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Per-capita income, consumption patterns and CO_2 emissions
Preliminary working paper

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Abstract

This paper investigates the importance of per-capita income and the sectoral composition of consumption as determinants for the level and evolution of carbon dioxide (CO_2) emissions across countries. It is based on the model and estimation strategy in Caron, Fally and Markusen (2012) which allows the identification of the income elasticity of consumption by controlling for cross-country price differences which are inferred from bilateral trade flows.

At the sector-level, we find a statistically significant negative correlation between income elasticity and the total CO_2 intensity of production. At the country-level, the data exhibits an inverted-U relationship between per-capita income and the average CO_2 content of both consumption and production. The relationship holds when evaluated using average production intensities and is thus partially generated by differences in consumption patterns. In turn, we find these differences to be explained by per-capita income levels. Importantly, the link is much weaker for the total CO_2 content of consumption than for the direct content, as total energy demand is more income-elastic than direct household consumption.

This finding implies a modest scope for per-capita income growth to reduce aggregate CO_2 emission intensity purely through its impact on consumption shares. We estimate the elasticity of the average total CO_2 content of worldwide consumption (which equals that of production) to per-capita income to be only -0.06, with, however, larger reductions in rich countries.

Keywords: CO_2 content of consumption, consumption patterns, Environmental Kuznets Curve, emissions predictions, per-capita income, Non-homothetic preferences, income-emissions-relationship, structural change

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1   Introduction

The emissions of green-house gases (of which carbon dioxide CO_2 is the most prevalent) is widely believed to be responsible for changes in the planet's climate. Although extremely uncertain, many studies find the expected costs of these changes to be high. There is therefore widespread interest in understanding the determinants behind emission levels. Worldwide CO_2 emissions are constantly growing, but the highest growth rates in the recent years are found in the developing world. Many industrialized countries are seeing declining levels of emissions, and most regions' emissions intensities (defined as emissions per dollar of output) have been declining for decades.

The literature has found evidence for an inverted-U relationship between levels of CO_2 per capita and per-capita income across countries. This relationship, which implies that countries become comparatively cleaner after reaching a certain level of development, is sometimes referred to as the carbon dioxide version of the environmental Kuznets curve (EKC). Amongst other explanations for this phenomenon is a shift of consumptions patterns towards less emissions-intensive goods, in particular the shift from emission-intensive industrial sectors to comparatively clean service sectors. Many studies have focused on the importance of shifting consumption patterns in determining emissions at the household level. To our knowledge, only a few studies have attempted to examine the determinants behind CO_2 intensity across a wide range of countries, and those have typically not focused on the importance of consumption patterns.

The objective first of this paper is thus to estimate the extent to which per-capita income influences average CO_2 intensities by systematically shifting consumption patterns. The second objective is to estimate whether and to what extent we can expect future growth in per-capita income levels to contribute to further declining CO_2 intensities.

To do this, we rely on a framework and estimation strategy introduced in Caron, Fally and Markusen (2012) (henceforth CFM) which allows the identification of income elasticities of household consumption whilst controlling for cross-country price differences. Reliable price data matched to production and trade data are hard to come by, and we estimate a proxy for cross-country prices differences in a gravity framework which identifies supply-side comparative advantages forces and trade costs. The framework includes a demand system with non-homothetic preferences (that is, allows per-capita income to determine consumption patterns). The analysis relies primarily on the Global Trade Analysis Project (GTAP8) dataset, a large dataset covering consumption, input-output, production and trade data for a wide range of countries and sectors. This dataset allows us to compute the total CO_2 content of consumption by keeping track of both domestic and imported intermediate demand using multi-regional

input-output (MRIO) analysis.

Correlating total CO_2 emission requirements with income elasticity estimates across sectors gives us preliminary evidence for a demand-side explanation of the income-emissions link. We find that most CO_2 emitting energy goods have low income elasticities of final consumption (below unity). Also, there is evidence for a negative correlation between income elasticity and CO_2 requirements within non-energy goods.

However, a large share of CO_2 emissions occur in the intermediate use of energy. To capture this, we compute a measure of "total income elasticity" which keeps track of the all end use for each sector. We find that the total income elasticity of energy goods is considerably larger than their direct income elasticity. Across all sectors, there is less variability in these estimates which implies that changes in per-capita income will affect total demand (absorption) patterns less than final consumption patterns. Total income elasticity estimates are also more weakly correlated with total CO_2 intensity coefficients, and we can expect a smaller scope for changes in the composition of consumption to reduce total emissions.

We then compute the direct and the total average CO_2 content (or CO_2 intensity) of consumption, imports, and production across countries. The data to exhibit considerable cross-country variation and a distinct inverted-U relationship with per-capita income for the direct and total average CO_2 contents of consumption and production. Of course, this variability can stem not only from differences in consumption patterns, but from differences in the emissions intensity in production and differences in trade patterns as well. We thus decompose this variability by using average production CO_2 intensities and find consumption patterns alone to generate this relationship.

In a second step, we find changes in consumption patterns predicted under the assumption of identical but non-homothetic preferences to also contribute to generating an inverted-U pattern. This suggests that per-capita income, through its influence on consumption patterns, has the potential to explain a substantial part of the variability in the average CO_2 content of consumption across countries, although the slope of the effect is much flatter for total consumption than for direct consumption.

Finally, we investigate the potential for increasing levels of per-capita income to shift consumption patterns in a way which affects aggregate energy use and CO_2 emissions, absent any technical change. We find a strong impact of income growth on the average direct content of consumption. It does not, however, translate to large impacts on total demand for energy, and the estimated world elasticity of the total CO_2 content of consumption (which equals that of production) to per-capita income is only -0.06. This indicates little scope for shifts in consumption patterns to significantly reduce the CO_2 intensity of absorption and production on their own.

Literature - INCOMPLETE

A large number of papers investigate the relationship between expenditure patterns and CO_2 emissions at the household level in single-country studies (see Wier et al. (2001), Munksgaard et al. (2001) and others). They generally find differences in income levels to significantly affect household consumption patterns, and tend to find direct energy consumption to be a necessity good (have low income elasticity of consumption) - at least in the industrialized countries in which these studies are conducted.

Wolfram et al. (2012) review the implications of growing demand for energy-intensive appliances in the developing world. They rely on survey data describing household appliance and vehicle purchases which they have collected in several large developing countries. They repeatedly find an S-Shaped relationship between expenditure levels and ownership of energy-intensive appliances such as refrigerators. They predict large coming increases in energy demand as a large population is just at the beginning of this process.

The present study differs from the above in that, despite relying on less detailed (more aggregated) consumption data, it covers a wide range of countries across the whole per-capita income spectrum.

Another large strand of the literature documents the relationship between per-capita income and environmental quality across countries. Among these, a number focus on the identification of an Environmental Kuznets Curve for CO_2 emissions (see Schmalensee et al. (1998) for a cross-country study, or Aldy (2005) for a comparison across US states). These studies find significant evidence for an inverted-U relationship. However, they use aggregate data, and hence cannot estimate differences in income elasticities across sectors and cannot account for the role of shifting consumption patterns. Moreover, none of the surveyed studies account for differences in energy prices. Also, most focus on per-capita emissions, not emissions per dollar (intensity). The input-output literature, while trying to estimate the differences between emissions embodied in consumption from production based emissions, has also identified evidence for both a consumption and a production based Environmental Kuznets curve (see Peters (2008)).

Only a limited number of studies have focused on the role of consumption patterns. Of these, Medlock III and Soligo (2001), relies on panel data and identifies an asymmetric inverted-U EKC for energy intensity. They estimate income elasticities, but rely on a very crude sectoral decomposition. The study has poor matching with the supply side and does not track total energy requirements. Their results show that households will become saturated with energy intensive durables, and that the transport sector will eventually account for the majority of energy use. This is not totally consistent with our findings.

Finally, of the reviewed literature, the most similar in spirit to the present paper is un-

published work from De Nooij et al. (2003), which develops a general equilibrium model to analyze the role of sectoral composition by allowing income elasticities to differ between goods. It identifies the assumptions under which an inverted-U relationship can be derived. In a crude calibration attempt, it uses structural decomposition analysis to come to the conclusion that changes in the sectoral composition of the economy will not be sufficient to persistently delink income and emissions.

Most of the computable general equilibrium literature relies on simple homothetic demand systems and ignore income elasticity. An interesting exception is Dai et al. (2012). In attempting to improve the forecasts of emissions growth in China, they provide non-parametric income elasticity estimates. However, their final analysis does not include these estimates within the model and instead use arbitrary scenarios describing the growth paths of future expenditure shares.

Thus, to our knowledge at this point, this is the first study which uses consistently estimated income elasticities across a wide range of sectors in a list of countries which covers most of the world economy. It is thus unique in providing estimates of the importance per-capita income growth, through consumption patterns, in determining future worldwide emissions levels.

