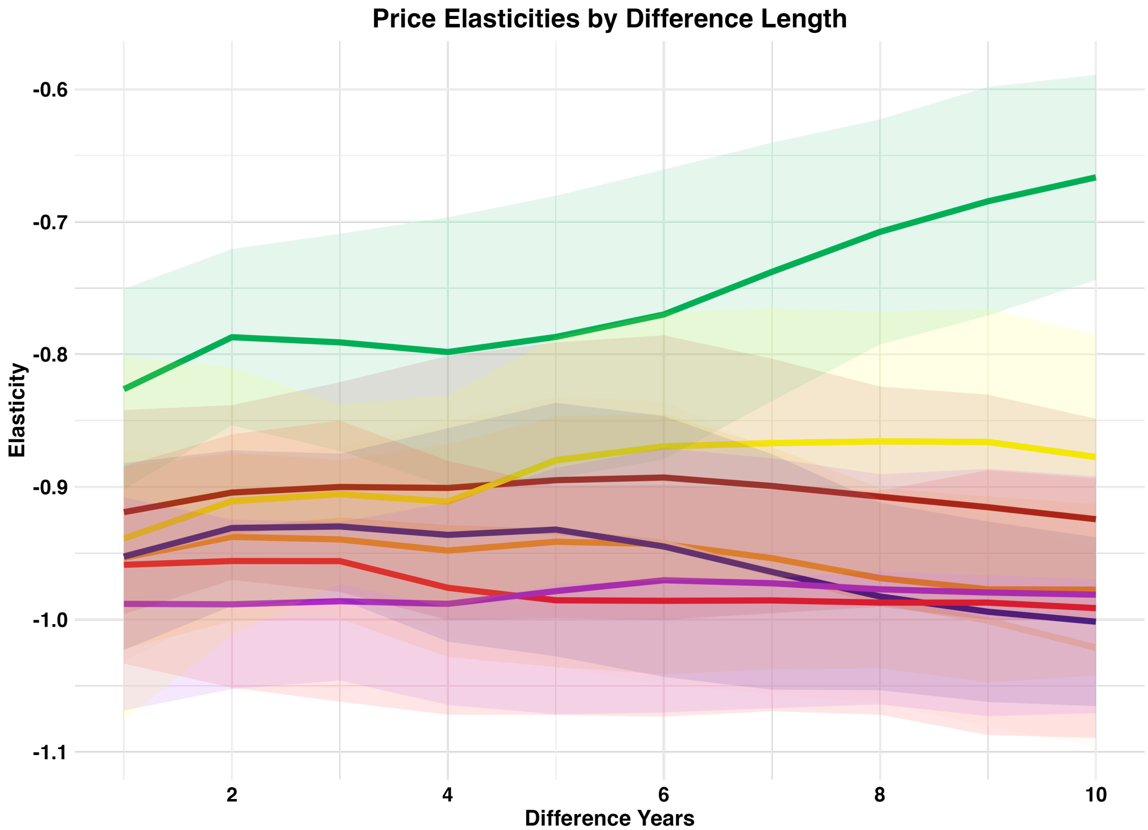


Figure 24. **Price Elasticities of Sectoral Final Demand by Eight Sectors with Different Long-Difference Length**. Percentage change in sectoral volume FD associated with a one-percent increase in the sector's relative price (price elasticity).

D Hypothetical Final Demand Composition

This section describes the framework used for the results of Section 7.2. In total, I apply five steps to get from setting a carbon price to the counterfactual emission scenario under the hypothetical final demand composition.

Step 1: Set Carbon Price

First, I define a carbon price schedule. I refrain from additional complexity and set a global carbon price by sector. All material sectors are taxed by a carbon price which starts with 0 Euro/ton of CO_2e in 2000 and increases by 10 Euros/ton each year to reach 220 Euros/ton in 2022.

Step 2: Adjust Relative Prices

The tax is only applied to industrial sectors. The tax revenue is then used to subsidize services and agricultural consumption. This results in the following price adjustments:

- *Industrial sectors* face a price increase proportional to their emission intensity.
- *Agriculture and Service sectors* receive a uniform price deduction such that the total carbon revenue is redistributed across them.

The carbon price per euro of final demand depends on the emission intensity of the sector and therefore varies by sector and year:

$$\text{CarbonUplift}_{i,t} = \frac{E_{i,t} \cdot p_t^{\text{CO}_2}}{FD_{i,t}^{\text{nom}}}$$

where

- $E_{i,t}$ = Emissions (in tons of CO_2e) of sector i in year t
- $p_t^{\text{CO}_2}$ = carbon price in Euros/ton in year t
- $FD_{i,t}^{\text{nom}}$ = nominal final demand of sector i in year t

As the complete revenue is distributed across the non-industrial sectors, they experience a price deduction according to the following rate:

$$\text{DeductionRate}_t = \frac{\sum_{\text{material } i} \left(\frac{E_{i,t}}{1000} \cdot p_t^{\text{CO}_2} \right)}{\sum_{\text{immaterial } i} FD_{i,t}^{\text{nom}}}$$

The introduction and redistribution of the carbon taxation affect the relative price of all sectors according to the following formulas. It has the highest price effect on the most emission-intensive industrial sectors, i.e., energy and mining.

For industrial sectors:

$$\text{RelPrice}_{i,t}^{\text{adj}} = \text{RelPrice}_{i,t} \cdot (1 + \text{CarbonUplift}_{i,t})$$

For agriculture and service sectors:

$$\text{RelPrice}_{i,t}^{\text{adj}} = \text{RelPrice}_{i,t} \cdot (1 - \text{DeductionRate}_t)$$

As a result, the relative prices between 2000 and 2022 change as shown in the figure below.

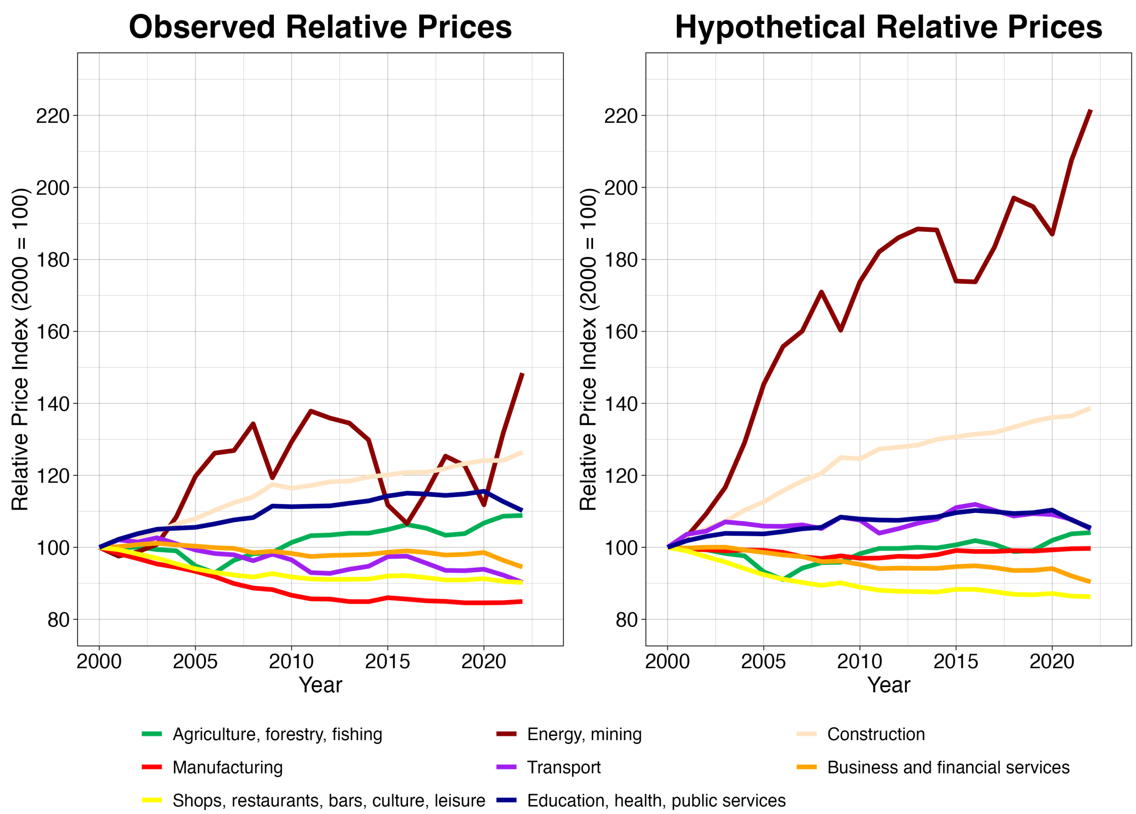


Figure 25. **Observed and Hypothetical Final Demand Indices by Eight Sectors (2000-2022).** Relative prices are set to 100 and equivalent in 2022, hypothetical prices then change according to the gradual introduction of the carbon price in addition to the already observed price changes.

Step 3: Adjust Final Demand with Price Elasticities

To predict how final demand would adjust to the changes in relative prices, I use the eight sectoral price elasticities from Appendix Section C. The price elasticity of sector i is denoted as ε_i. Then, the counterfactual final demand in constant prices is:

$$FD^{\text{cf}}_{i,t} = FD^{\text{real}}_{i,t} \cdot \exp\left(\varepsilon_i \cdot \log\left(\frac{\text{RelPrice}^{\text{adj}}_{i,t}}{\text{RelPrice}_{i,t}}\right)\right)$$

From these new final demand volumes, I calculate the new final demand shares, which I use as the hypothetical composition of final demand.

