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Putting the Green Back in Greenbacks

Opportunities for a Truly Green Stimulus

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Abstract

Can countries reorient their productive capacity to become more environmentally friendly and inclusive? To investigate this question, this paper uses a standard input-output modeling framework and data from 141 countries and regions to construct a new global data set of employment, value-added, greenhouse gas emissions (disaggregated into carbon dioxide and non-carbon dioxide elements), and air pollution (including nine categories of air pollutants such as fine particulate matter multipliers from supply-side investments. The analysis finds that many of the traditional sectors in agriculture and industry have large employment multipliers, but also generate male dominant, lower skill employment, and tend to have higher emissions multipliers. It is in economies dominated by these sectors that trade-offs to a "greener" transition will emerge most sharply. However, the analysis finds substantial heterogeneity in outcomes, so even in these economies, there exist other sectors with high employment multipliers and low emissions, including sectors that are more conducive to female employment. In addition, the analysis finds a high correlation between industries that generate greenhouse gas emissions, which cause long-term climate impacts, and those that generate air pollution, which have immediate harmful impacts on human health, suggesting that policies could be designed to confer longer climate benefits simultaneously with immediate health improvements. The results confirm some of the findings from recent research and shed new light on opportunities for greening economies.

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Putting the Green Back in Greenbacks: Opportunities for a Truly Green Stimulus

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1. Introduction

The aftermath of the COVID-19 induced recession has rekindled interest in a recovery that can be inclusive and deliver growth without significant climate and environmental degradation. Central to these discussions are aspirations to create jobs in sectors that are relatively clean and low in emissions, while simultaneously improving gender balances, and benefiting the poorer and less skilled segments of the labor market. Proponents of a low-carbon green economy tout the many benefits and argue that such opportunities abound (UNEP 2015). Critics of strong climate actions point to the job losses that may ensue especially in the more emission intensive sectors of the economy (e.g., Greenstone, 2002, Kahn and Mansur, 2013). While the pandemic has unleashed an outpouring of fiscal spending, estimated at US$14 trillion so far, much has been concentrated on measures to address the health emergency and support household and firms stranded by the lockdowns (IMF, 2021). As a result, much spending has been on supporting the 'legacy' economy, including incumbent technologies and sectors (such as coal) that are environmentally harmful (Vivid Economics, 2020). This may reflect, and be a rational response to, the uncertainty about the economic implications of investing in greener and lower emissions sectors. Such reticence is perhaps unsurprising during an economic crisis and public health emergency, especially when there is a paucity of information and research on the effectiveness of green stimuli.

This paper seeks to fill this gap in the literature by generating new information that could assist in the design of better informed and greener policy making. Specifically, this paper makes three key contributions. First, we construct a new global data set of employment, value-added, greenhouse gas (GHG) emissions (disaggregated into CO_2 and non-CO_2 elements), and air pollution (including 9 categories of air pollutants such as PM2.5) multipliers. Results are available at the global scale, and are also disaggregated into 141 countries and regions,[3] using the Global Trade Analysis Project (GTAP) database in a standard input-output model.

There are well-known methodological and data challenges in assessing the macroeconomic and environmental effects of green stimulus measures. Ex post evaluations face the difficult task of defining a suitable counterfactual and addressing biases that derive from violations of numerous exclusion restrictions. For instance, since a fiscal stimulus is typically introduced during a recession, spending will be endogenous to the business cycle. Likewise, if "greener" spending is allocated in a non-random manner and directed towards certain sectors or regions with higher (or lower) transformational potential, this too would bias the estimates. As a result of these, and other challenges, previous work has tended to rely on simulated impacts and ex ante evaluations. The contribution of this paper is in this latter category. We provide baseline estimates using the GTAP database and simple input-output analyses that can be used to benchmark performance against more detailed country level estimates where these become available. A comparison with countries similar in structural attributes would provide a useful way to cross check and validate results.

Second, the global data set enables a ranking of industries across countries, and within countries, in terms of employment, value-added, GHG emissions, and other air pollutants (e.g., $PM_{2.5}$). It provides a way of determining whether a country can reorient its productive capacity while creating employment. Adverse distributional impacts on manual labor may be a

[3] Regions represent aggregations of small countries.

particular concern in sectors where a greener transformation involves the substitution of manual labor for a higher skilled workforce or moving to less labor-intensive technologies. Hence, new estimates are provided of the distributional and gender consequences of different investment choices to enable a first-order assessment of the potential equity and inclusion impacts of any spending package. Additionally, investments that stimulate rapid increases in value-added (growth) need not coincide with those that generate the highest levels of employment. Our results identify where such trade-offs may occur and their prevalence across countries.