2 Data

As in Caron, Fally and Markusen (2012) (CFM), the empirical analysis is based on the Global Trade Analysis Project (GTAP) version 8 dataset (Aguiar et al., 2012). The dataset is well suited to this purpose as it contains consistent and reconciled production, input-output, consumption and trade data. It covers 57 sectors of the economy, providing considerable heterogeneity in energy and CO_2 intensities as well as income elasticity across sectors which cover manufacturing, agriculture, transport and services. The 109 countries in the dataset (the composite regions are dropped) cover a wide range of per-capita income levels at all stages of economic development. The full list of countries in the dataset can be found in the appendix.

The dataset includes energy use and CO_2 emissions data, by fossil fuel, for both intermediate demand and final consumption, and makes it straightforward to compute CO_2 intensity coefficients by sector. The full description of bilateral trade and input-output tables for all countries allows for the computation of total (direct and indirect) multi-regional intensity coefficients.

Despite the clear advantage of supplying harmonized consumption, production and trade data for a wide range of countries, two weaknesses of the GTAP data should be discussed. First, not all values in the dataset are directly observed in all countries for the same year. Some values are extrapolated from previous years and some missing sectors are shared out proportionally to world averages or to similar countries. Second, the data has been adjusted in order to provide

a balanced micro-consistent dataset which can be used for (computable) general equilibrium analysis. This procedure modifies the raw data by an undocumented amount.

Throughout the analysis, final consumption is defined as the sum of household and government consumption as defined in GTAP.

The gravity estimations rely on bilateral variables describing physical distance, common language, colonial link and contiguity which are obtained from CEPII (www.cepii.fr).

3 Per-capita income, consumption patterns and CO_2 emissions

The objective of this section is first to understand the role that consumption patterns play in determining CO_2 emissions levels, and then to investigate the role of per-capita income in determining these patterns. The following section uses the same framework to estimate the extent to which per-capita income growth affects CO_2 emissions.

3.1 Estimating income elasticities

Analyzing the relationship between per-capita and consumption patterns can and will be done in a purely descriptive way, using observed consumption shares. Understanding the shape of the relationship can also be estimated as a non-parametric relationship between income and consumption shares, as has been done in several papers in the literature (see Schmalensee et al. (1998)). In order to be able to predict changes in consumption shares due to counterfactual changes in income, however, it is necessary to make assumptions about the functional form of their relationship. Many demand systems have been used in the literature[1] to estimate the parameters driving income elasticity .

This paper relies on the general equilibrium setting, demand system and estimation strategy presented in CFM. This framework allows the estimation of income elasticity parameters whilst controlling for cross-country price differences. Controlling for prices is important in order to identify the true effect of income on consumption patterns. However, reliable price data matched to production and consumption data in a large number of countries are hard to obtain. Therefore, CFM propose a two-step estimation strategy which exploits bilateral trade data to estimate cross-country price differences. First, gravity equations in each industry are used to estimate how trade costs will impact prices differences due to cross-country differences in patterns of comparative advantages. In the second step, the estimated parameters are then

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[1]LES, AIDADS, and AIDS are commonly used demand systems.

used to structurally control for supply-side effects in the estimation of demand parameters. The procedure is summarized here but the interested reader should turn to CFM for a more detailed exposition.

Estimating price differences In each industry, bilateral trade flows follow an Eaton and Kortum (2002) specification in which x_{nik}, the value of bilateral trade from country i to country n in sector k, is given by:

$$x_{nik} = \frac{S_{ik}(t_{nik})^{-\theta_k}}{\Phi_{nk}} x_{nk} \tag{1}$$

Where x_{nk} is total absorption in country n and t_{nik} represents a vector of bilateral trade costs. S_{ik} is an "exporter fixed effect" capturing comparative advantage forces and is inversely related to the cost of production in country i and industry k. θ_k is inversely related to the dispersion of productivity within sectors and represents the elasticity of trade to trade costs. Finally Φ_{nk}, the value we are ultimately interested in, is the sum of exporter fixed effects deflated by trade costs, and serves as a proxy for a cross-country price index.

By transforming equation 1 in logs and allowing trade costs t_{nik} to depend on a number of factors such as distance and contiguity, we obtain a set of gravity equations in which S_{ik}, Φ_{nk} and x_{nk} are captured using exporter (FX_{ik}) and importer (FM_{nk}) fixed effects. This gravity equation is estimated separately for each sector using Poisson regressions:

$$
\begin{aligned}
\log x_{nik} \quad = \quad & FX_{ik} + FM_{nk} - \beta_{Dist,k} \log Dist_{ni} \; + \; \beta_{Contig,k}.Contiguity_{ni} \\
& + \; \beta_{Lang,k}.CommonLang_{ni} \; + \; \beta_{Colony,k}.ColonialLink_{ni} \; + \; \beta_{HomeBias,k}.I_{n=i} + \varepsilon_{nik}
\end{aligned}
$$

Following the strategy developed by Redding and Venables (2004), we then use the estimates of S_{ik} ($\widehat{FX}_{ik}$), θ_k and $\log t_{nik}$ (using all transport cost proxies and their coefficients) to construct an estimate of Φ_{nk}, our price index proxy, such that:

$$
\begin{aligned}
\widehat{\Phi}_{nk} \quad = \quad & \sum_i \exp \left(\widehat{FX}_{ik} - \widehat{\beta}_{Dist,k} \log Dist_{ni} \; + \; \widehat{\beta}_{Contig,k}.Contiguity_{ni} \right. \\
& \left. + \; \widehat{\beta}_{Lang,k}.CommonLang_{ni} \; + \; \widehat{\beta}_{Colony,k}.ColonialLink_{ni} \; + \; \widehat{\beta}_{HomeBias,k}.I_{n=i} \right)
\end{aligned}
$$

Estimating income elasticity parameters The second step consists in the estimation of the demand parameters. For this, we use a demand system which results from "constant relative income elasticity" (CRIE) non-homothetic preferences. These preferences have been used in Fieler (2011) and generate the following equation for final consumption d_{nk}:

$$d_{nk} = \alpha_k \lambda_n^{-\sigma_k} \widehat{\Phi}_{nk}^{\frac{(\sigma_k-1)}{\theta}} \tag{2}$$

In which α_k is an sector fixed effect, λ_n is the shadow value of the budget constraint, and σ_k, our main parameter of interest drives both income and price elasticity. θ_k, which is not directly estimated and is calibrated to estimates from the literature and is assumed to be equals to 4. The stochastic version of equation 2 is then estimated in logs as:

$$\log d_{nk} = \log \alpha_k + -\sigma_k.\log \lambda_n + (\sigma_k - 1).\frac{\log \widehat{\Phi}_{nk}}{\hat{\theta}} + \varepsilon_{nk}$$

This demand systems is estimated in a constrained non-linear least squares regression, in which λ_n is identified as the shadow value of the budget constraint. Finally, using the estimates of σ_k, we can compute the income elasticity of consumption for sector k in country n as:

$$\varepsilon_{nk} = \hat{\sigma}_k \cdot \frac{\sum_{k'} d_{nk'}}{\sum_{k'} \hat{\sigma}_{k'} d_{nk'}} \tag{3}$$

These elasticities vary across countries according to initial consumption shares. The interested reader can jump to Figure 2 in section 3.3 to find the distribution of these estimated elasticities. These exhibit considerable variability across sectors, a variability similar to what would be obtained with competing demand systems such as AIDS. Although some demand systems (such as AIDADS) are more flexible, we believe this demand system to be sufficiently non-restrictive given the small number of parameters to be estimated.

3.2 Multi-regional input-output framework

This section describes the computation of the total CO_2 embodied in final consumption, production and trade. Doing so requires a framework which tracks CO_2 emissions across the multi-regional supply chain, as the total impact of consumption patterns on CO_2 emissions cannot be captured by simply accounting for the emissions incurred by the direct consumption of fossil fuels by households. Indeed, as the literature documents, a large part of the emissions attributable to consumption are through embodied in the intermediates required in the production of consumption goods. Moreover, some of these emissions may have occurred in other countries from which final goods or intermediates are imported. Thus, computing the exact CO_2 content of consumption requires keeping track of both domestic and imported intermediate demand in what is called Multi-regional Input-Output (MRIO) analysis. The GTAP dataset lends itself well to such analysis (see Peters et al. (2011)). The notation used here follows the input-output literature (see, for example, Peters (2008)) when possible.