Step 5: Counterfactual Emissions

I compare emissions with the alternative final demand composition to the observed emissions in Figure 21. Thereby, it is assumed that population, consumption per capita, and emission intensity would have developed the same with the hypothetical composition.

E Additional Figures

E.1 Emissions

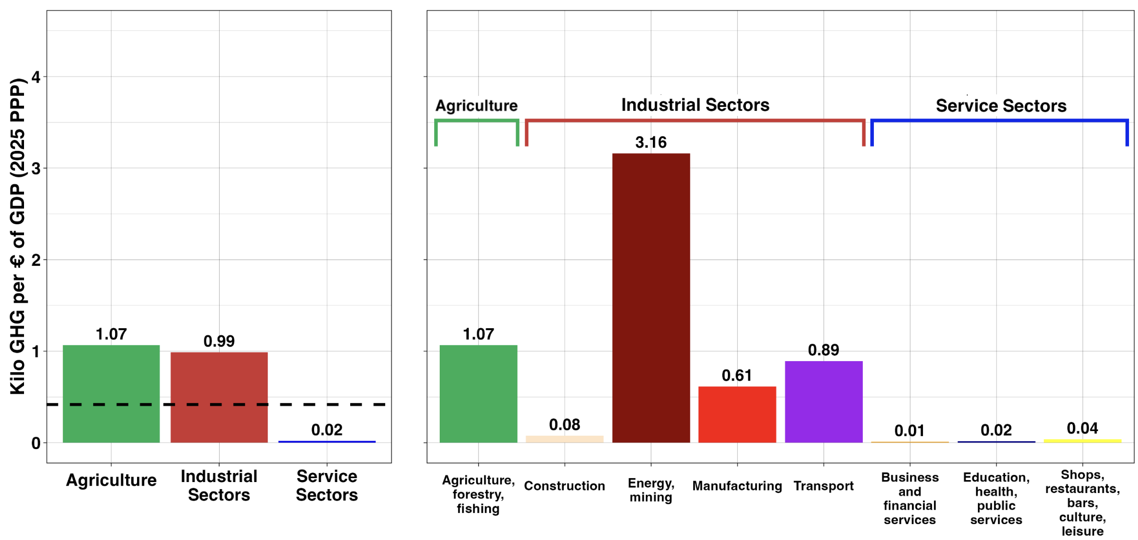


Figure 26. **Global Value-Added-Based Emission Intensities in 2022**. CO_2 equivalents in kilos per euro of GDP (in 2025 PPP Euros). The eight sectors sum up to the three sectors. The three add up to the total economy, which is shown as the black dashed line (0.42 Kilos/Euro). On average, value-added of services causes around 2% of the emissions of industrial or agricultural value-added. The next two figures show the evolution of emission-intensities over time.

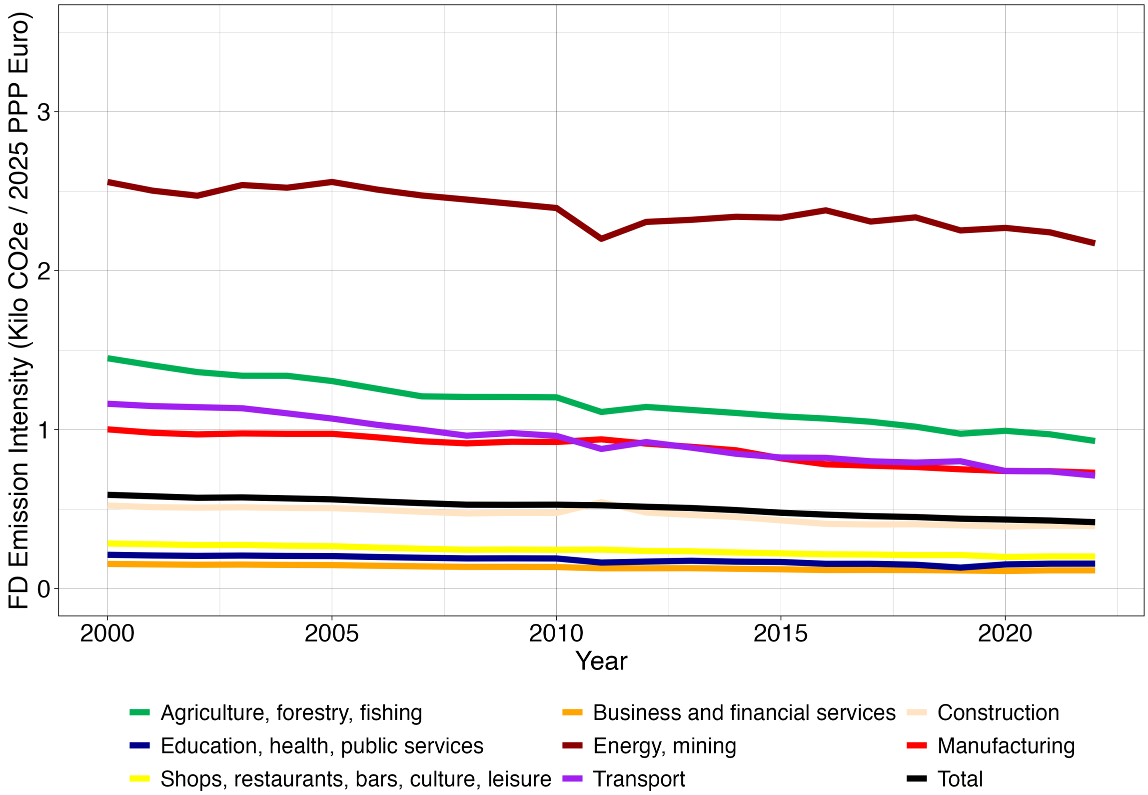


Figure 27. **Global Final-demand-Based Emission Intensities (2000-2022).** Kilos of greenhouse gas equivalents emitted per Euro of Final Demand consumed (in 2025 PPP Euros). Emission intensities have declined in all sectors between 2000 and 2022, the difference between sectors stay largely constant.

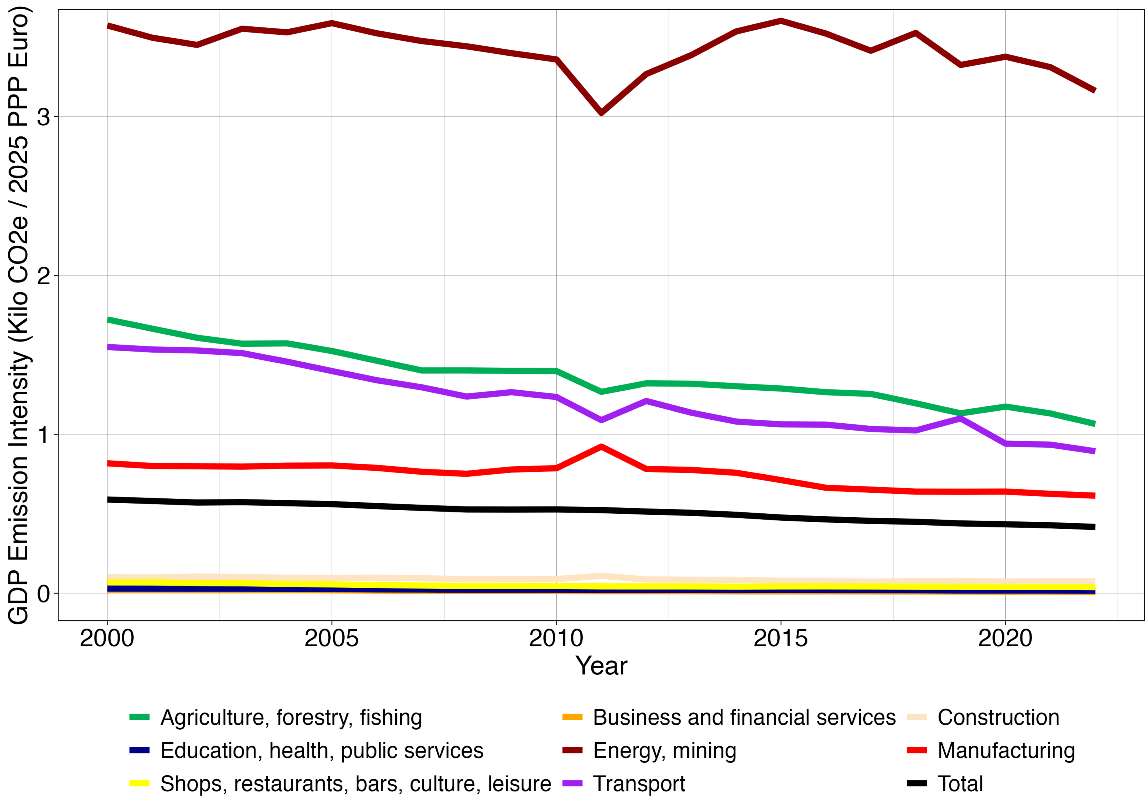


Figure 28. **Global Value-Added-Based Emission Intensities (2000-2022).** Kilos of greenhouse gas equivalents emitted per Euro of GDP produced (in 2025 PPP Euros). Emission intensities have declined in all sectors between 2000 and 2022, the difference between sectors stay largely constant and are substantially larger than in final-demand-based accounting.