Third, the study provides estimates of local air pollution as measured through $PM_{2.5}$, which is known to be responsible for the premature loss of around 4 million lives each year – a number greater than deaths due to war and violence, and more than has been lost in the COVID-19 pandemic. Effective design of stimulus packages could provide an opportunity for governments to reduce harmful and even fatal levels of exposure to air pollution, while creating new jobs and stimulating the economy. Additionally, it is shown that many of the industries that generate local pollutants are also responsible for high levels of GHG emissions suggesting that there may be opportunities to simultaneously address immediate and local health priorities, while also supporting longer term global climate change goals. Remarkably, as shown in this paper, the correlation (R^2) between GHGs and $PM_{2.5}$ is around 85% indicating that significant opportunities exist to tackle global and local pollution problems simultaneously, with the appropriate interventions.

Finally, the results also highlight the importance of distinguishing between *absolute* emissions and emission *intensities*. The focus of much climate change policy is predictably on sectors with high absolute GHG emissions. The absolute emissions in a sector may be high, either due to the size of that sector (i.e., the scale effect), or because of high emissions generated per unit of value added produced in the sector (i.e., the emissions intensity of the sector). If the aim is to green growth, then emission intensities provide valuable information as these capture changes due to cleaner production processes (holding value added constant), as well as changes due to increases in value added (holding emissions constant). Both changes are desirable to decouple economic growth from environmental damage. The analysis in this paper identifies several prominent examples of sectors that are often deemed "dirty" due to the size of the industry. However, neglecting the distinction between scale effects and intensity effects could encourage suboptimal policy choices, if it leads to expanding sectors that generate fewer benefits for the same level of emissions.

This paper is related to a growing literature on the greening of the economy. In one of the few empirical estimates available, Popp et al. (2020) find that in the United States the green stimulus of the Obama era, termed the American Recovery and Reinvestment Act (ARRA), increased total employment slower than other stimulus investments and created around 15 jobs per $1 million in the long-run. Focusing on habitat restoration projects, Edwards et al. (2013) find that restoration projects created, on average, 17 jobs per million dollars spent. Some forms of green spending such as land and habitat restoration projects, exhibit high direct and indirect employment multipliers as they are labor intensive and tend to hire lower-skilled workers, who may have higher marginal propensities to consume. In perhaps the most advanced empirical assessment, Batini et al. (2021) show that every dollar spent on key carbon-neutral or carbon-sink activities generates more than a dollar's worth of economic activity. The estimated multipliers associated with green spending are about 2 to 7 times larger than those associated with non-eco-friendly expenditure, depending on sectors, technologies, and horizons.

Complementing these empirical assessments is a growing simulation-based literature that focuses on job creation potential in particular sectors, or geographies with a typical focus on the high emitting energy sector. For instance, IMF and IEA (IEA, 2020) identify a USD 1 trillion investment package that could add 1.1 percentage points to global economic growth each year. Early results from the ILO suggest that investments in renewable energies, building efficiency and green transport would create almost six times as many jobs by 2030 than similar stimulus focusing on cutting value-added taxes (Camecon and Page 2021). This paper is also related to the pioneering work of Hepburn et al. (2020) which sought to identify climate friendly and employment intensive sectors by surveying perceptions of experts and high ranked government officials. This paper augments these findings with simulations which show that in some sectors there is considerable heterogeneity across countries, which would imply that broad generalizations may mislead.

The remainder of this paper is organized as follows. Section 2 provides an outline of the approach and summary of the data used. Sections 3 presents the main results. Section 4 concludes with broad policy implications and suggestions for future research.