Full MRIO analysis requires information about the multi-regional input-output (n^2 x k^2) block-matrix A, in which each sub-matrix A_{in} represents the intermediate input requirement

coefficients in n for country i's goods, with elements $a_{nkk'}$.

$$A = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{i1} & A_{i2} & \cdots & A_{in} \end{bmatrix}$$

We also require knowledge about the source and composition of final consumption in the $(n \times k)$ multi-regional final demand vector D_n in which each element represents the imported consumption goods from country i to country n.

$$D_n = \begin{bmatrix} d_{1n} \\ d_{2n} \\ \vdots \\ d_{in} \end{bmatrix}$$

In GTAP (nor in most datasets), neither the A_{in} nor the d_{in} parameters are directly observed, as bilateral trade flows typically do not distinguish between final and intermediate use. Thus, and as in most of the literature, we compute these parameters using a "proportionality assumption" according to which the bilateral import shares of final consumption and intermediate demand are proportional to the bilateral shares given by total trade flows.

Different types of CO_2 emissions coefficients are defined. First, the $(n \times k)$ row vector B^{dir} has elements β_{nf}^{dir} which represent the amount of CO_2 emitted when fossil fuel f is used (either as an intermediate or in final consumption). Then, we define the $(n \times k)$ vector of output intensity of CO_2 B^{output} whose elements correspond to $\beta_{nk}^{output} = \sum_f \beta_{n,ff}^{dir} A_{n,ff,k}$.

In the literature, the definition of direct consumption of CO_2 sometimes includes the CO_2 embodied in electricity consumption. This is also done here by adding the country-specific CO_2 intensity of electricity output. We thus define a vector of direct emissions which includes electricity, $B^{dir-ele}$ whose elements are $\beta_{nf}^{dir} + \beta_{n,ele}^{output}$

It is widely recognized that a large part of the CO_2 which is attributable to consumption is embodied. Computing the exact CO_2 intensity of each good thus requires knowledge about the input-output structure of both the local economy as well as that from all countries from which goods (as final goods or intermediates) are imported.

Being ultimately interested in the total impact of consumption patterns on CO_2 emissions, we then use A and D_n in a multi-regional extension of the Leontief inversion technique to compute the MRIO estimate of the total CO_2 emissions attributable to country n's consumption as a function of its consumption vector. Then, we use the MRIO Leontief inverse method to

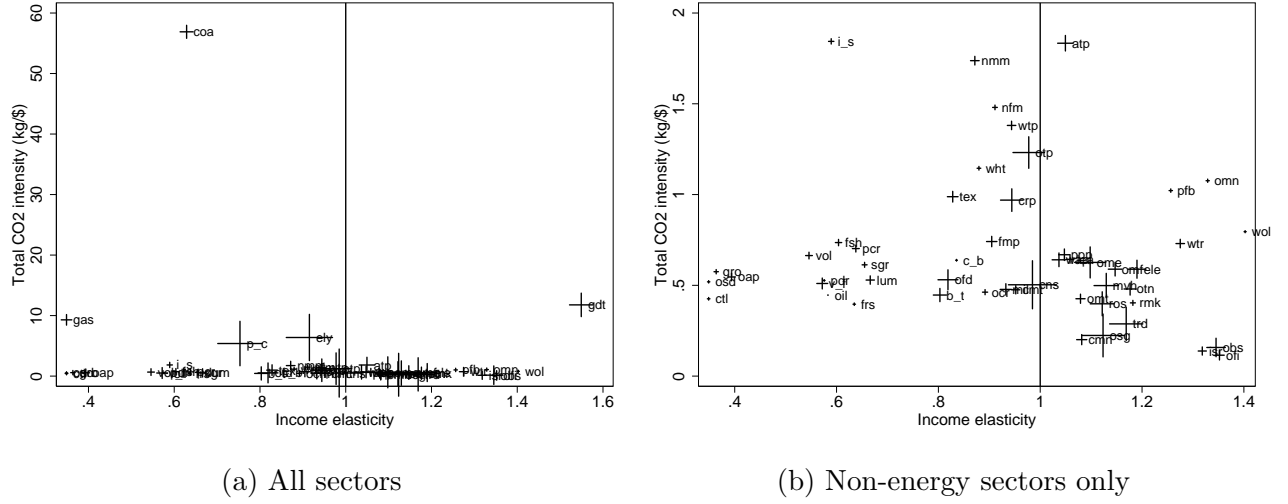|	
(a) All sectors	(b) Non-energy sectors only

Figure 1: The correlation of income elasticities and CO_2 intensities at the sector-level (marker size: total emissions associated to sector's consumption as share of total emissions)

define a vector of the intensity in total (direct and indirect) emissions embodied in the final consumption: $B_{nk}^{total} = B^{output}(I - A)^{-1} + B^{dir}$.

3.3 Sector-level correlation of income elasticities and CO_2 intensities

Before turning to the link between consumption patterns and emissions at the country-level, it is interesting to look at the sector-level relationship between the income elasticities estimated in section 3.1 and the CO_2 intensity coefficients computed in section 3.2. A sector-level correlation between these parameters can provide preliminary evidence for the possibility of a demand-side link between the evolution of CO_2 emissions and income levels.

Both CO_2 intensity coefficients and income elasticity parameters vary across countries, and so will their correlation. For exposition purposes, we display this relationship using (weighted) average values. While interesting, we will see later that these average values hide significant cross-country variability.

Figure 1 displays the relationship between income elasticity evaluated using mean consumption shares, $\bar{\varepsilon}_k$, and average total CO_2 intensity coefficients $\bar{\beta}_k^{total}$. The size of the markers represents total emissions associated to each sector's consumption as share of total emissions. The left side of the Figure displays all sectors, including the energy sectors which clearly dominate in terms of CO_2 intensity. The right side displays only non-energy goods. The scatter-plot reveals the CO_2 intensity of goods whose consumption shares will most increase with per-capita income.

First, Figure 1 reveals that energy goods (coal, gas, refined oil P_C and electricity ELY),

except for gas distribution (the next version of paper will have gas and gdt aggregated) all have mean income elasticities below unity. Household consumption of energy goods thus corresponds to larger shares of household expenditures in lower income countries. This is particularly true for coal, but also for refined oil (primarily used for private transportation. It is also true, in this dataset, for household electricity consumption.

Second, there seems to be somewhat of a negative correlation between income elasticity and CO_2 intensity within the set of energy goods, with consumers switching from coal and gas to refined oil and electricity as per-capita income rises.

Table 1: Correlation of income elasticity estimates and total CO_2 intensity coefficients (p-values in parenthesis)

income elasticity	direct		total	
weighted	no	yes	no	yes
non-energy sectors	-0.09	-0.37	0.02	-0.24
	(0.484)	(0.01)	(0.834)	(0.07)
manufacturing only	-0.63	-0.55	-0.56	-0.43
	(0)	(0.05)	(0.04)	(0.16)
all sectors	-0.12	-0.32	0.05	-0.15
	(0.41)	(0.1)	(0.27)	(0.24)

Then, Figure 1b displays the link between income elasticity and CO_2 intensity for non-energy goods. Clearly, the relationship is noisy. However, when weighting sectors according to the relevant weights, the sector share of consumption CO_2 in total CO_2, a negative relationship emerges. Table 1 summarizes correlation coefficients with and without weighting, and shows that, for non-energy goods, the weighted coefficient is -0.37 and significant at the 1 % level.

Despite this, there is evidence for a non-linear inverted-U pattern: allowing for a quadratic term in a regression of CO_2 intensity on income elasticity increases the R squared from 0.14 to 0.23. In broad terms, this reflects a transition from low-income elasticity, low-CO_2 intensity agricultural sectors (GRO, OAP) to medium-income elasticity, high-CO_2 intensity industrial goods such metals and fossil fuels (NMM, NFM), to high-income elasticity, low-CO_2 intensity service sectors such business services and financials (OBS, OFI). However, there is also a switch to cleaner sectors within manufacturing, as the correlation coefficient is -0.55. Then, some sectors, in particular air transport (ATP) stand out as being both income-elastic and highly CO_2 intensive.