E.2 Final Demand: Investment and Consumption Shares

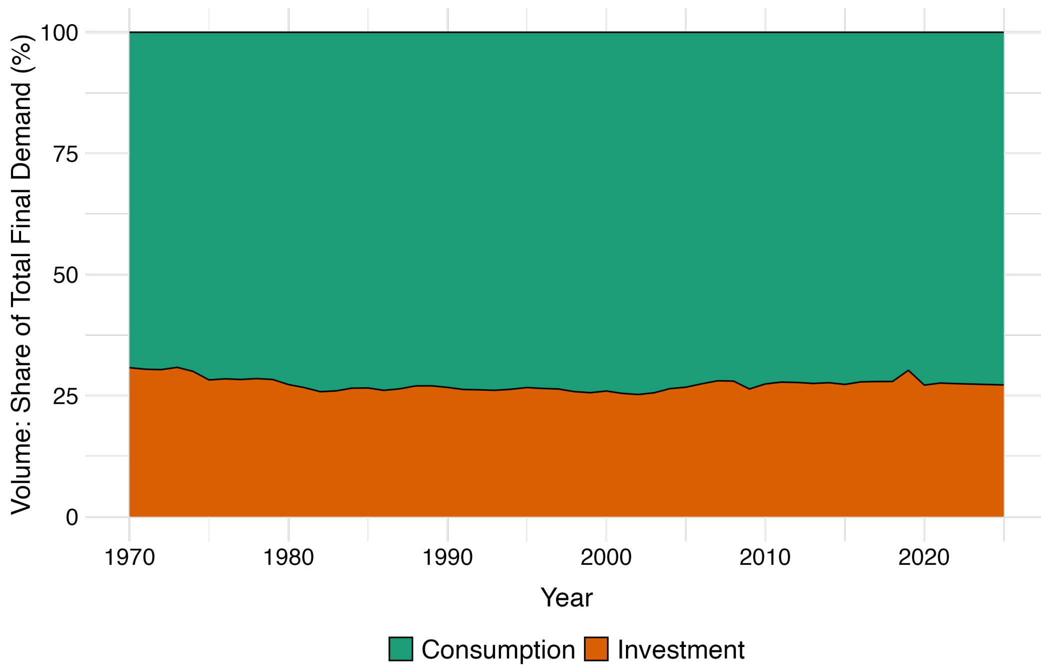


Figure 29. **Global Consumption and Investment Shares in Final Demand (1970-2025, 2025 PPP Euros).** Between 1970 and 2025, investment (GFCF and changes in inventories) have made up around one-fourth of total final demand.

E.3 GDP Volume

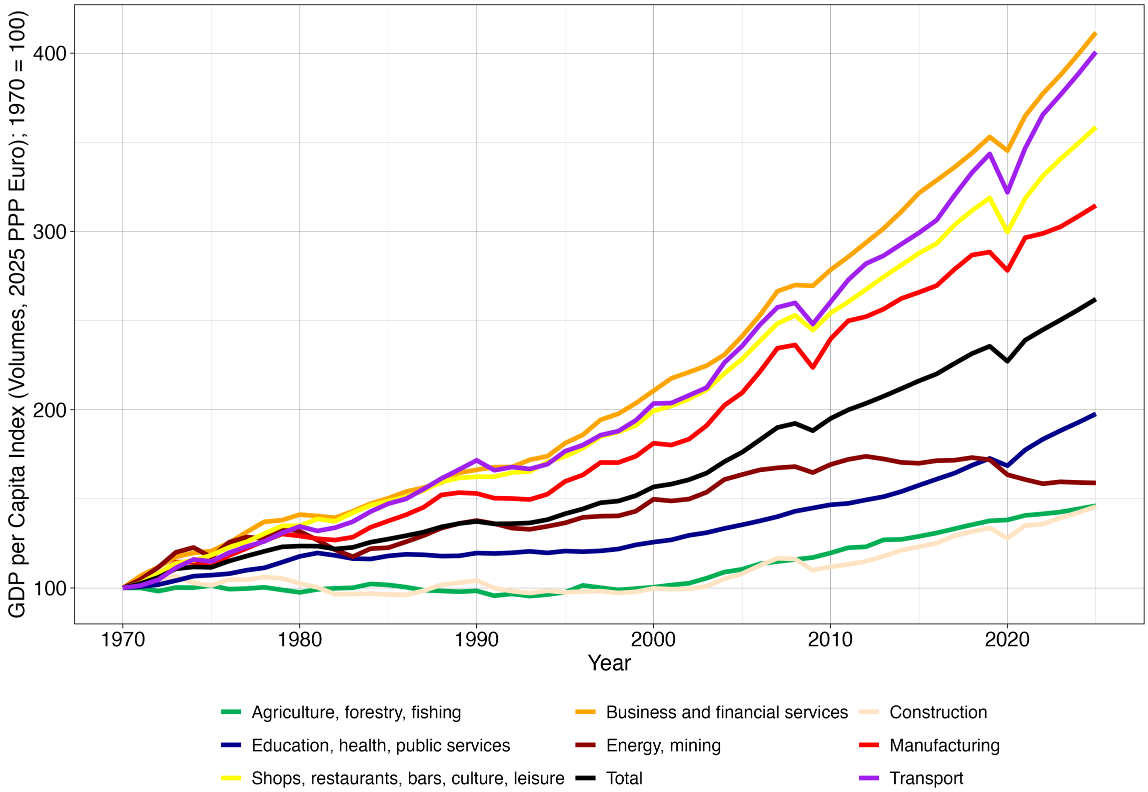


Figure 30. **Sectoral GDP per Capita Growth (Index, 1970 = 100).** Global per capita GDP is today 2.5 times higher than 1970, all sectors have seen in increase in per capita volumes.

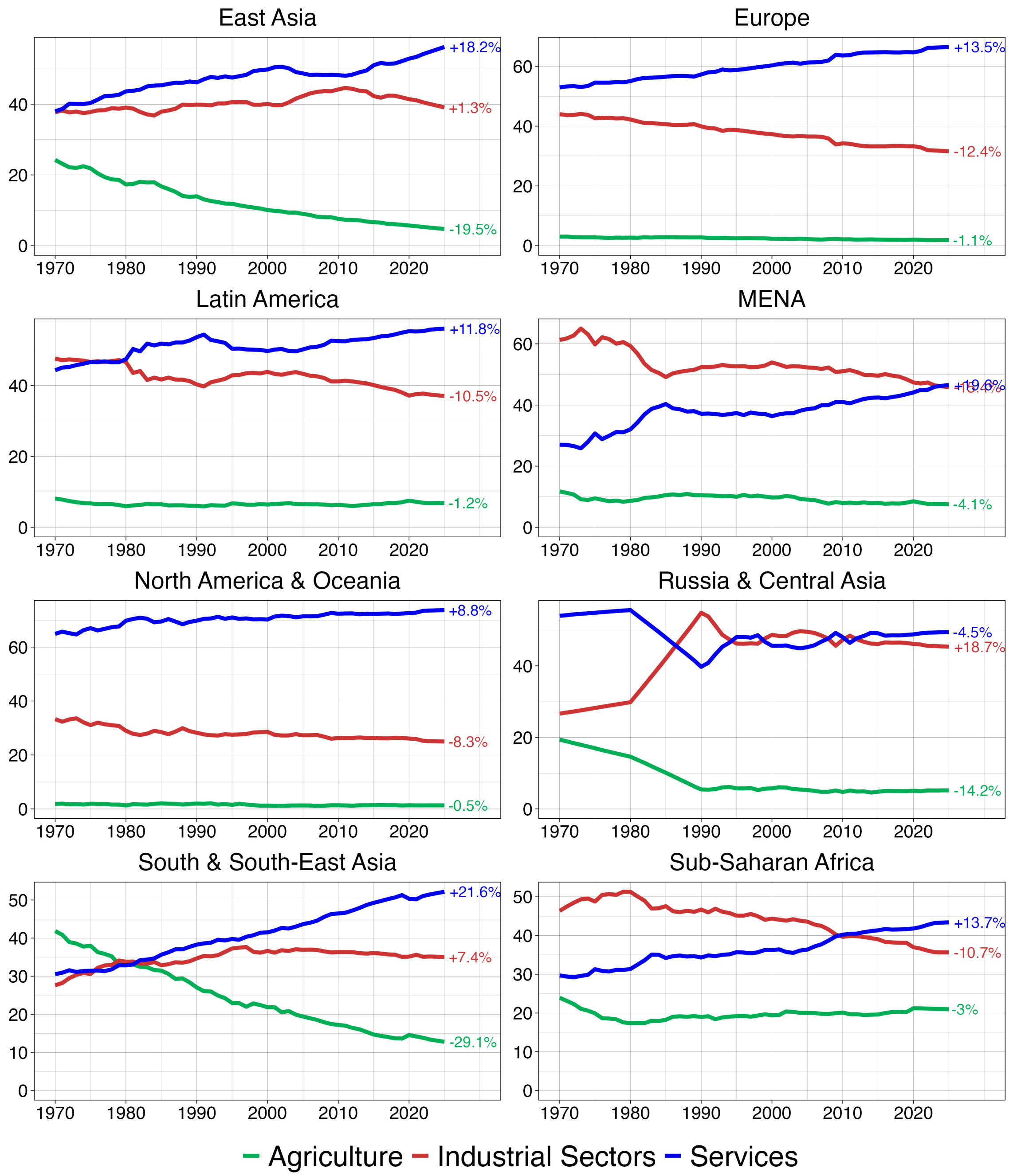


Figure 31. **Regional GDP Shares in Volume Terms by Three Sectors (2025 PPP Euros).** Percentages show difference between 1970 and 2025 shares.