2. Methods and data

To evaluate the economic and environmental implications of fiscal policies we use an Input-Output (I-O) modeling framework. Two types of policies can be examined using this modeling approach – those that capture the impacts of exogenous increases in sectoral final demands and those that evaluate the consequences of exogenous increases in sectoral investments. Most of the existing applied research in this field has evaluated the demand multipliers by sector, even though much of this research (misleadingly) refers to demand multipliers as investment multipliers. This section provides clarity on the theoretical background and differences between the demand and investment multipliers. Though our focus in what follows is on investment multipliers.[4]

We present results on employment and income multipliers which are the most common measures used to summarize the many economic impacts of demand and investment policies, as well as measures of impacts on the gender and the skill distribution of employment patterns. We complement these with measures of environmental implications that includes CO_2, non-CO_2 GHG emissions, and a variety of other air pollutants described in the Annex. This range of indicators provides information that is relevant in assessing the wider social and environmental implications of investment policies beyond the usual macroeconomic indicators.

The theoretical foundation of using I-O tables to measure changes in final demand or investment has been widely discussed in the literature (e.g., Miernyk (1967); Richardson (1972); Miller and Blair (1985); Pleeter (1980); Richardson (1985)) and used to evaluate

[4] Upon request from the authors results from the demand multipliers are available. These are not presented here due to our interest in exploring the potential of sectoral investments to generate more environmentally benign employment and growth.

multipliers at both regional and national levels (Lenzen (2001); Bekhet (2011); Bivens (2019); Cassar (2015; and Liu and Liang (2017)).

2.1. Income and employment multipliers

The relationship between the demand and supply sides in an I-O framework is described by the following relationship:

$$Y = (I - A)^{-1} \times F \qquad (1)$$

Where Y is a vector of $n \times 1$ and its elements are: Y_i, value of production of commodity i which is equal to the value of output of sector Y_j for $i = j$; I is an identity matrix of $n \times n$; A is a matrix of $n \times n$ and its elements are: $a_{ij} = \frac{X_{ij}}{Y_j}$; where X_{ij} stands for the intermediate use of commodity i used in sector j and F is a vector of $n \times 1$ and its elements are: F_i, final demand for commodity i. Using equation (1), assuming no technological progress, one can determine the impacts of changes in the sectoral final demands on sectoral outputs.

On the other hand, in an I-O framework, the following relationship establishes the links between production and primary production inputs such as labor, capital, and resources:

$$Y' = V' \times (I - B)^{-1} \qquad (2)$$

Where Y' is the transpose of vector Y; V'represents transpose of vector of value-added (payments to primary inputs such as labor and capital); and B is a matrix of $n \times n$ and its elements are $b_{ij} = \frac{X_{ij}}{Y_i}$. Note that the elements of matrices A and B are not identical as: $a_{ij} = \frac{X_{ij}}{Y_j} \neq b_{ij} = \frac{X_{ij}}{Y_i}$, except when *i=j*. Using equation (2), assuming no technological progress, one can determine the impacts of changes in the sectoral value-added on sectoral outputs.

In an I-O framework, the link between inputs used by each sector and its output represents a linear relationship. In this type of production function, the ratios of labor to output (α_j) and capital to output (β_j) are fixed in each sector. That implies:

$$\alpha_j = \frac{L_j}{Y_j} \Rightarrow L_j = \alpha_j Y_j \Rightarrow \Delta L_j = \alpha_j \Delta Y_j \qquad (3)$$

$$\beta_j = \frac{K_j}{Y_j} \Rightarrow K_j = \beta_j Y_j \Rightarrow \Delta K_j = \beta_j \Delta Y_j \qquad (4)$$

Using equations 1 to 4 one can determine labor and income multipliers due to sectoral increases in final demand (i.e., $+\Delta F_i$) or changes in capital (i.e., $+\Delta K_j$ or investment). To calculate the investment multipliers sectoral rates of return are also required (see chapters 2 and 12 of Miller and Blair 1985). Note that the labor multipliers could be calculated by skill and gender as well.

2.2. Emission multipliers

Emissions accounting could be considered across three different scales as suggested in the literature.[5] The most restrictive, *Scope 1*, considers only direct emissions from a single source

[5] For details on emissions scopes see: GHG Inventory Guidance for Low Emitters | EPA Center for Corporate Climate Leadership | US EPA.

(e.g., emissions associated with fuel combustion in a boiler). *Scope 2* refers to indirect emissions associated with purchase of a typical good or service (e.g., purchase of electricity). *Scope 3* takes into account the entire supply chain from a life cycle perspective. In developing emission multipliers, we compute *Scope 3* emissions which are the most comprehensive that can be readily computed from I-O tables (Peters 2008). For each type of emission (CO_2, each element of non-CO_2 GHG emission, and each element of air pollution) we develop two sets of multipliers: one set for changes in the sectoral final demands and the other for changes in the sectoral investments. Air pollutants are measured in metric tons per million USD.