Total income elasticity   Many of the sectors displayed in Figure 1 have a very low household consumption share and are used primarily as intermediates. An alternative way of thinking

of the problem is to look not only at each sector's income elasticity of direct consumption, but defining a measure of each sector's income elasticity of total demand (or absorption), including intermediate use. As in CFM, we compute a total income elasticity parameter ϵ_k^{TOT} which corresponds to the weighted sum of income elasticities of all goods in which sector k is demanded:

$$\epsilon_k^{TOT} = \frac{\sum_{k'} \gamma_{kk'} d_{k'}(\epsilon_{k'})}{\sum_{k'} \gamma_{kk'} d_{k'}} \tag{4}$$
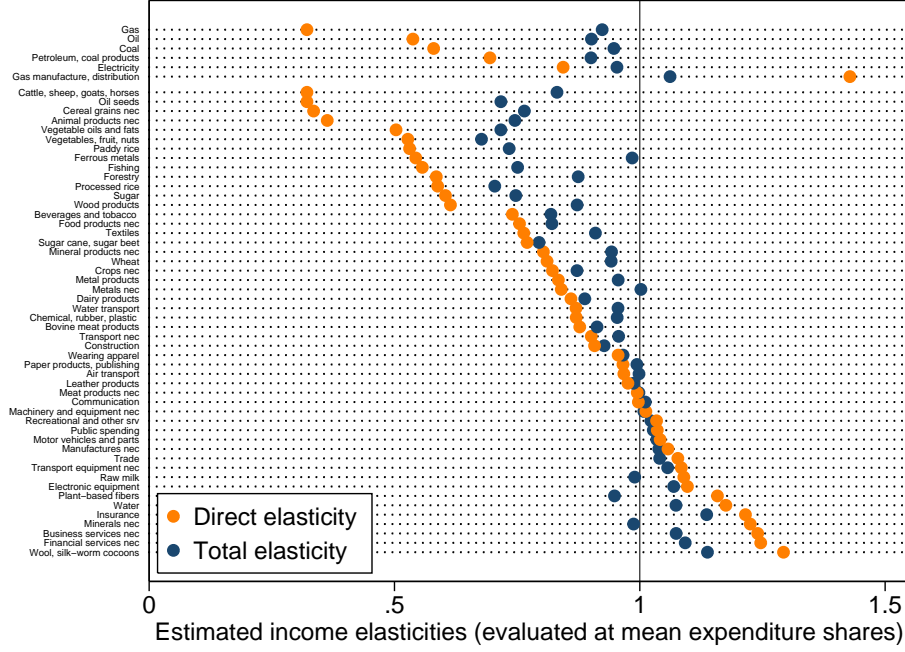

Figure 2: Direct versus total income elasticities

Figure 2 compares these total income elasticity estimates to their direct counterparts and reveals several interesting facts.

First, the variance in these elasticities is smaller and the estimates exhibit smaller deviations from unity. While the range of estimates can only be equal or smaller to that of direct estimates, the possibility that the variance would have been bigger is mathematically possible. It is thus an empirical fact that low (high) income elasticity goods are required as intermediate inputs to sectors with higher (lower) income elasticity then theirs. As discussed in CFM, this implies that changes in per-capita income will affect absorption (total demand) patterns less than final consumption patterns.

In particular, Figure 2 shows that the total income elasticity of energy goods is considerably larger than their direct income elasticity. Thus, energy goods are used as intermediates to disproportionally high-income elasticity goods. The total demand for energy goods (absorption)

is likely to be quite differently affected by per-capita income than their direct demand.

Second, not only is the variance of total income elasticity estimates lower, they are also more weakly correlated with total CO_2 intensity coefficients, as shown in Table 1. We can thus expect total emissions embodied in consumption to be less affected by changes in per-capita income than direct emissions.

3.4 The average CO_2 content of consumption, imports and production across countries

This section investigates the extent to which the above sector-level correlation translates to a country-level correlation between per-capita income and the average CO_2 content of consumption, imports, and ultimately production. If preferences are non-homothetic, income levels may affect consumption patterns in a way which systematically affects the overall energy and CO_2 content of a country's final consumption.

In the literature, the definition of direct consumption of energy typically includes direct electricity consumption. We abide to this definition and define CDd_n, the direct CO_2 content of consumption, to include the CO_2 emitted in the direct burning of fossil fuels (oil, gas, and in some regions coal) by households as well as that embodied in electricity consumption in region n:

$$CDd_n = B^{dir-ele}D_{nk} = B^{dir}D_{nk} + \beta^{output}_{n,ele}d_{n,ele}$$

Being ultimately interested in the total impact of consumption patterns on CO_2 emissions, we then use A and D_n in a multi-regional extension of the Leontief inversion technique to compute the MRIO estimate of the total CO_2 emissions attributable to country n's consumption as a function of it consumption vector. CDt_n denotes the total MRIO CO_2 content of final consumption:

$$CDt_n = B^{total}D_n = B^{output}(I-A)^{-1}D_n + B^{dir}D_n$$

Defining M_n as the vector of imported final demand (equals to D_n with elements $d_{nn} = 0$), we also compute the total CO_2 content of imported final demand:

$$CMt_n = B^{total}M_n$$

Finally, it is interesting to investigate the extent to which differences in consumption patterns filter to differences in the CO_2 intensity of production. For that we define the "final

production" vector Y_n as:

$$Y_n = \begin{bmatrix} 0 \\ \vdots \\ \sum_i d_{ni} \\ \vdots \\ 0 \end{bmatrix}$$

In which $\sum_i d_{ni}$ corresponds to all final demand for n's goods in all countries. The CO_2 content of production can thus be computed as a function of final consumption patterns:

$$CY_n = B^{output}(I - A)^{-1}Y_n$$

As trade creates a wedge between consumption and production, this value can differ substantially from the CO_2 attributable to consumption in some countries.
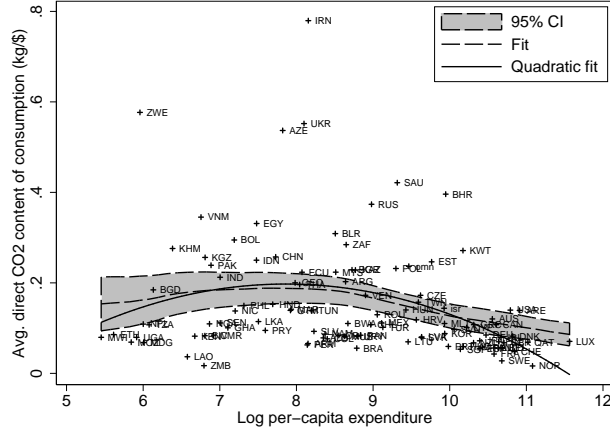
3.5   In the data

The CO_2 content parameters CDd_n, CDt_n, CM_n and CY_n are computed as averages (that is divided by the consumption, imported consumption and production totals, respectively) and are displayed in Figure 3 as a function of logged per-capita expenditure (which in most regions is close to per-capita income). In each subfigure, the dashed lined represents a kernel-weighted local-mean smoothing regression of the average content on log per-capita expenditure (the shaded area representing the 95 % confidence interval). The solid line represents the fitted prediction from a quadratic least-square regression (several papers in the literature assumes a quadratic functional form for this relationship).

Figures 3a and 3c show that both the direct and the total CO_2 contents of consumption follow a distinct inverted-U pattern. Indeed, the quadratic fit resembles the non-parametric fit quite closely. In all cases, the coefficients of the quadratic regressions have a p-value < 0.01. There is, however, a lot of variability around that pattern that is not explained by per-capita income levels and R-squared values are fairly low: 0.11 for direct consumption and 0.19 for total consumption. Thus, although average CO_2 content does seem to co-vary significantly with per-capita income levels, most of the variability is due to unobserved idiosyncrasies across countries. The average values for total consumption are around three times as large as those of direct consumption, consistent with the fact that a large part of the CO_2 content of consumption is indirect. In order to better compare the contribution of each value to total CO_2 emissions, all CO_2 content variables are plotted using total GDP as a denominator in Figure 4

The fitted values from the non-parametric local mean smoothing regressions give arbitrary
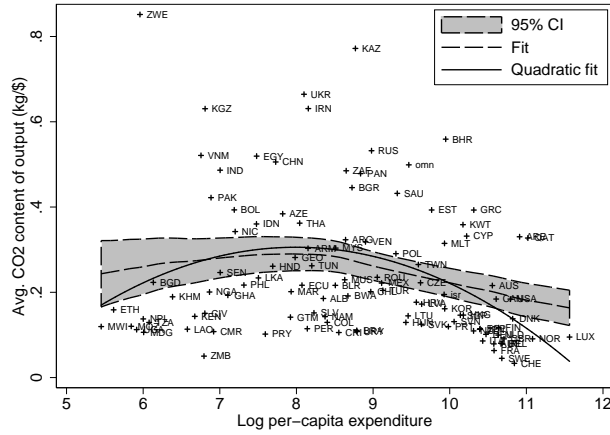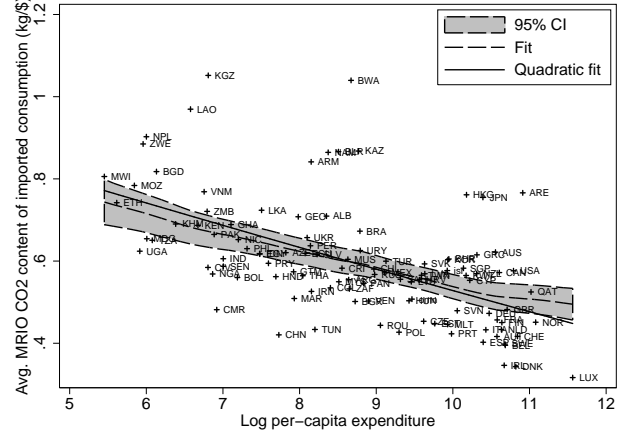
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(a) Direct CO$_2$ content of consumption