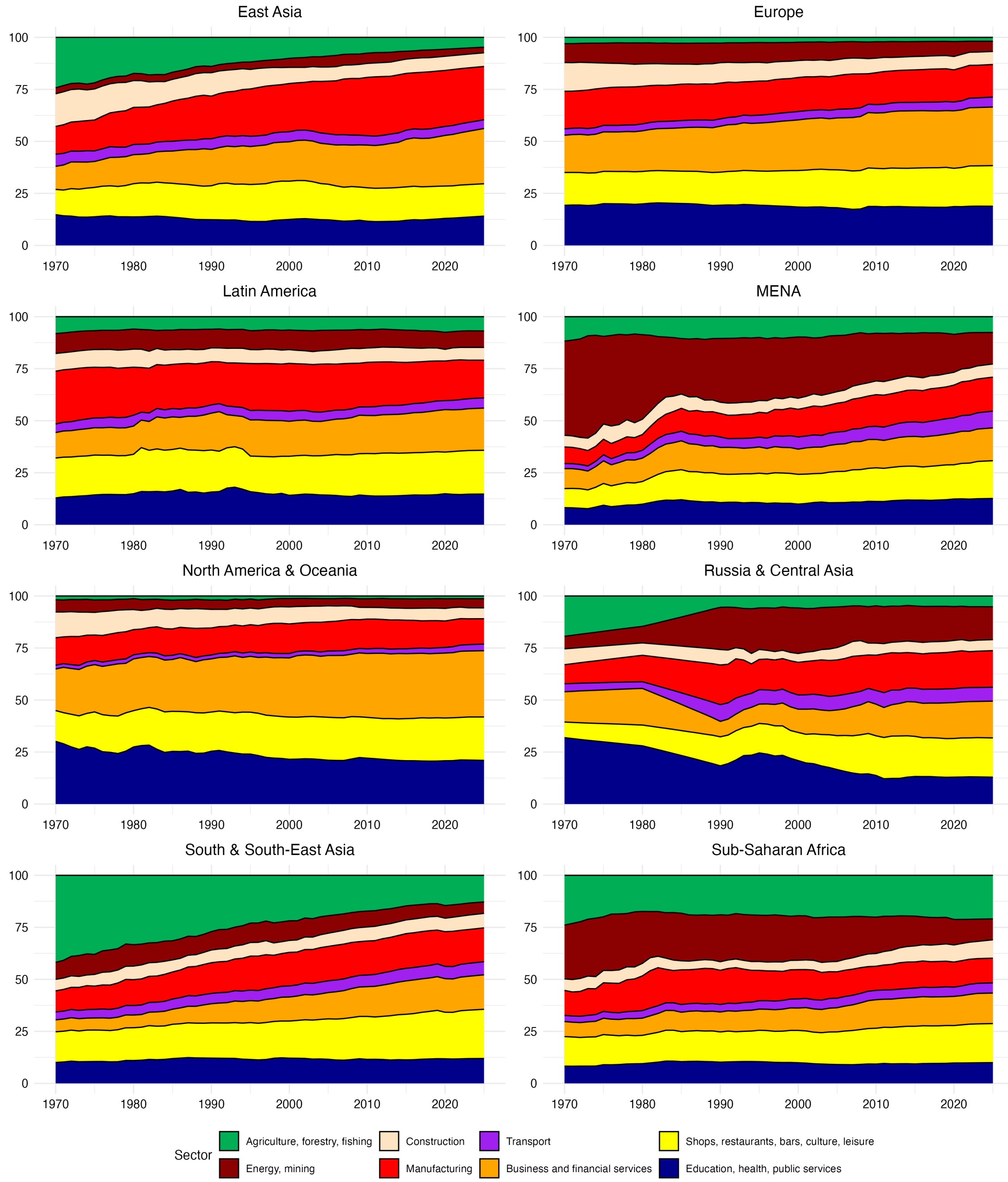


Figure 32. **Regional GDP Shares in Volume Terms by Eight Sectors (2025 PPP Euros).**

E.4 Final Demand Volume

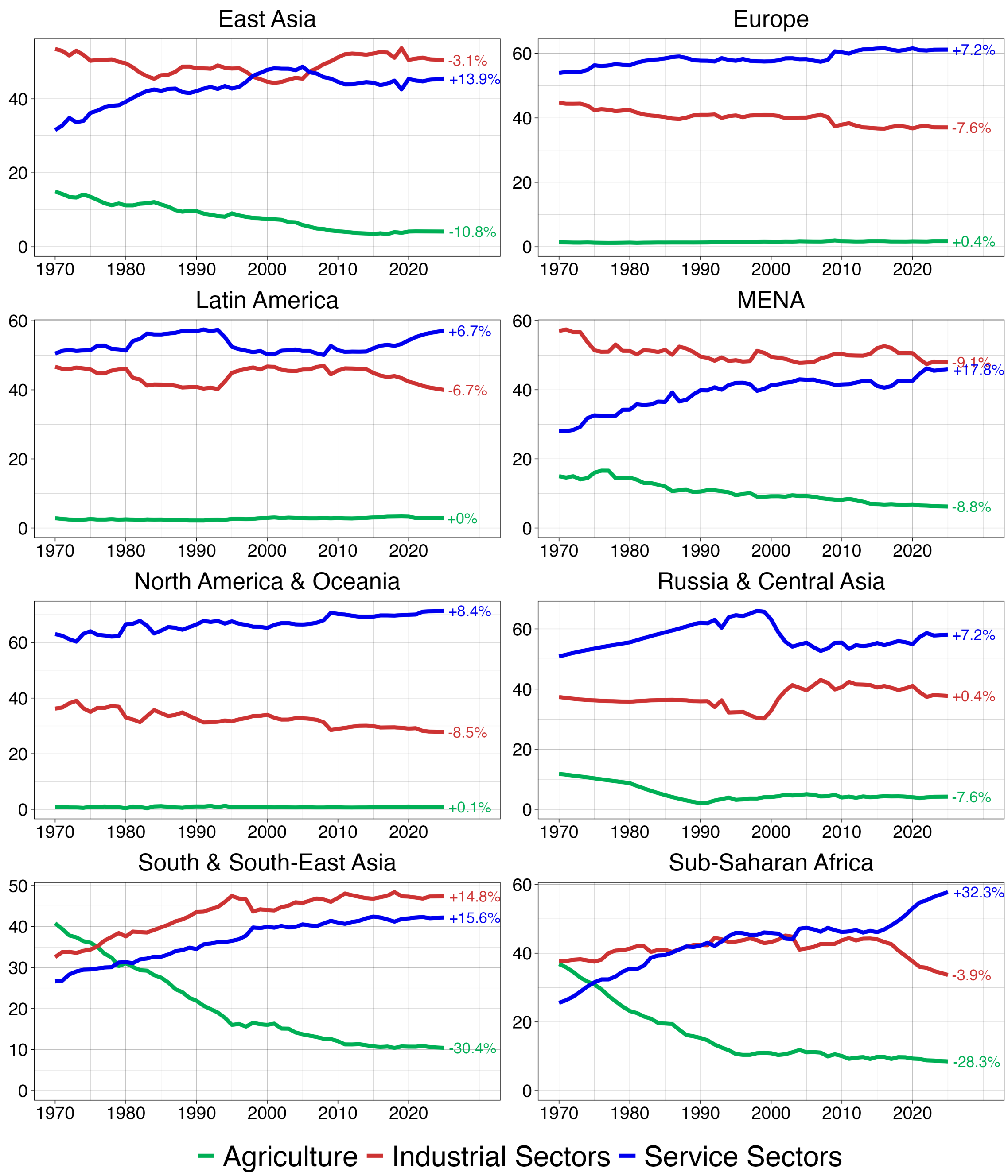


Figure 33. **Regional Final Demand Shares in Volume Terms by Three Sectors (2025 PPP Euros).** Percentages show difference between 1970 and 2025 shares.