To calculate the demand emissions multipliers, the following equation can be used:

$$ED_i^{er} = \underbrace{\sum_i \sum_j EX_{ij}^{er} \Delta X_{ij}^r}_{Emi.form\ intmedaite\ inputs} + \underbrace{\sum_k \sum_j EP_{kj}^{er} \Delta P_{kj}^r}_{Emi.form\ primary\ inputs} + \underbrace{\sum_j EY_j^{er} \Delta Y_j^r}_{Emi.form\ outputs} + \underbrace{EF_i^{er} \Delta F_i^r}_{Emi.from\ final\ demand} \quad (5)$$

In this equation i, j, k, e, and r represent indices for goods (or services), sectors, primary inputs, types of emissions, and regions, respectively. The variable names used in this equation are:

ED_i^{er}: Demand multiplier of emission type *e* in region *r* for final demand of commodity *i*,

EX_{ij}^{er} : Emission intensity for intermediate demand of *i* used in *j* for emission *e* in *r*,

EP_{kj}^{er} : Emission intensity for primary demand *k* used in *j* for emission *e* in *r*,

EY_j^{er} : Emission intensity for output *j* for emission *e* in *r*,

EF_i^{er} : Emission intensity for final demand *i* for emission *e* in *r,*

ΔX_{ij}^r : Change in intermediate demand of *i* used in *j* in *r*,

ΔP_{kj}^r : Change in demand of *k* used in *j* in *r*,

ΔY_j^r : Change in output of *j* in *r*,

ΔF_i^r : Change in final demand of *i* in *r*.

The I-O simulations mentioned above provide the values of ΔX_{ij}^r, ΔP_{kj}^r, and ΔY_j^r. In addition to these changes, data on emissions intensities are required to calculate the demand emissions multipliers. The last component of the above equation represents direct emissions due to final demand for 1 million USD. To avoid double counting there is no need to consider emissions due to exports of *i* form *r* to other countries. The investment emissions multipliers (ES_j^{er}) are obtained by simply excluding emissions induced by final demand (i.e., ΔF_i^r)**.**

Finally, it is important to note that the investment emission multiplier is a relative measure that compares changes in emissions induced by changes in the value chain of a sector, due to an investment of 1 million USD. Hence, an investment in a "dirty" sector with high emissions and a large value chain, may lead to a small emission multiplier and vice versa. Having information on the magnitude of emissions that result from an investment of a given amount (i.e., the emission multiplier and not just absolute emissions), is one of the vital pieces of information that would be needed to determine the design of efficient "green" policies that seek to decouple economic growth from environmental damage.

Data for the employment, income, and emission multipliers are from the GTAP-POWER database version 10 which includes the global economy in 2014 and represents the I-O tables of 141 countries and regions, where regions represent aggregations of small countries by continents.

2.3. Emission data

We calculate three sets of emission multipliers: CO_2, Non-CO_2 GHGs, and a set of Other Air Pollutants. To estimate emission multipliers, three key emission data sources were used. The GTAP 10 Power database (Chepeliev, 2020c) is used as the source of CO_2 emissions from fossil-fuels combustion. For the non-CO_2 greenhouse gas (GHG) emissions, which include CH_4 (methane), N_2O (nitrous oxide) and the group of fluorinated gases (F-gases), we rely on Chepeliev (2020a). Global warming potentials (GWPs) for conversion to CO_2-equivalents are based on the IPCC's Fourth Assessment Report (AR4) (Forster et al., 2007). Though, IPCC's AR5 also provides GWPs, current UNFCCC guidelines require the use of the GWP values for the IPCC's AR4. For other air pollutants – black carbon (BC), carbon monoxide (CO), ammonia (NH3), non-methane volatile organic compounds (NMVOC), nitrogen oxides (NO_x), organic carbon (OC), particulate matter 10 (PM_{10}), particulate matter 2.5 ($PM_{2.5}$) and sulfur dioxide (SO_2), we rely on Chepeliev (2020b). For all substances 2014 emissions data are used, which corresponds to the latest reference year of the GTAP 10A database (Aguiar et al., 2019).