(b) Total CO$_2$ content of production
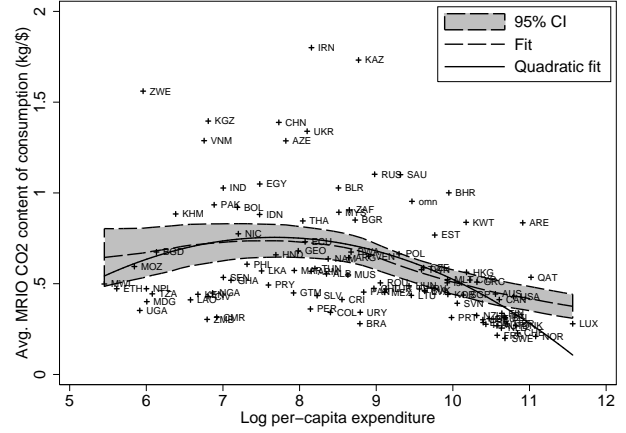
(c) Total CO$_2$ content of consumption

(d) Total CO$_2$ content of imports

Figure 3: Average CO_2 content in the data

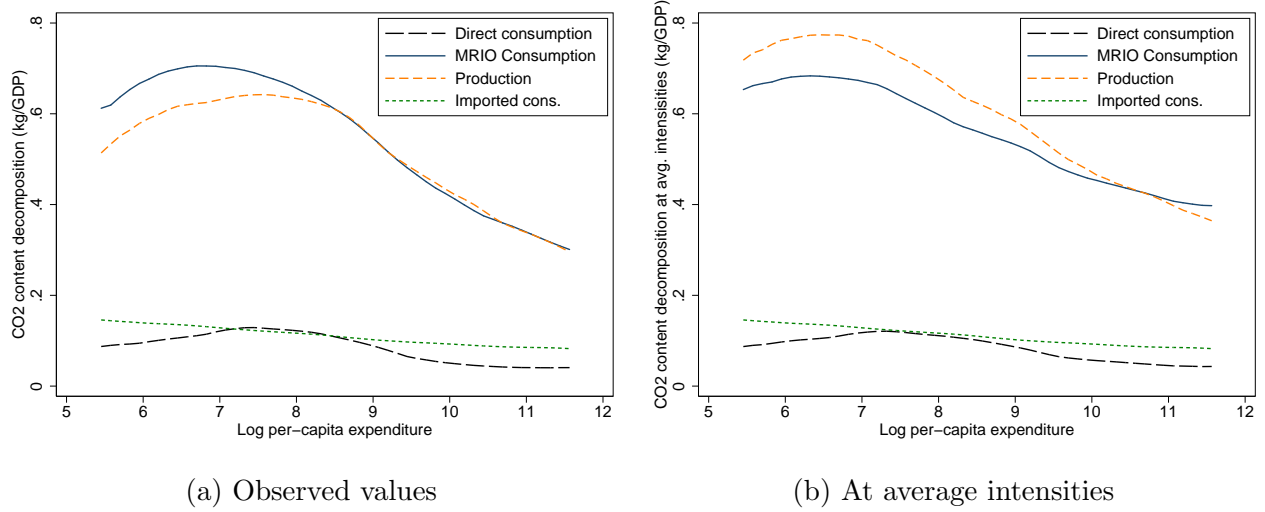(a) Observed values   (b) At average intensities

Figure 4: CO2 content as function of GDP

(they depend on the bandwidth size used) but interesting insights about the shape of the inverted-U relationship. For direct consumption, the curve starts at a value of 0.15 for the poorest country in the sample (Malawi), reaches a maximum of 0.19 at a per-capita income level of 3434\$ (Peru) and reaches a minimum of 0.09 for the richest country (Norway, excluding Luxemburg). For MRIO consumption, the curve starts at a value of 0.64 for the poorest country, reaches a maximum of 0.73 at a per-capita income level of 1985\$ (Paraguay) and reaches a minimum of 0.41 for the richest country.

Figure 3b shows that the average CO_2 content of production also follows an inverted-U pattern, even though it is flatter and the quadratic fits seems to exaggerate the pattern somewhat. This is a form of Environmental Kuznets Curve for carbon. Finally, Figure 3d shows that the average CO_2 content of imported consumption (an interesting value, as it is not linked to local production intensities), follows a clear downwards pattern.

3.6 Decomposing the cross-country variability in CO_2 content

Of course, the cross-country variability observed in Figure 3 can be due not only to differences in consumption patterns but also differences in both production intensities and trade patterns. In order to identify the importance of consumption patterns, we neutralize differences in production intensities by re-calculating CDd_n, CDt_n, CM_n and CY_n using average production intensities. This requires computing the (weighted) average output intensity vector $\bar{B}^{output}$ (as all intensities are the same across countries, it simplifies to a row vector of length k) and the average k x k input-output matrix $\bar{A}$.

In a second step, we investigate the predictive power of per-capita income as a determinant,

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through consumption patterns, of the CO_2 content of consumption. This is done by using fitted consumption estimates from the demand system computed under the assumption of identical but non-homothetic preferences as presented in equation 2. In order to distinguish the impact of prices differences from that of per-capita income, demand is also fitted with homothetic preferences by imposing $\sigma = 1$ in equation 2. Thus, three types $\Delta \in \{\text{data}, \text{homoth}, \text{non-homoth}\}$ of consumption values d_{nk} are defined:

$$
d_{nk}^{\Delta} = \begin{cases}
d_{nk}^{data} & \text{observed} \\
\hat{d}_{nk}^{homoth} = \hat{\alpha}_k \widehat{\Phi}_{nk}^{\frac{(\hat{\sigma}_k-1)}{\hat{\theta}}} & \text{fitted, homothetic} \\
\hat{d}_{nk}^{non-homoth} = \hat{\alpha}_k \hat{\lambda}_n^{-\hat{\sigma}_k} \widehat{\Phi}_{nk}^{\frac{(\hat{\sigma}_k-1)}{\hat{\theta}}} & \text{fitted, non-homothetic}
\end{cases}
$$

For each Δ, the bilateral demand D_n^{Δ}, the imported consumption M_n^{Δ} and the final production Y_n^{Δ} vectors are recalculated using observed bilateral trade shares and the proportionality assumption. Using all of this, we then compute:

$$
\begin{aligned}
\overline{CDd}_n^{\Delta} &= \bar{B}^{dir} D_{nk}^{\Delta} + \bar{\beta}_{ele}^{output} d_{n,ele}^{\Delta} \\
\overline{CDt}_n^{\Delta} &= \bar{B}^{output}(I - \bar{A})^{-1} D_n^{\Delta} + \bar{B}^{dir} D_{nk}^{\Delta} \\
\overline{CMt}_n^{\Delta} &= \bar{B}^{output}(I - \bar{A})^{-1} M_n^{\Delta} \\
\overline{CY}_n^{\Delta} &= \bar{B}^{output}(I - \bar{A})^{-1} Y_n^{\Delta}
\end{aligned}
$$

In order to decompose the variability into its different components, Table 2 presents a measure of fit, $R2^{\text{pseudo}}$ which summarizes the percentage variability in each CO_2 content measure CC_n which is explained by the different constructed measures $\widehat{CC}_n$:

$$
R2^{\text{pseudo}} = 1 - \frac{SSR}{SSE} = 1 - \frac{\sum_n (CC_n^{true} - \widehat{CC}_n)^2}{\sum_n (CC_n^{true} - \overline{CC}_n^{true})^2}
$$

Figure 5 shows that both the direct and the total average CO_2 content of consumption exhibit an inverted-U relationship with per-capita income even if it is evaluated at constant intensities ($\overline{CDd}_n^{\text{data}}$). Differences in consumption patterns alone (solid line, non-parametric fit of $\overline{CDd}_n^{\text{data}}$) contribute to explaining about half of the relationship found in the data (dotted line, non-parametric fit of CDd_n^{data}). However, the 95% confidence interval shows that if the second part of the curve is significantly decreasing, the first part of the curve is not significantly increasing.