E.5 Prices & Productivity

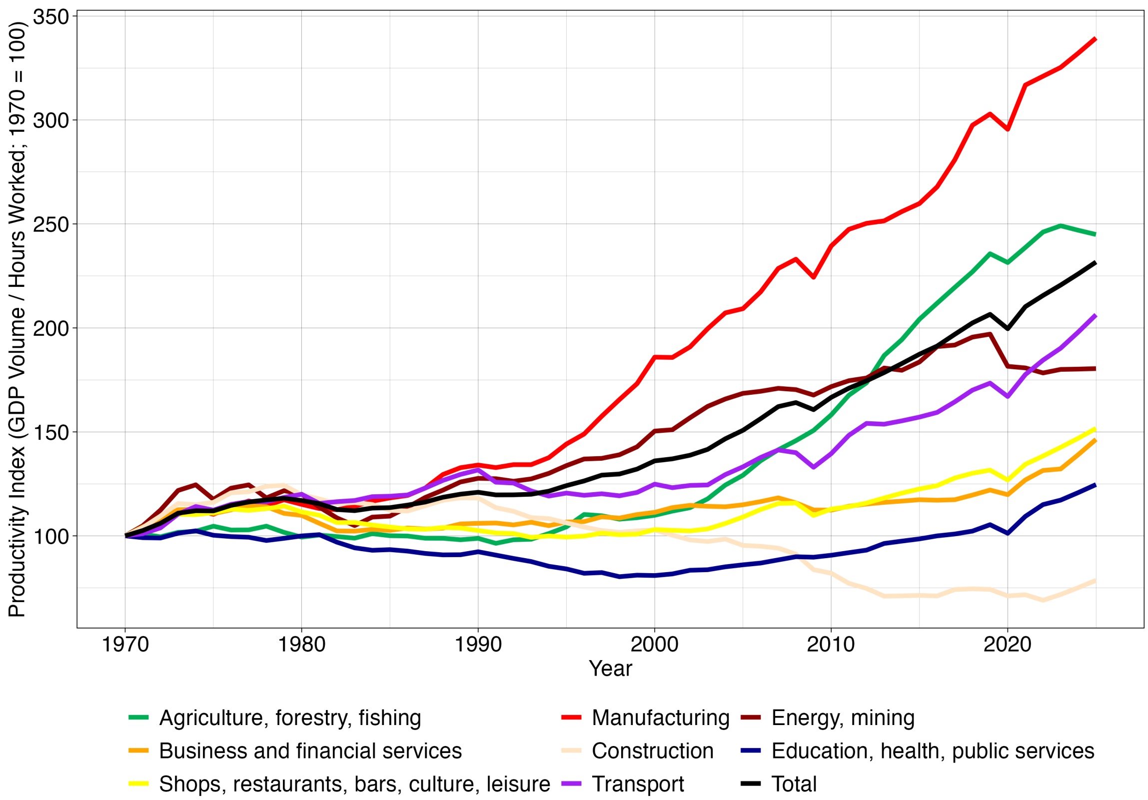


Figure 34. **Global Sectoral Productivity (real GDP per hour worked)**. Indexed to 100 in 1970. Manufacturing productivity increased most sharply, where an hour worked today produces 3.4 more value-added than in 1970.

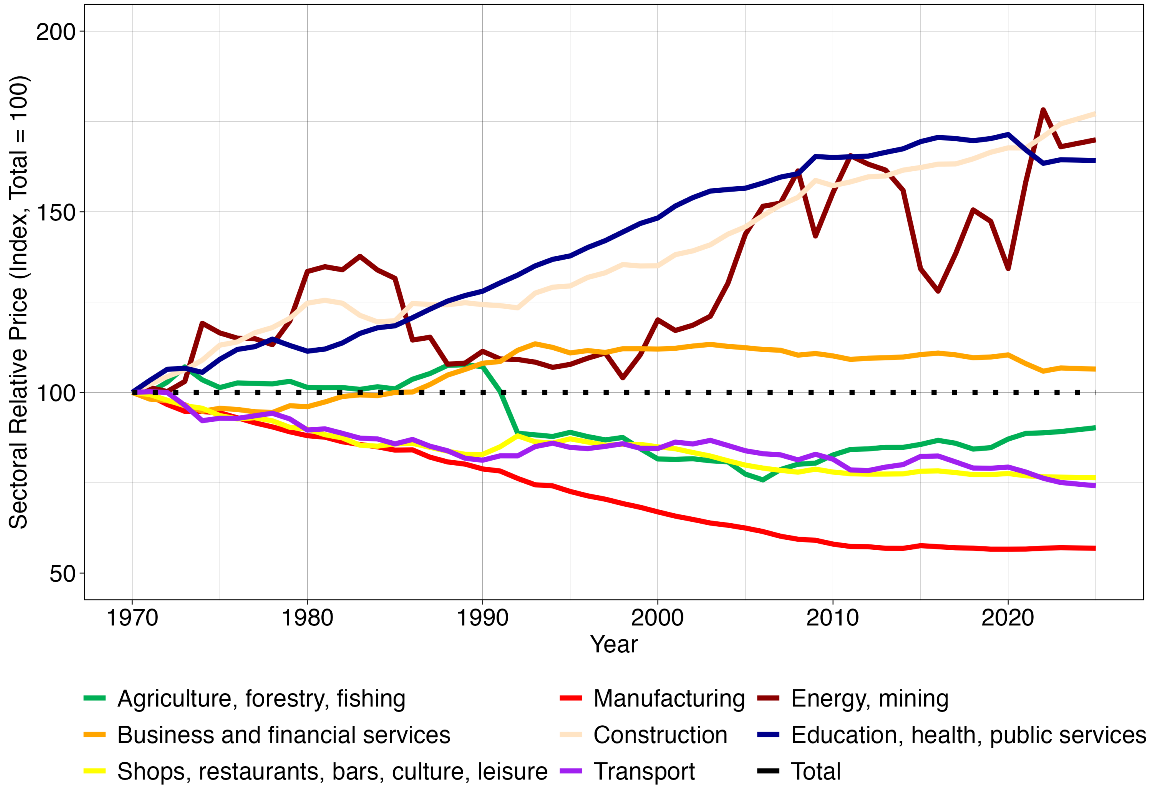


Figure 35. **Global Relative Prices (1970-2025, PPP Euros).** All prices relative to the economy average and indexed to 100 in 1970.

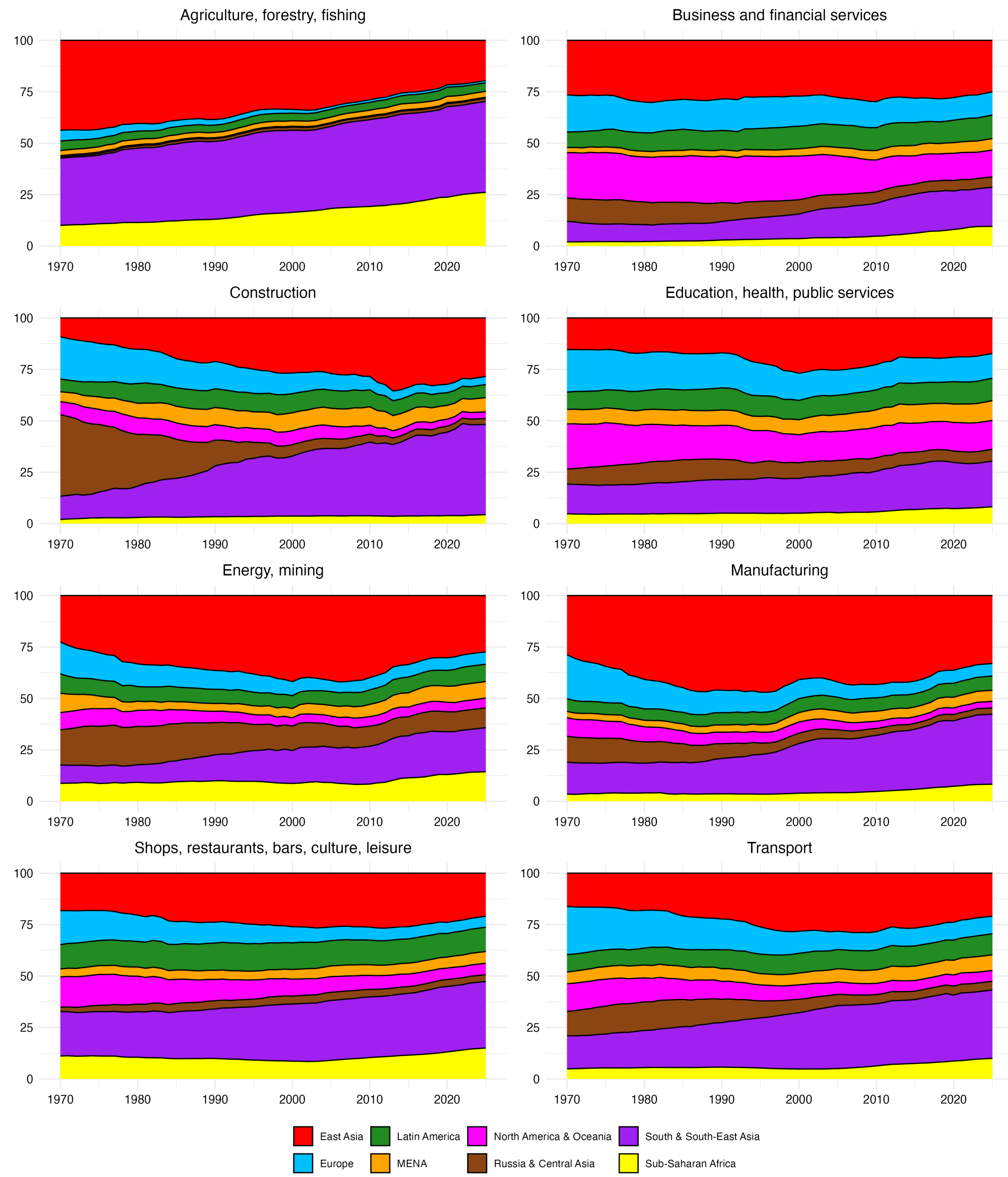


Figure 36. **Sectoral Work Hours by Region (1970-2025).** Each figure shows the evolution of the composition of work hours in one sector.