For non-CO_2 GHG emissions and emissions of air pollutants, two local modifications have been introduced relative to the publicly available versions of the corresponding databases, as documented in Chepeliev (2020a; 2020b). The data are adjusted to ensure accuracy and consistency with other sources, such as national emissions inventory.[6]

2.4. Sectoral and geographical aggregation

The sectoral aggregation is presented in Annex I. As shown in this Annex, economic activities are classified into 37 sectors. The GTAP power database divides the global economy into 141 countries. In this paper we cover all countries presented in this database.

3. Results

This section presents some of the key findings from the simulations. We begin by ranking sectors by their employment, value-added, GHG emissions and $PM_{2.5}$ emissions multipliers to

[6] Two adjustments are important to note. First, it was identified that in some country cases reported Fugitive emissions from solid fuels (IPCC 1B1 category), which in the GTAP database correspond to the coal sector ('coa'), are much higher than the corresponding regional average intensities per ton of solid fuel production. This was the case for both non-CO2 GHG emissions and air pollutants. To address this issue, we have revised an approach for emissions redistribution (for the selected country cases) and redistributed "1B1" emissions between not only coal, but also other fossil fuels and electricity, assuming that in the initial country reporting some misallocation of emissions could have occurred. Such treatment has impacted mostly small fossil fuel producers in Africa. Second, in the case of non-CO2 GHG emissions only, it was identified that emission intensity of the raw milk production activity ('rmk') in the GTAP database is much higher in some countries compared to the corresponding region's average intensity. As in the case of fugitive emissions discussed above, such large deviations for the raw milk activity were observed mostly in some African countries. To address this issue, we have revised the treatment of emissions reallocation and assumed that emissions from dairy animal care attributed to both raw milk and cattle sectors ('ctl') in the GTAP database.

provide a global picture of the potential for job creation, economic growth, and "greening" the economy through lower emission investments.[7] In the Annexes we also provide regionally disaggregated estimates using the World Bank's classification of regions.[8]

We exclude the primary and secondary energy sectors (fossil fuels and electricity) that have been intensively examined in previous work. Overall, the analysis finds that investment in service sectors such as health, education, communication, and a few non-service sectors such as forestry and construction are associated with relatively high job multipliers and lower GHG emissions multipliers. In some countries agriculture also falls into this category, with crops (with the exception of rice) and non-ruminant livestock, being associated with lower emissions and high employment multipliers. Conversely there are more severe trade-offs in other sectors where relatively high job growth is associated with large emission multipliers. As expected, the transport sectors elicit high GHG emission multipliers, with water transportation in particular exhibiting especially high GHG emissions. These are also sectors, where much of the benefits of job creation accrue to low-skill males. The direct employment multipliers of these sectors are usually small, but with large spillovers of jobs to the rest of the economy. In contrast, the "greener" education and health sectors tend to have high direct job multipliers, but limited spill-over to the rest of the economy, resulting in lower indirect job multipliers.

Beyond these broad trends there is considerable heterogeneity in the job creation potential, value-added, and emission intensities of economic activities across sectors and countries. Regardless of the global ranking of economic activities, the results suggest that the ratios of GHG emissions to job creation, or value-added, vary significantly across regions for each sector and across sectors within each country. This suggests that generalizations can be misleading. It also points to the fact that opportunities could be available for greening many sectors and making them more inclusive. Different emission intensities of economic activities *across* countries typically reflect the fuel mix in an economy, and the reliance on fossil fuels. Without a fundamental shift towards cleaner sources of energy, economic activities in fossil fuel dependent countries will continue to generate higher levels of GHGs than in those with cleaner fuel sources.

Finally, it is important to note that access to national I-O tables that provide more detailed sectoral disaggregation could help identify trade-offs between employment and emissions more effectively and accurately at the country level. The GTAP database used in the present study could be viewed as a first step in developing these more granular assessments of opportunities and trade-offs.

3.1. Ordinal ranking of economic activities

To identify common patterns in sectoral emissions and employment we divide each sector into terciles (33.3 percentile) first at the country level and then globally. At the country level, emissions multipliers are labeled brown, for the "dirtiest" industries in the highest tercile of emission multipliers; green representing the cleanest sectors in the lowest tercile of emission multipliers; and yellow for the intermediate tercile. The exercise thus identifies the relatively

[7] One could develop similar analyses using demand multipliers.