As the $R2^{\text{pseudo}}$ in Table 2 shows, consumption patterns play an important role in determining the direct CO_2 content of consumption: 67 % of the variability in CDd_n is explained

Table 2: Variability decomposition

Avg. CO_2 content	Production intensities	Consumption		
		homoth	*non-homoth*	*data*
Direct consumption	data	0.25	0.51	1.00
Direct consumption	average	-0.03	0.28	0.67
MRIO consumption	data	0.88	0.94	1.00
MRIO consumption	average	0.13	0.27	0.35
Production	data	0.92	0.93	1.00
Production	average	0.35	0.39	0.42
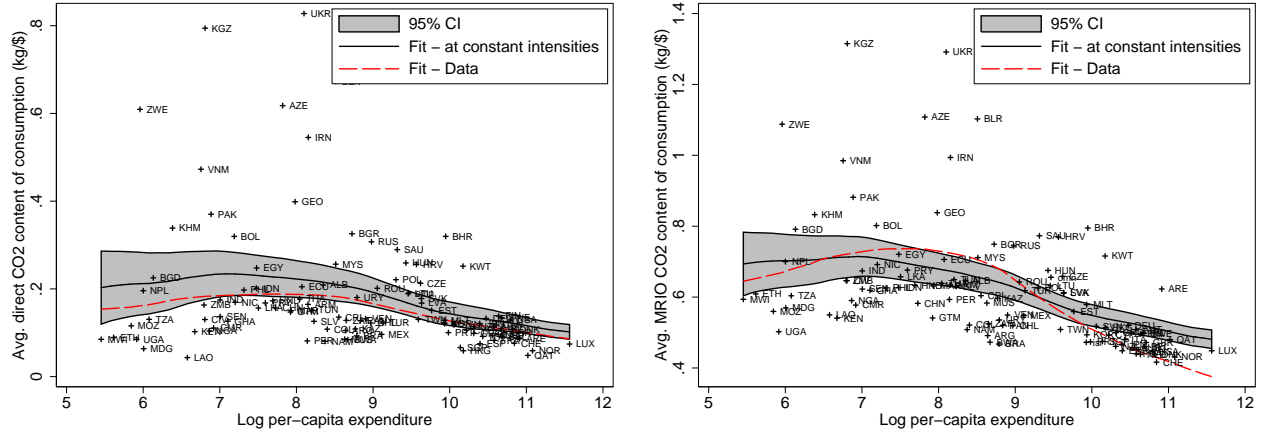
(a) Avg. direct CO_2 content of consumption   (b) Avg. MRIO CO_2 content of consumption

Figure 5: Average MRIO CO_2 content of consumption, evaluated at average intensities.

by $\overline{CDd}_n^{\text{data}}$ (holding production intensities constant). This is not surprising as, apart from electricity, direct emission coefficients do not vary much across countries. This value is much lower when evaluating the total MRIO content, and only 35% of the variability in CDt_n is explained by $\overline{CDt}_n^{\text{data}}$. However, given that the latter ignore all cross-country differences in technological (IO coefficients) and CO_2 emission coefficients (differences which are known to be large), this number remains significant.

Differences in consumption patterns alone also contribute to explaining why CM_n and CY_n decrease with per-capita income. This can be seen in the long-dashed lines of Figure 6 which displays the fitted values of the local-mean smoothing regression of $\overline{CDd}_n^{\Delta}$, $\overline{CDt}_n^{\Delta}$, $\overline{CMt}_n^{\Delta}$ and $\overline{CY}_n^{\Delta}$, for all demand assumptions Δ. In this figure, all regressions are weighted by either total consumption, total production or total imported consumption.
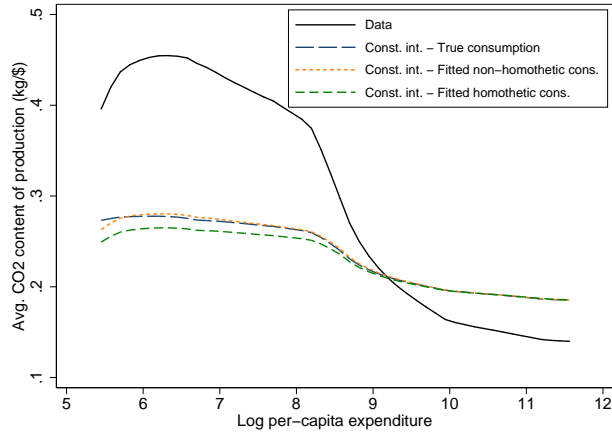
Now that we have found differences in consumption patterns to contribute to generating the observed inverted-U relationship between CO_2 content and per-capita income, the question
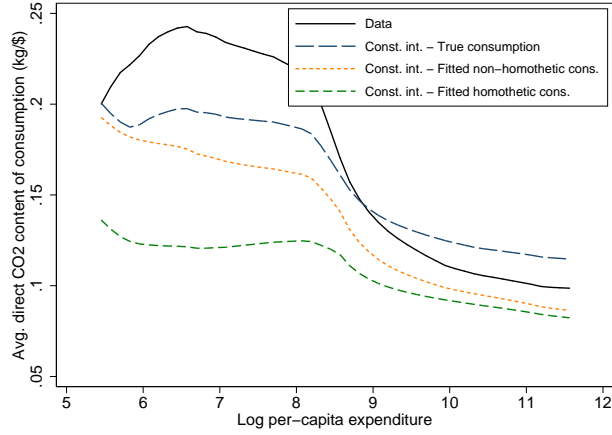
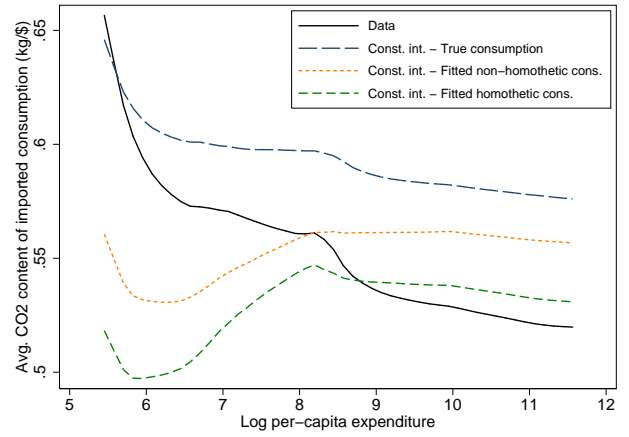(a) Avg. Direct CO_2 content of consumption
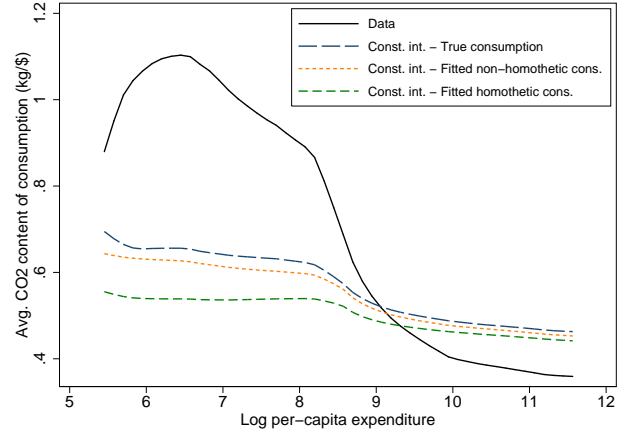
(c) Avg. MRIO CO_2 content of consumption

(b) Avg. MRIO CO_2 content of production

(d) Avg. MRIO CO_2 content of imported consumption

Figure 6: Average CO_2 content, non-parametrically fitted

becomes whether we can say anything about how they systematically differ across countries. In particular, we are interested in the predictive power of per-capita income in determining consumption patterns in a way which affects emissions. As Figure 6 shows, the predicted values from the model also generate either an inverted-U or a decreasing relationship.

First, we find that generating consumption patterns under the restrictive assumption that preference are not only identical across countries but homothetic still generates a weakly decreasing relationship between average CO_2 content and per-capita income (see the green medium-dotted line in Figure 6). Thus, the cross-country price differences estimated in the gravity framework generate consumption patterns which are skewed towards less CO_2 intensive goods, and implies that CO_2-intensive goods are on average proportionally cheaper in poorer countries. This effect is not strong, however, and Table 2 shows that homothetic consumptions patterns only explain a very small share of variability.

Relaxing the assumption of homothetic preferences and allowing per-capita income to determine consumption patterns increases the slope of the negative relationship (see the orange small-dashed line in Figure 6). It is now much closer to that found using observed consumption patterns. The fit to the data is also considerably higher. It increases from 0 to 0.28 (out of 0.67) for direct consumption and from 0.13 to 0.27 (out of 0.35) for total consumption.

Interestingly, this does not translate to large differences in the CO_2 content of production. This should be further investigated.

We conclude that per-capita income has the potential to explain a substantial part of the variability in the average CO_2 content of consumption across countries through its influence on consumption patterns. However, as is clear from Figure 3c, the slope of the effect is much flatter for total consumption than for direct consumption, when evaluated with either fitted non-homothetic shares or observed shares. The explanation for this was given in section 3.3: total income elasticities are both closer to unity than direct elasticities, and less correlated with total CO_2 intensities.