E.6 Baumol

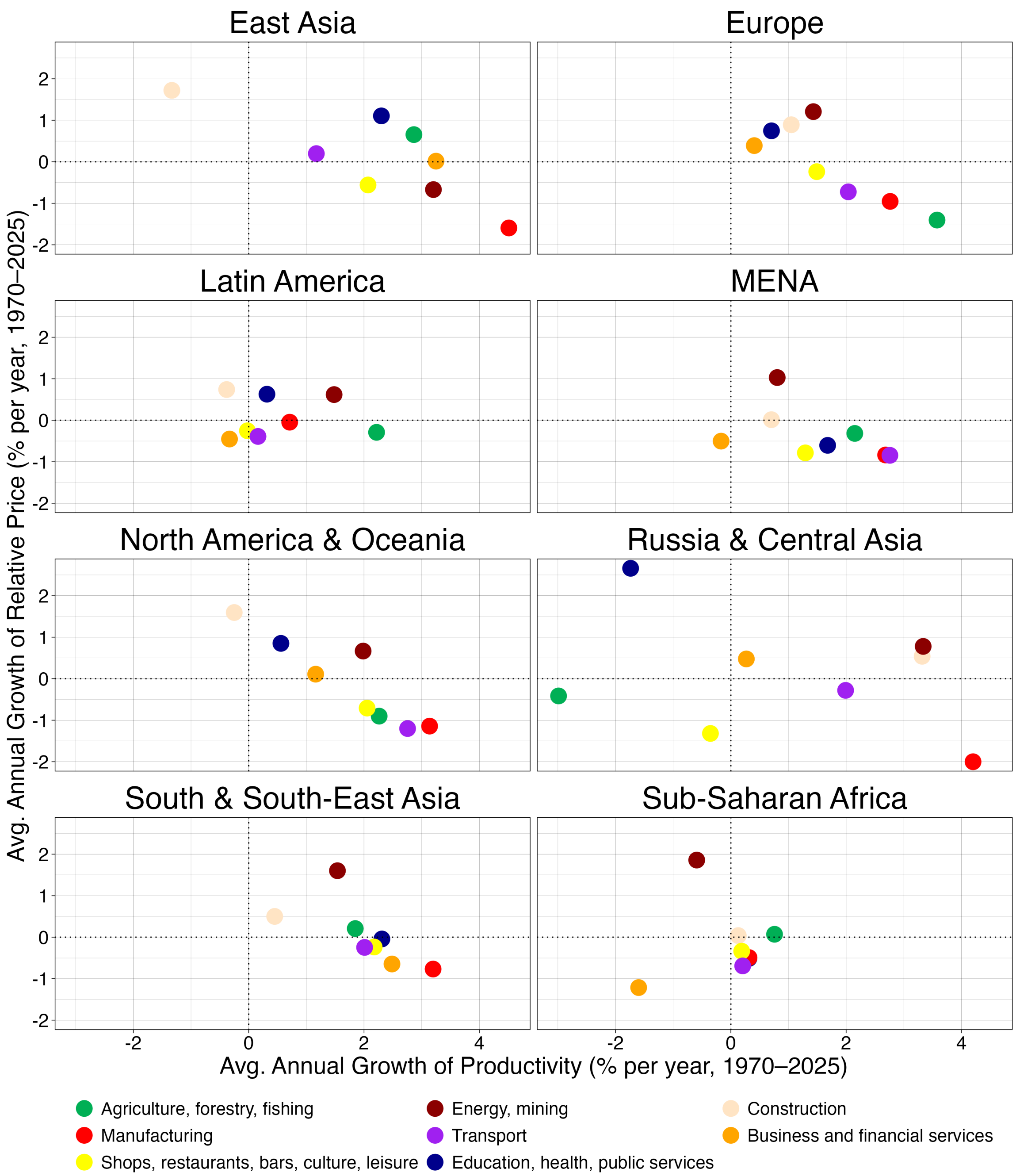


Figure 37. **Scatterplot of Global Annual Productivity (x-axis) and Relative Price Change (y-axis) by World Region.** Both are relative, so a negative value does not mean falling productivity or price but only smaller growth than average. Baumol effects would predict an inverse relationship, so a decreasing fitted regression line across sectors, which can be seen in most regions. In most regions, the service sectors are closer to the upper-left (lower productivity growth, rising relative prices) than manufacturing (higher productivity growth, falling relative prices).

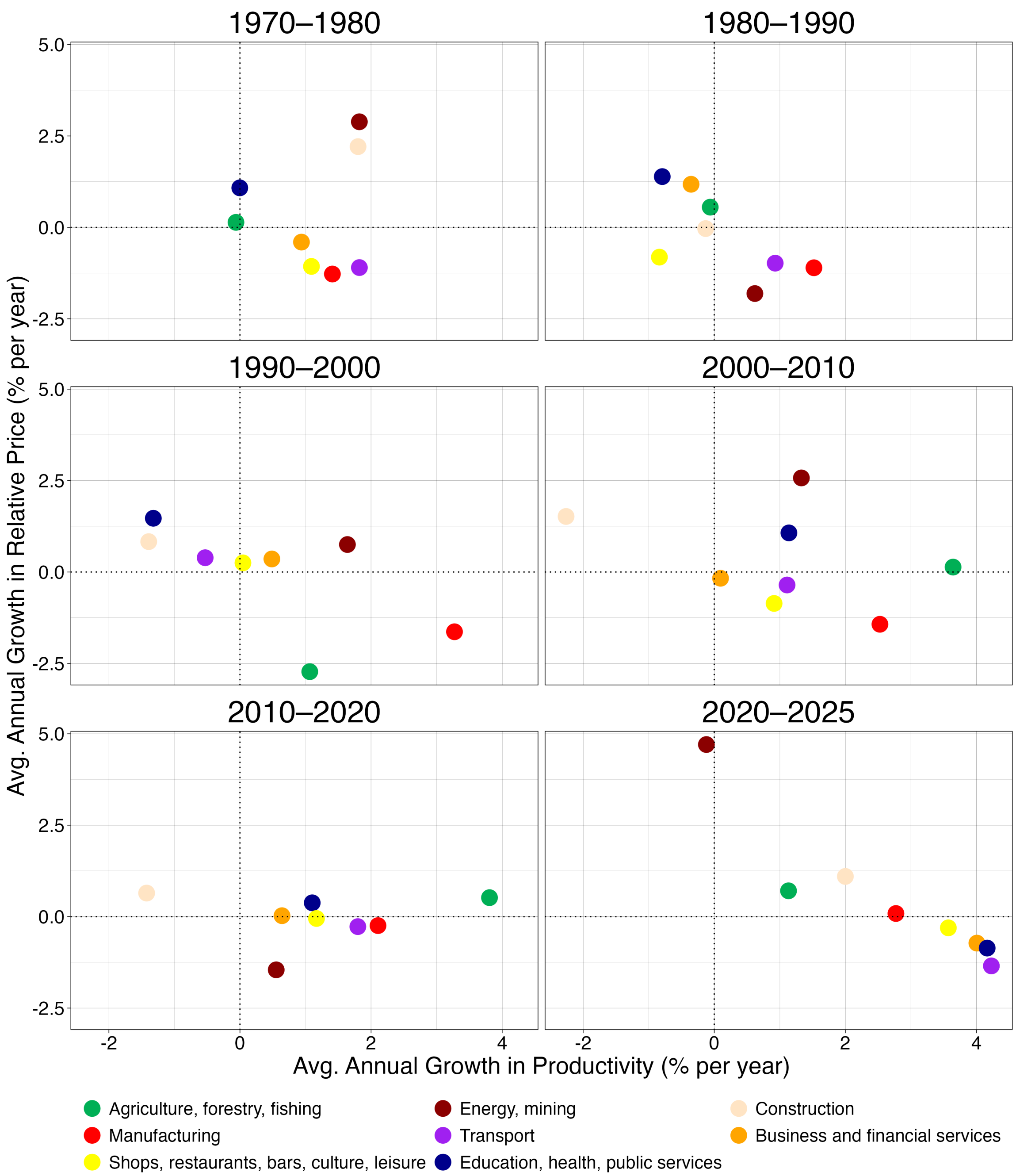


Figure 38. **Scatterplot of Global Annual Productivity (x-axis) and Relative Price Change (y-axis) by Decade.** Both are relative, so a negative value does not mean falling productivity or price but only smaller growth than average. Baumol effects would predict an inverse relationship with manufacturing being further to the bottom left than the services, which can be seen in most regions.