[8] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

"greener" sectors within a country in the first instance.[9] Investment in such green sectors would imply that a country can reduce the average emission intensity of the economy, as a step towards decoupling economic expansion and pollution emissions on the path to greening the economy.

Turning next to a comparison of sectors across countries, we use a similar ranking procedure. If a sector is classified as green (yellow, or brown) in a plurality (i.e., relative majority) of countries it is labeled as a globally green (yellow or brown) sector.[10] This is one way of illustrating similarities (or differences) in the relative performance of sectors across countries.

Employment multipliers are ranked in an analogous manner: High, Medium, and Low to provide a broad summary across sectors. The High and Low classes represent the sectors in the terciles with the highest and lowest employment multipliers, while Medium includes the intermediate sectors. Similarly, at the global scale, a sector is considered as High/Medium/Low if it falls in the High/Medium/Low category in a plurality of countries.

In summary, within country rankings provide a snapshot of where low emission and high job opportunities exist within the country, while the distribution of performance across countries can be used to identify outliers where attention may be needed to implement measures that can contribute to reducing emissions.

GHG emissions multiplier

Figure 1 summarizes the outcome of the ranking process for the emission multipliers. It shows that in an overwhelming majority (139 of 141) of countries the Other Transportation sector is ranked in the highest tercile of GHG emissions multipliers. Other brown sectors include: Livestock (excluding non-ruminants), Water Transportation, Water (including sewage), Air Transportation, Paddy Rice, and Non-Ruminant Livestock. There is much variation across countries in some sectors – such as the Non-Ruminant Livestock sector which is brown in a relatively smaller number of countries. Similarly, 10 sectors fall in the intermediate category, which generally exhibits much more heterogeneity across countries. For instance, Trade with 97 countries and Mining with only 64 countries representing the upper and lower boundaries of a relative majority. On the other hand, the Green category includes: Public Administration, Health, Education, Textile-Wearing-Leather, Construction, Machinery-Equipment, Wood-Paper, Forestry, Communication, and Fishing.

In interpreting these results it is instructive to distinguish between *absolute* emissions and *relative* emissions. The absolute emissions in a sector may be high, either due to the size of the sector (the scale effect), or because it has a high emissions intensity. The emissions multiplier measures the latter – the relative emissions that results from an investment of a given amount. Hence, an investment in a sector with high absolute emissions but a large value chain would lead to a lower emission multiplier than a sector with the same level of emissions but a smaller value-added chain. If the aim is to green growth of an economy, then emission intensities provide valuable information as these capture changes due to (say) cleaner production techniques (holding value added constant), as well as changes due to improvements in

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[9] A sector with the same emission multiplier in two countries, could be classified as Green in one and Brown in the other depending upon the emission performance of other sectors in each economy.

[10] Note that since there are three categories, a plurality (which identifies the highest number) rather than an absolute majority (which requires more than 50 percent), is the more appropriate criterion to classify the distribution of sectors globally. However, in most cases the plurality coincides with the absolute majority.

productivity (holding emissions constant). Both changes are desirable to decouple economic growth from environmental damage. However. a focus on absolute emissions will ignore the benefits of expanding sectors with lower emission intensities, at the expense of others.

A notable example in Figure 1 is the Construction sector which is categorized as green. However, Construction is often viewed as a is a major source of GHG emissions - but this may be due to the size of the sector in most countries. The production value created by the sector is significantly large,[11] with value-added (wages and payments to capital) accounting for a large share of the cost structure. Moreover, the polluting materials that are used in the sector are relatively inexpensive compared to the cost of other inputs. Hence, the overall value of the dirty inputs used by the sector represents a small fraction of its overall production costs. These factors contribute to a low GHG emission multiplier for the Construction sector. Another prominent example of a sector typically perceived as being highly polluting is the Textile-Wearing-Leather industry. While the sector uses emissions-intensive inputs such as cotton, industrial fibers, livestock products, and petrochemical products to operate, like the Construction sector, these inputs account for a relatively small share in the overall cost structure of the sector, while the value-added share is significant. Moreover, the combustion emissions due to energy consumption of the sector are not large. Thus, additional investment in the sector generates substantially greater additional output, relative to the emissions that it generates. The forestry sector is another case that may seem anomalous. It emerges as "green" for a different reason. The GHG multiplier captures improvements in soil organic carbon and forest carbon sequestration due to investment in the forestry sector.[12]

For completeness, Figure 2 summarizes the entire distribution of GHG emission multipliers across the three categories and confirms the same patterns and heterogeneities across sectors. Sectors such as Public Administration sector are ranked Green in an overwhelming majority (134) of countries, while the Other Transportation sector is also Brown in a majority (139) of countries. On the other hand, there is considerable heterogeneity across countries in sectors such as Mining, Electronics, and Processed Food and Crops.