The corollary to this conclusion is that any model which ignores differences in consumption patterns or any predictive exercise which fails to account for the evolution of these patterns due to growth in per-capita income will be missing a small, but arguably non-negligible part of the story. Even if differences in production intensities where perfectly accounted for, 12% of the variability in the total CO_2 attributable to consumption would ignored, as would be 8$ of the variability in the CO_2 intensity of production. If one were interested in the direct CO_2 emissions caused by consumers, though, this number would be 75%.

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4 Predicting the evolution of the CO_2 content of consumption

What is the potential for economic growth to reduce aggregate CO_2 emissions through a shift consumption patterns, even absent any technical change?

The model and demand system introduced in section 3.1 can be used to compute an analytical approximation for the change in the average CO_2 content of consumption which would be caused by an increase in per-capita income. This response is estimated using a simple closed economy partial equilibrium approximation and thus neglects general equilibrium feed-backs which might occur through changes in factor prices or consumption changes in trading partners. We believe these feed-backs to be of second order. The approximation uses "hat" notation in which $\hat{x}$ represents the percentage change in variable x.

The counterfactual of interest is an increase in per-capita income. There, are however, many ways to introduce such an increase in the model. We are interested in finding the impact of a "neutral" per-capita income increase which could be caused, for example, by a sector-neutral increase in total factor productivity. The mechanism would not function if the economy were growing due to the accumulation of labor (population) or if technology growth were biased towards more or less CO_2 intensive sectors.

We chose to simply assume that the rise in real per-capita income is driven by a uniform price decrease in all sectors and remain agnostic about what is driving this decrease. Thus:

$$\hat{p}_k = \hat{p} < 0$$

The variables of interest are the percent changes in the CO_2 content of consumption $\widehat{CD}d_n$ and $\widehat{CD}t_n$. These are given by:

$$\widehat{CD}d_n = \frac{\sum_k \beta_{nk}^{dir-ele} d_{nk} \hat{d}_{nk}}{\sum_k \beta_{nk}^{dir-ele} d_{nk}} = \sum_k sh_{nk}^{dir-ele} \hat{d}_{nk}$$

and:

$$\widehat{CD}t_n = \frac{\sum_k \beta_{nk}^{total} d_{nk} \hat{d}_{nk}}{\sum_k \beta_{nk}^{total} d_{nk}} = \sum_k sh_{nk}^{total} \hat{d}_{nk}$$

Where $sh_{nk}^{dir-ele}$ is sector k's share of direct consumption emissions in total direct consumption emissions in country n, and sh_{nk}^{total} is the equivalent for total emissions. Deriving equation (2) we obtain the change in final demand $\hat{d}_k$:

$$\hat{d}_{nk} = -\sigma_k \hat{\lambda}_n + (1 - \sigma_k)\hat{p}_{nk}$$

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We need to solve for the change in the budget constraint Lagrangian λ. We therefore take the first difference of the budget constraint. Normalizing nominal income to a constant, the following condition must be satisfied:

$$\sum_k \hat{d}_k d_k = 0$$

Inserting demand into the budget constraint, we obtain an expression for the change in Lagrangian:

$$\hat{\lambda} = \frac{\sum_k (\sigma_k - 1) d_k}{\sum_k \sigma_k d_k} \hat{p}$$

Incorporating back into demand, we get:

$$\hat{d}_{nk} = -\hat{p}(\varepsilon_{nk} - 1)$$

Thus, the change in the direct CO_2 content of consumption are :

$$\widehat{CDd}_n = -\hat{p} \sum_k sh_{nk}^{dir-ele}(\varepsilon_{nk} - 1)$$

and

$$\widehat{CDt}_n = -\hat{p} \sum_k sh_{nk}^{total}(\varepsilon_{nk} - 1)$$

The variable of interest is the elasticity of emissions intensity to income (or equivalently, price) growth driven purely by changes in consumption patterns:

$$E^d = \frac{\widehat{CDd}_n}{-\hat{p}} = \sum_k sh_{nk}^{dir-ele}(\varepsilon_{nk} - 1) \tag{5}$$

and

$$E^t = \frac{\widehat{CDt}_n}{-\hat{p}} = \sum_k sh_{nk}^{total}(\varepsilon_{nk} - 1) \tag{6}$$

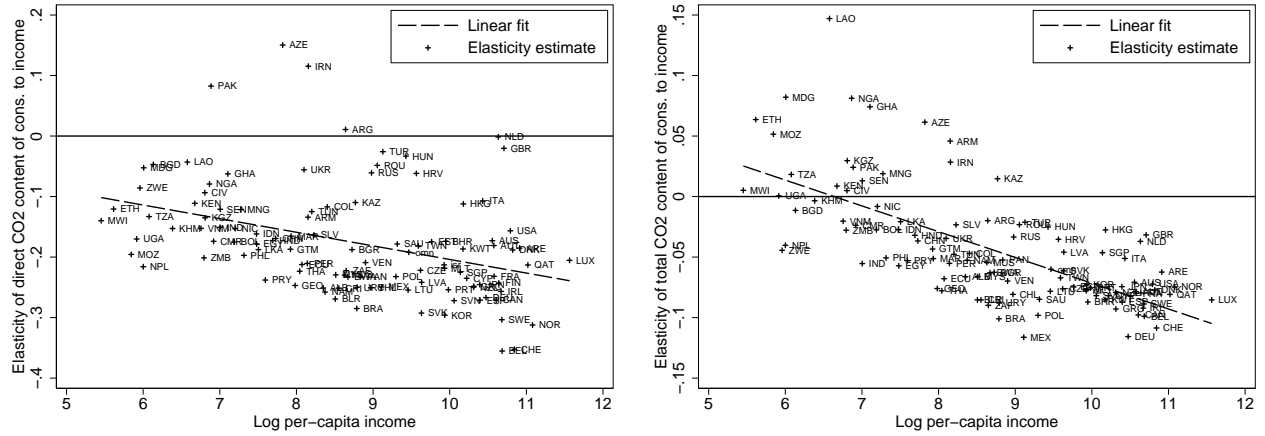These two values are displayed in Figures 7a and 7b. Also of interest are the changes in the CO_2 content of worldwide consumption due to uniform productivity grow:

$$\frac{\widehat{CDt}_W}{-\hat{p}} = \sum_n sh_n^{total} \widehat{CDt}_n$$

In which sh_n^{total} is country n's share of total consumption emissions.

Figure 7a shows that the elasticity of the average direct CO_2 content of consumption to

(a) Avg. direct CO_2 content of consumption   (b) Avg. total CO_2 content of consumption

Figure 7: Elasticity of the CO_2 content of consumption to per-capita income

income is negative for almost all countries. Estimates range from 0.15 for Azerbaijan, implying that a doubling of per-capita income in that country would increase the average CO_2 intensity of consumption by 15%, to -0.36 for Belgium (implying a 36 % decrease). For the USA, the country with the largest share of direct CO_2 emissions, the value is -0.16. The weighted average for the world is -0.17, implying that a doubling of per-capita income in all countries would reduce the average direct CO_2 content of consumption by 17%, absent any technical change. Interestingly, the estimates are more strongly negative in countries with higher per-capita incomes.

Figure 7b displays the elasticity of the average total CO_2 content to income. This is the more relevant metric from a policy perspective, as it closely reflects total CO_2 emissions. Consistent with the findings of the previous sections, the picture here is different. A larger number of countries have positive estimates. The effect tends to be larger (often positive) for countries with low initial levels of per-capita income, and negative for richer countries. This is consistent with the inverted-U patterns identified earlier and confirms that consumption patterns contribute to generating the inverted-U relationship with per-capita income. Poor countries are still shifting their consumption towards more CO_2 intensive goods.

Importantly, there is also less variation between countries and estimates are in general closer to zero. Estimates range from a 15% increase for Laos to a 12% decrease for Germany. The USA would see a 7% decrease. The weighted effect on world-wide emissions (at the world level, emissions embodied in consumption equal total emissions) is a 6% decrease. Thus, changes in consumption patterns due to a doubling of per-capita income in all countries of the world would decrease total emission intensity by 6% only.

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4.1 Decomposition by sector

Figure 8 decomposes these effects across sectors and displays weighted average $sh_{nk}^{dir-ele}(\varepsilon_{nk}-1)$ and $sh_{nk}^{total}(\varepsilon_{nk}-1)$. Again, as we have seen, mean shares are not representative but nevertheless allow for interesting insights.