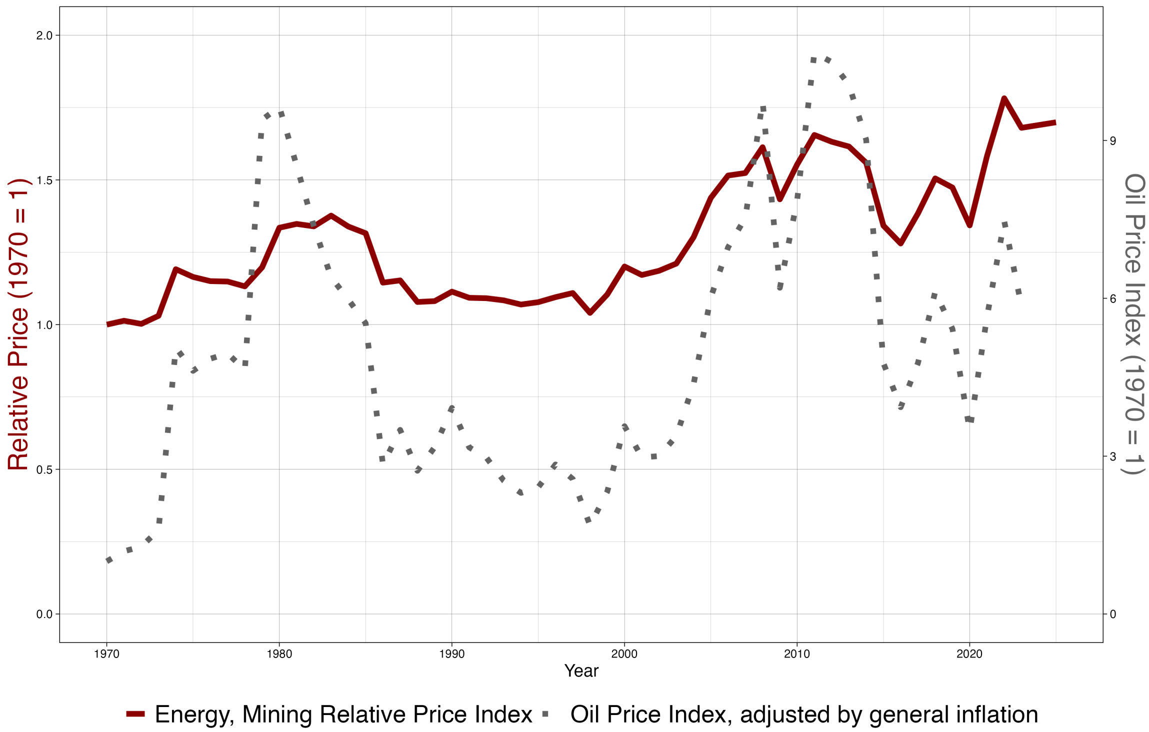


Figure 39. **Energy and Mining Deflator Plotted Over Global Oil Price (Indexed, 1970-2025).** Both series are indexed to 1 in 1970 but follow different y-axis. Price increase in oil was overall larger.

E.7 Engel

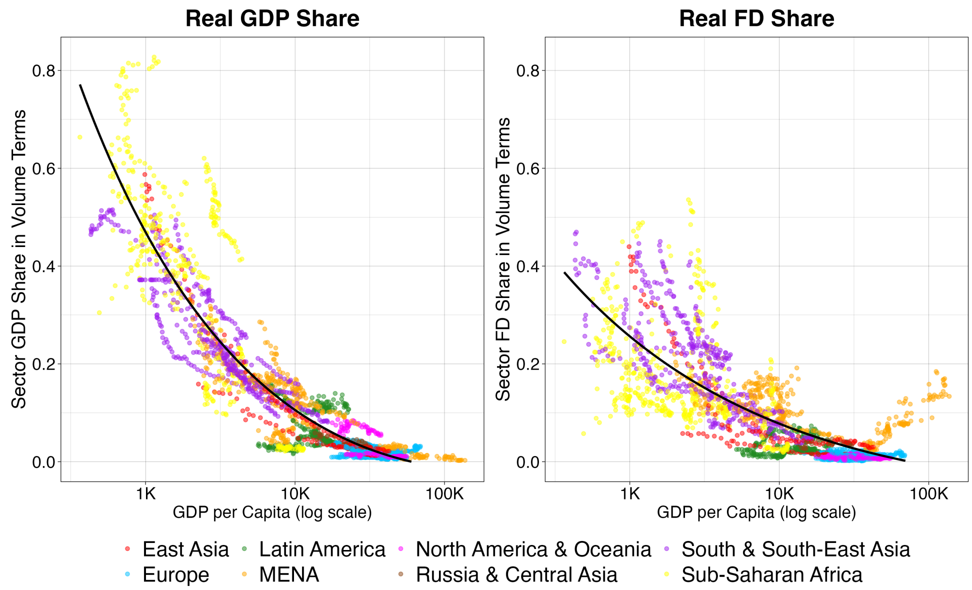


Figure 40. **Agriculture Sector Share in GDP and Final Demand across GDP per Capita (Log)**. The agricultural share falls within rising GDP per capita. The largest decline is at low per-capita GDP levels and then stabilizes of at low share.

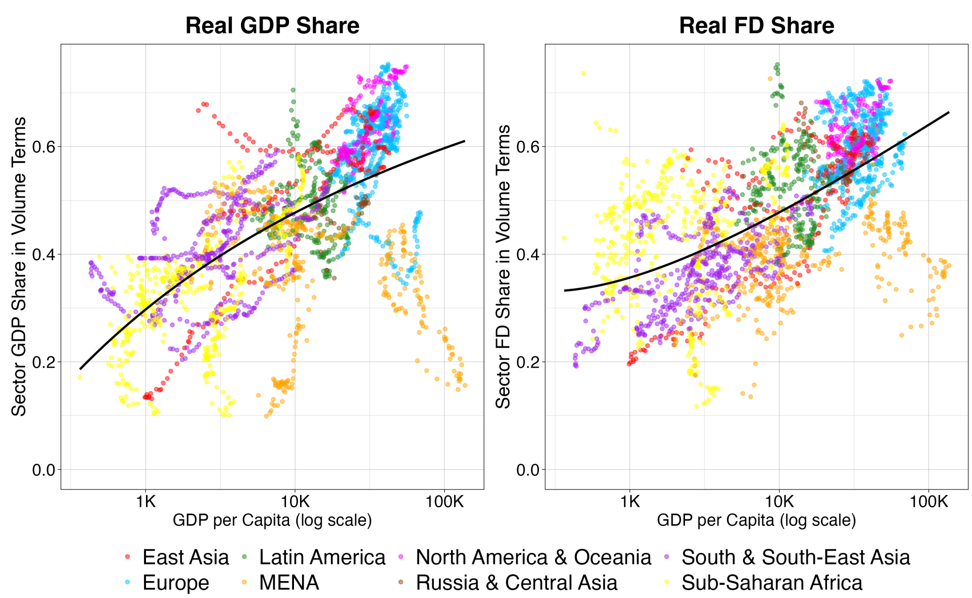


Figure 41. **Services Sector Share in GDP and Final Demand across GDP per Capita (Log)**. The service share rises continuously with GDP per capita, some oil-countries in MENA have especially small service shares.

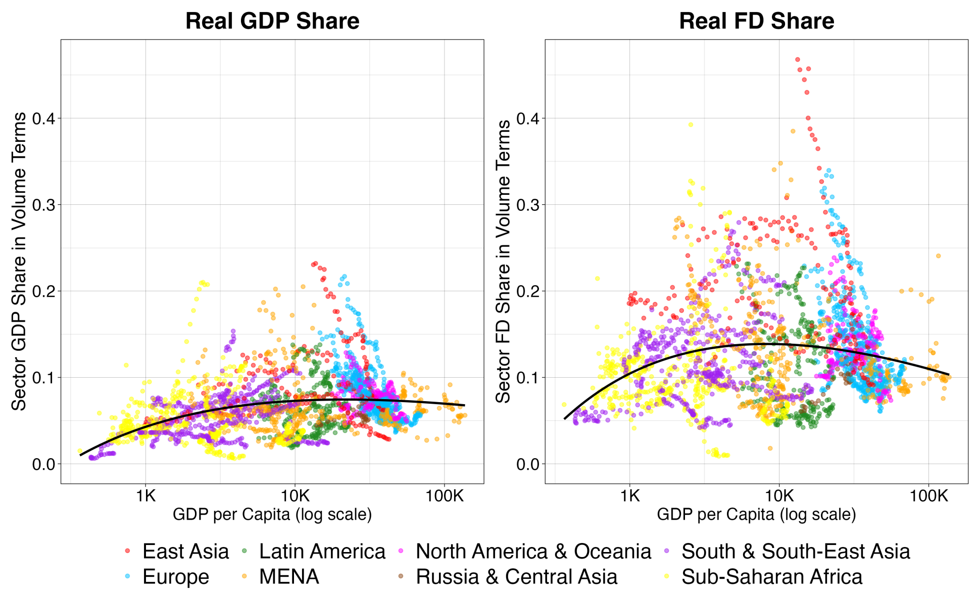


Figure 42. **Construction Sector Share in GDP and Final Demand across GDP per Capita (Log)**. Construction is one of the four industries in the industrial sectors.