[11] According to the GTAP database, at the global scale, Construction is the second largest sector in terms of the value of production, after the financial and insurance sector.

[12] Note that the forestry sector represents managed forest activities and its products. Since managed forests typically entail managed rotation, these activities do not entail deforestation.

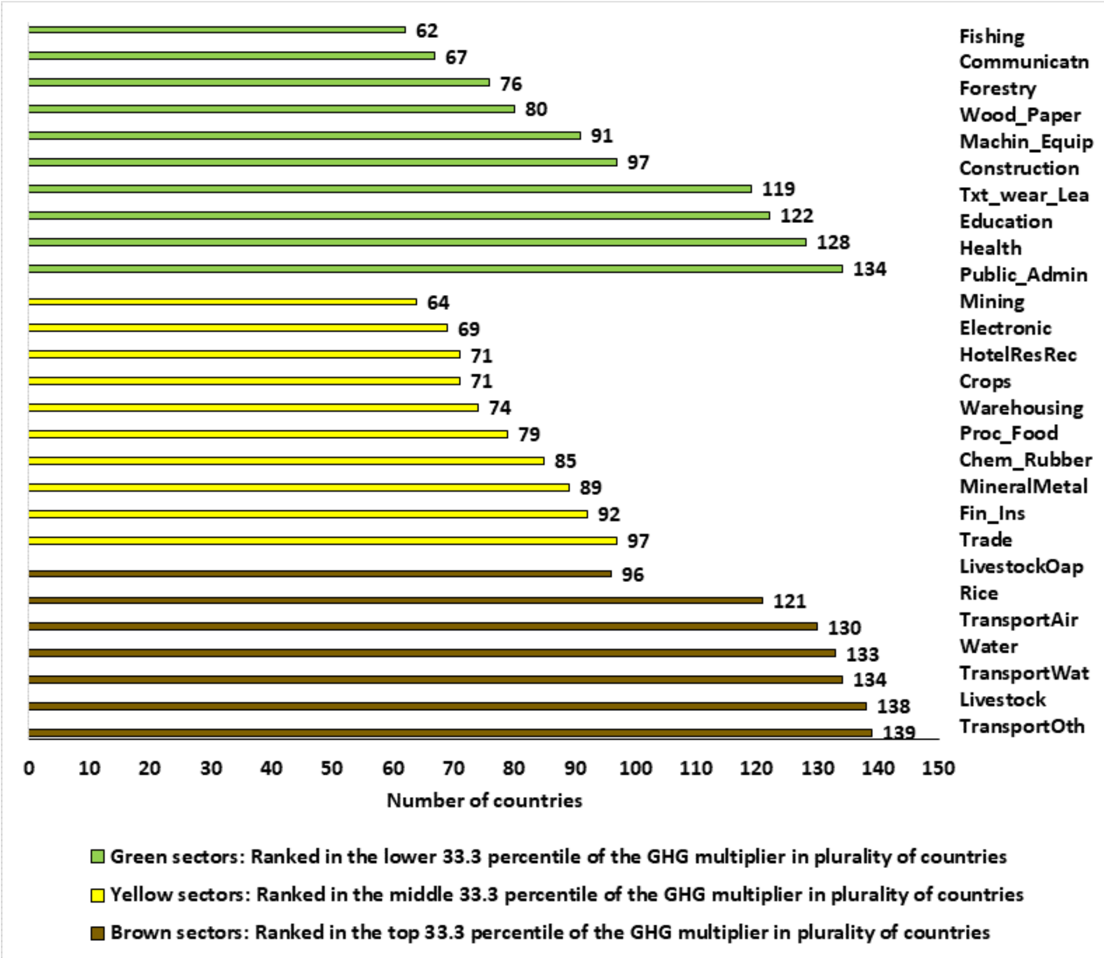

Figure 1. A global ranking of economic activities based on their GHG multipliers: Figures on the bars represent the number of countries that fall in the specified category for each sector