Almost all energy goods contribute to a decrease in the direct CO_2 content of consumption, with refined oil (P_C) and electricity leading the way. These two sectors are the most important contributors to the decrease in the total CO_2 content of consumption. Gas (if aggregate GAS and GDT) contributes positively to the shift.

In evaluating the contribution to the decrease in total CO_2 content of consumption, at mean shares, energy goods would lead to a 4.81% decrease and non-energy goods to a 2.92% decrease, thus about 40% of the decline is indirect through non-energy goods. Of these, the most important sectors contributing to the decline are construction, other transport, and other food products. Increases in motor vehicles, electronics, business services and trade counterbalance this decrease.

The graph also shows that most of the shift is determined by a comparatively small number of sectors. Many sectors are either not affected by per-capita income, or they correspond to a small share of overall CO_2 emissions. It is surprising to see, for example, the low contribution of air transport and bovine meat products, a fact which should be further investigated.
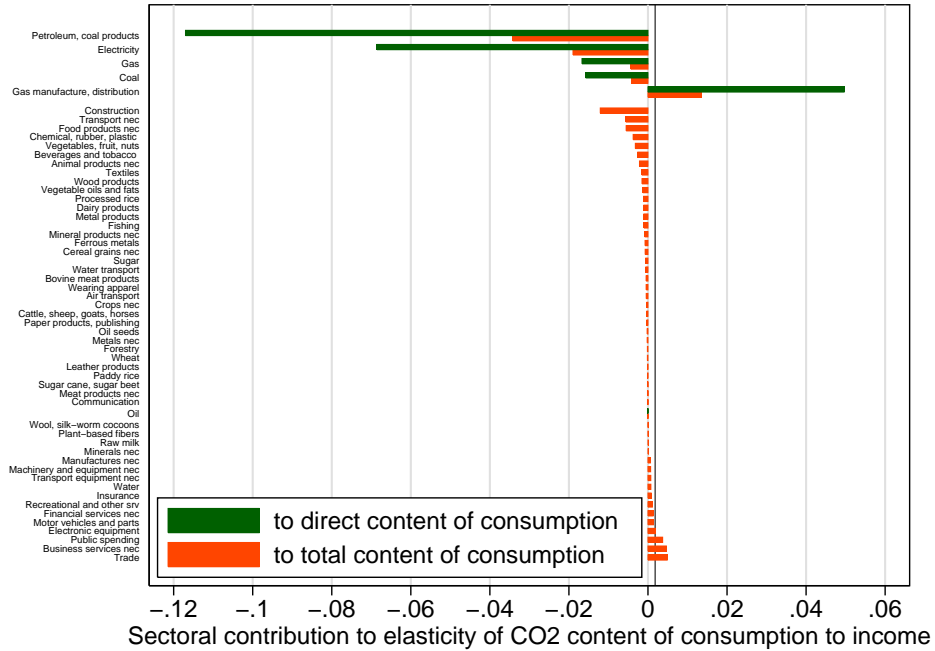

Figure 8: Decomposition of effect

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5 Next steps

A number of things still need to be done. First, we need to account for the uncertainty in parameter estimations and use bootstrapped estimates for all variables, including sigma, the income elasticities, and the predicted average CO_2 content values. It would also be interesting to replicate the analysis for energy intensity instead of CO_2 intensity (with a possible breakdown between fossil fuels). Additionally, the study could be complemented to include local pollutants, depending on the availability of data. Using the full general-equilibrium model to simulate per-capita income increases is also a possibility, however, it is very probable that general equilibrium feed-backs (through trade, factor prices, etc..) would be comparatively small and not qualitatively affect the conclusions.

Also, the analysis could try analyzing the impact on per-capita emissions, instead of emissions intensity in dollar terms. Per-capita income should maybe also be adjusted for differences in purchasing power parity.

6 Concluding remarks

This study has analyzed the importance of consumption patterns in determining CO_2 emissions levels across a large number of countries covering most of the world economy and a wide range of per-capita income levels.

We have found differences in consumption patterns to contribute to generating the inverted-U relationship between the average CO_2 content (or CO_2 intensity) of a country's economy and its level of income. They are not however a major determinant of the overall distribution of intensities. Indeed, the structure of technology as reflected by the input-output tables is such that the strong negative correlation between income elasticity and CO_2 intensity at the sector-level is much lower once the intermediate use of each sector is taken it account. CO_2 emitting energy goods exhibit low income elasticity of direct consumption, but tend to be used as intermediates for high income elasticity goods. Thus, energy goods themselves correspond to decreasing shares of consumer expenditures, but total energy embodied in consumption does not decrease significantly with income.

Indeed, while consumption patterns alone explain 67% in the observed cross-country variability in of the average direct CO_2 content of consumption, they only explain 35% of the total content of consumption. Most of the observed decrease in emissions intensities is thus to be attributed to differences in technology.

We have then found that the inverted-U pattern can be replicated by consumption shares built under the assumption that all countries have identical but non-homothetic preferences.

Thus, differences in per-capita income contribute to explaining the income-emissions relationship. They explain about half of the remaining variability in the total CO_2 intensity of consumption, relative to a counterfactual world in which preferences would be homothetic. This implies that per-capita income growth can be used to predict the extent consumption-driven decrease in CO_2 intensities. As the slope of the relationship is fairly flat, we know that the effect will not be big.

Indeed, we find that the average CO_2 content of consumption (and thus production) at the world level only reacts very weakly to income growth. Given observed consumption shares, many countries are still to the left of the peak and their consumption patterns are predicted to change in way which actually increases emissions. Richer countries are predicted to see their intensity decrease, but in a modest way. All in all, the elasticity of worldwide CO_2 intensity to per-capita income is estimated to be only -0.06. This is a small number: to put things in perspective, it has taken 49 years for real world income per capita to double (between 1967 and 2008). A further doubling would only lead to a 6% decrease in emissions intensity. Of course, this is a local approximation and the number may increase once all countries have passed the peak intensity level, but this is arguably still far in the future.

A side note can be made about the implications of these findings0 for general equilibrium exercises often used to estimate the impact of counterfactual CO_2 emission reduction policies or to make predictions about the future path of emissions growth. The models found in the literature often rely on homothetic constant elasticity of substitution (CES) preferences which do not allow consumption shares to vary with income. If they do allow for non-homothetic preferences, they are often calibrated to income elasticity parameters which areestimated outside of the model. Additionally, many models rely on LES preferences, which can be shown to be quite restrictive and generate very low variability in income elasticity estimates. This study gives us a good quantitative approximation of the importance of correctly modeling differences in consumptin patterns: they explain about 12 % of the total variability in consumption intensities (8% for production intensities). We are thus able to conclude that although a restrictive treatment of income effects on consumption will not lead to large errors in emissions predictions, including them is still quantitatively as important as many supply-side technology differences which researchers focus on.

To conclude: we expected technological differences to be the main driver behind differing CO_2 intensities, but we could have thought shifts in demand patterns to play a larger role. We now know that although they vary significantly with per-capita income, they to not do so in way which is significantly biased towards goods with lower *total* CO_2 requirements.

There is no silver bullet: economic growth will contribute to naturally decrease CO_2 intensity, but only very modestly.

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7 Appendix

Table 3: Sectoral classification in GTAP

Code	Description
PDR	Paddy rice
WHT	Wheat
GRO	Cereal grains nec
V_F	Vegetables, fruit, nuts
OSD	Oil seeds
C_B	Sugar cane, sugar beet
PFB	Plant-based fibers
OCR	Crops nec
CTL	Bovine cattle, sheep and goats, horses
OAP	Animal products nec
RMK	Raw milk
WOL	Wool, silk-worm cocoons
FRS	Forestry
FSH	Fishing
COA	Coal
OIL	Oil
GAS	Gas
OMN	Minerals nec
CMT	Bovine meat products
OMT	Meat products nec
VOL	Vegetable oils and fats
MIL	Dairy products
PCR	Processed rice
SGR	Sugar
OFD	Food products nec
B_T	Beverages and tobacco products
TEX	Textiles
WAP	Wearing apparel
LEA	Leather products
LUM	Wood products
PPP	Paper products, publishing
P_C	Petroleum, coal products
CRP	Chemical, rubber, plastic products
NMM	Mineral products nec
I_S	Ferrous metals
NFM	Metals nec
FMP	Metal products
MVH	Motor vehicles and parts
OTN	Transport equipment nec
ELE	Electronic equipment
OME	Machinery and equipment nec
OMF	Manufactures nec
ELY	Electricity
GDT	Gas manufacture, distribution
WTR	Water
CNS	Construction
TRD	Trade
OTP	Transport nec
WTP	Water transport
ATP	Air transport
CMN	Communication
OFI	Financial services nec
ISR	Insurance
OBS	Business services nec
ROS	Recreational and other services
OSG	Public Administration, Defense, Education, Health
DWE	Dwellings