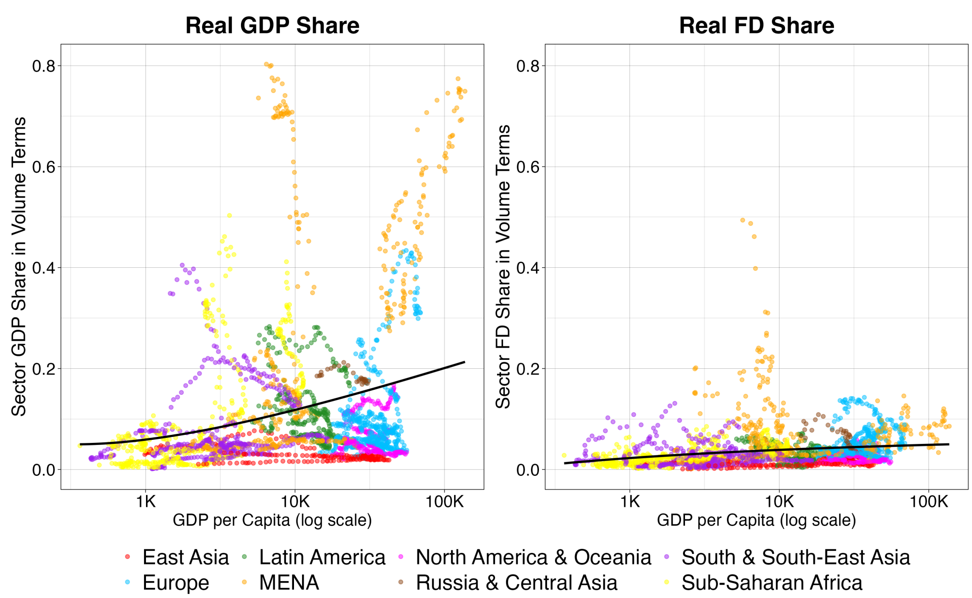


Figure 43. **Energy and Mining Sector Share in GDP and Final Demand across GDP per Capita (Log)**. Energy and Mining is one of the four industries in the industrial sectors. It is the only of the four industrial sectors not showing a reverse U-shape but a continuously rising share with GDP per capita.

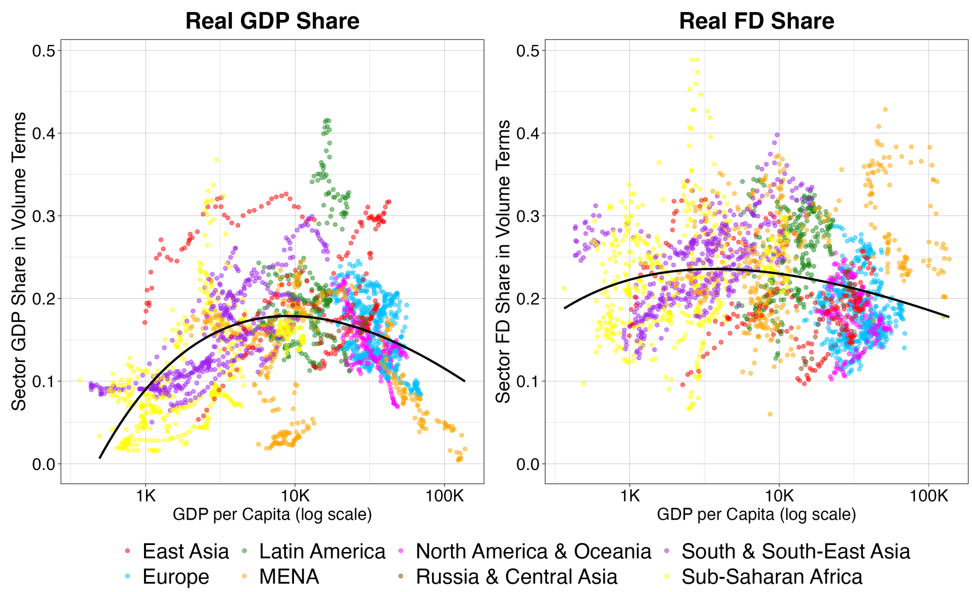


Figure 44. **Manufacturing Sector Share in GDP and Final Demand across GDP per Capita (Log)**. Manufacturing is one of the four industries in the industrial sectors.

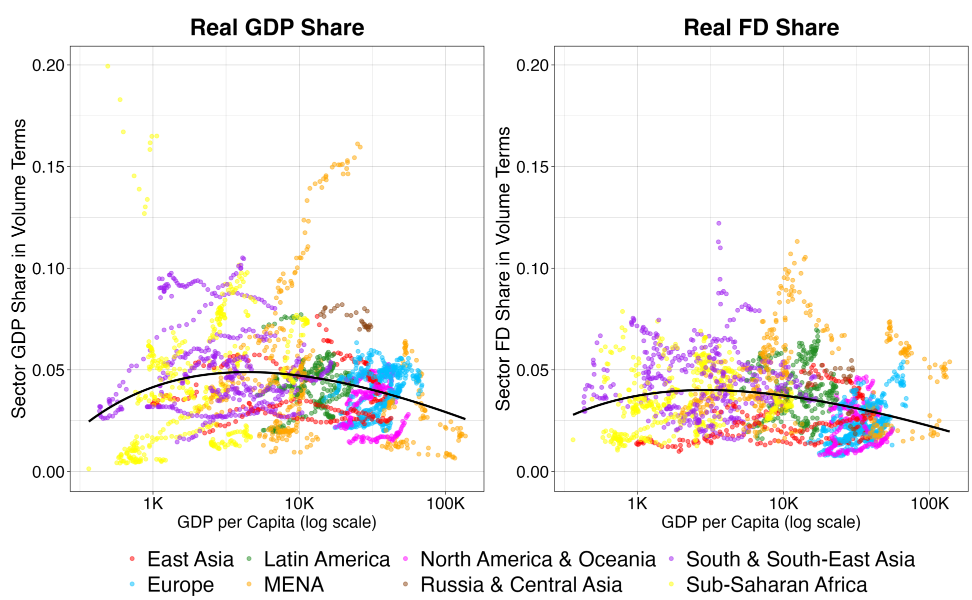


Figure 45. **Transport Sector Share in GDP and Final Demand across GDP per Capita (Log)**. Transport is one of the four industries in the industrial sectors.

E.8 Counterfactuals

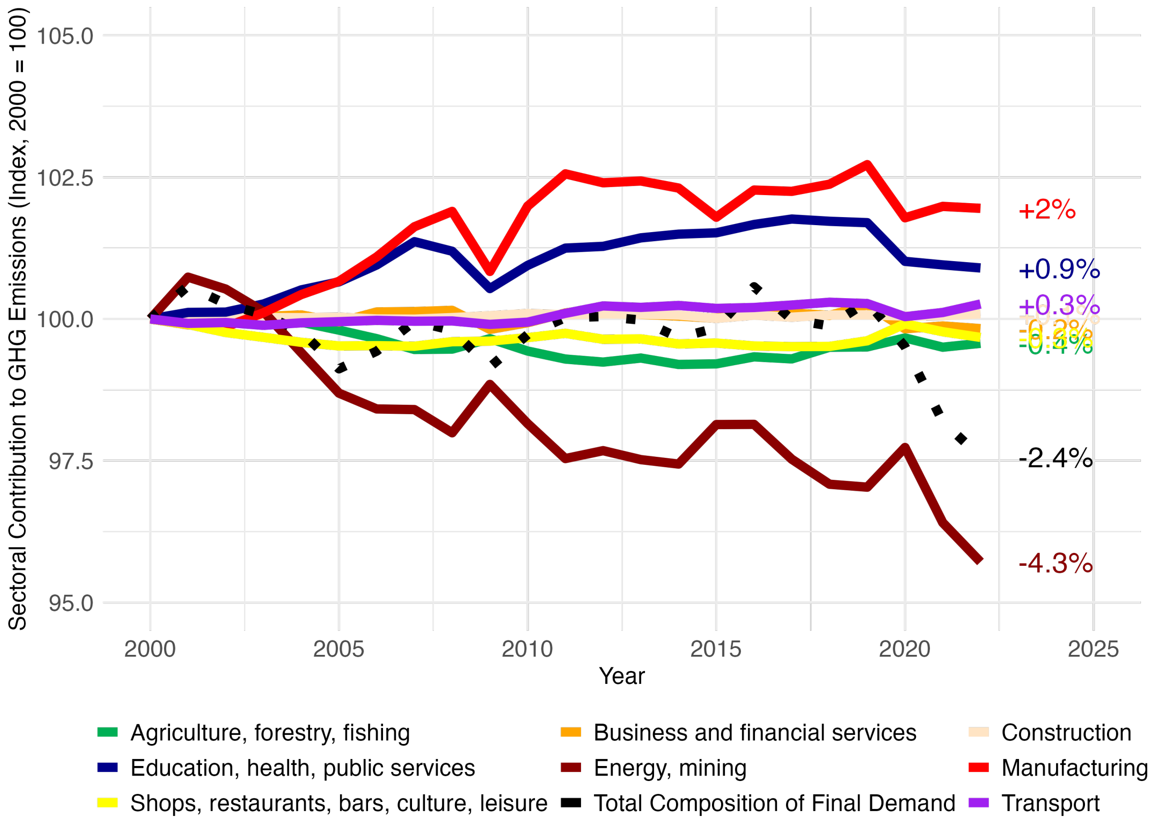


Figure 46. **Decomposition of FD Composition Impact on Emissions by Eight Sectors (2000-2022).** For each counterfactual final demand per capita, population, emission intensity, as well as the share of 7 out of eight sectors, is kept constant at the 2000 level. The share of the sector under study varies as observed in the data. The other seven sectors are adjusted in equal proportions, so that their shares add up to one each year.

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