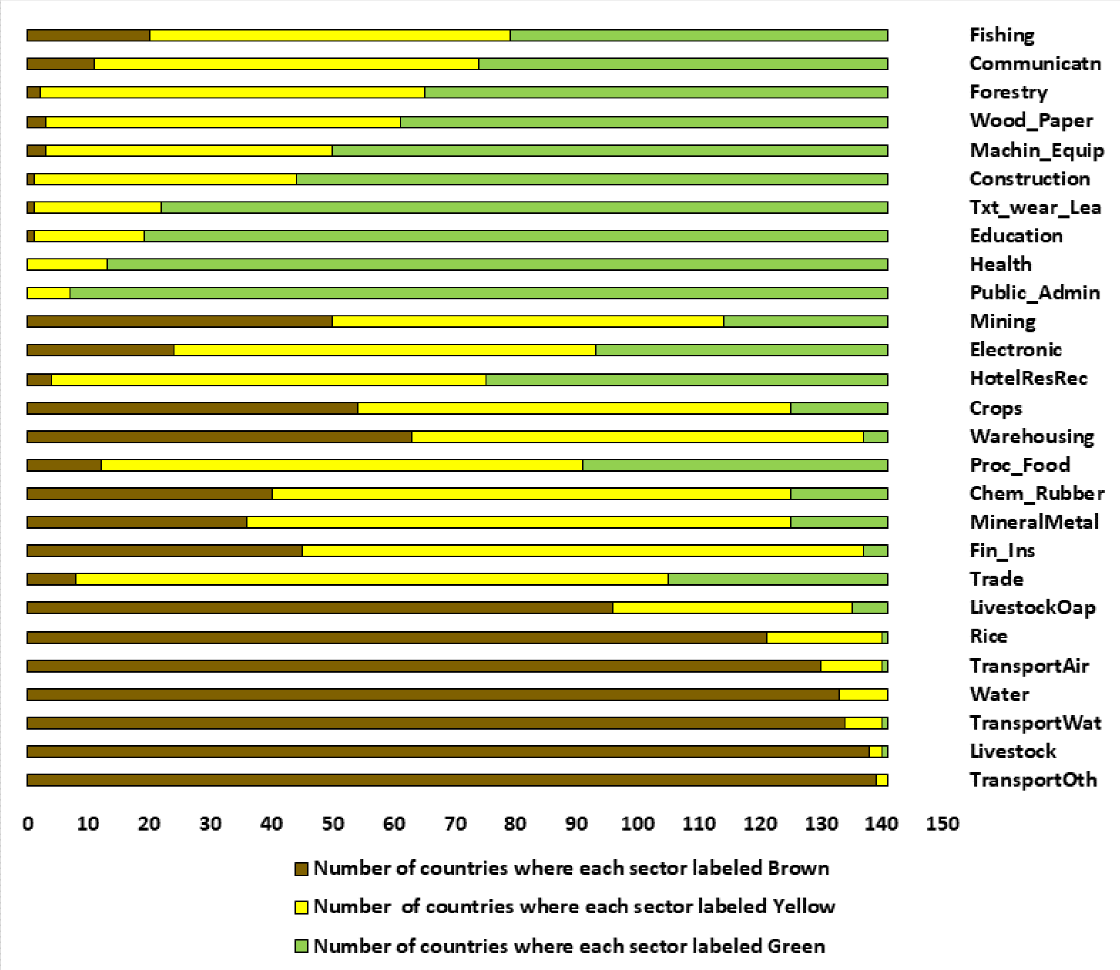

Figure 2. Number of countries that labeled Brown, Yellow, or Green for each non-energy sector based on the sectoral GHG emissions multipliers

$PM_{2.5}$ air pollutant multiplier

Using the same approach, we rank sectors by the $PM_{2.5}$ multiplier. Global rankings of economic sectors are shown in Figure 3. The rankings are similar to those of the GHG multipliers, with some exceptions. Figure 4 compares the $PM_{2.5}$ and GHG multipliers and clearly shows that the two are highly correlated, with an R^2 of about 0.85. Since $PM_{2.5}$ has local and immediate health effects an implication of this finding is that targeting sectors with high $PM_{2.5}$ emissions with the appropriate interventions would yield simultaneous longer-term climate co-benefits in terms of lower greenhouse gases. Given this high correlation, the rest of this paper mainly concentrates on GHG emissions.

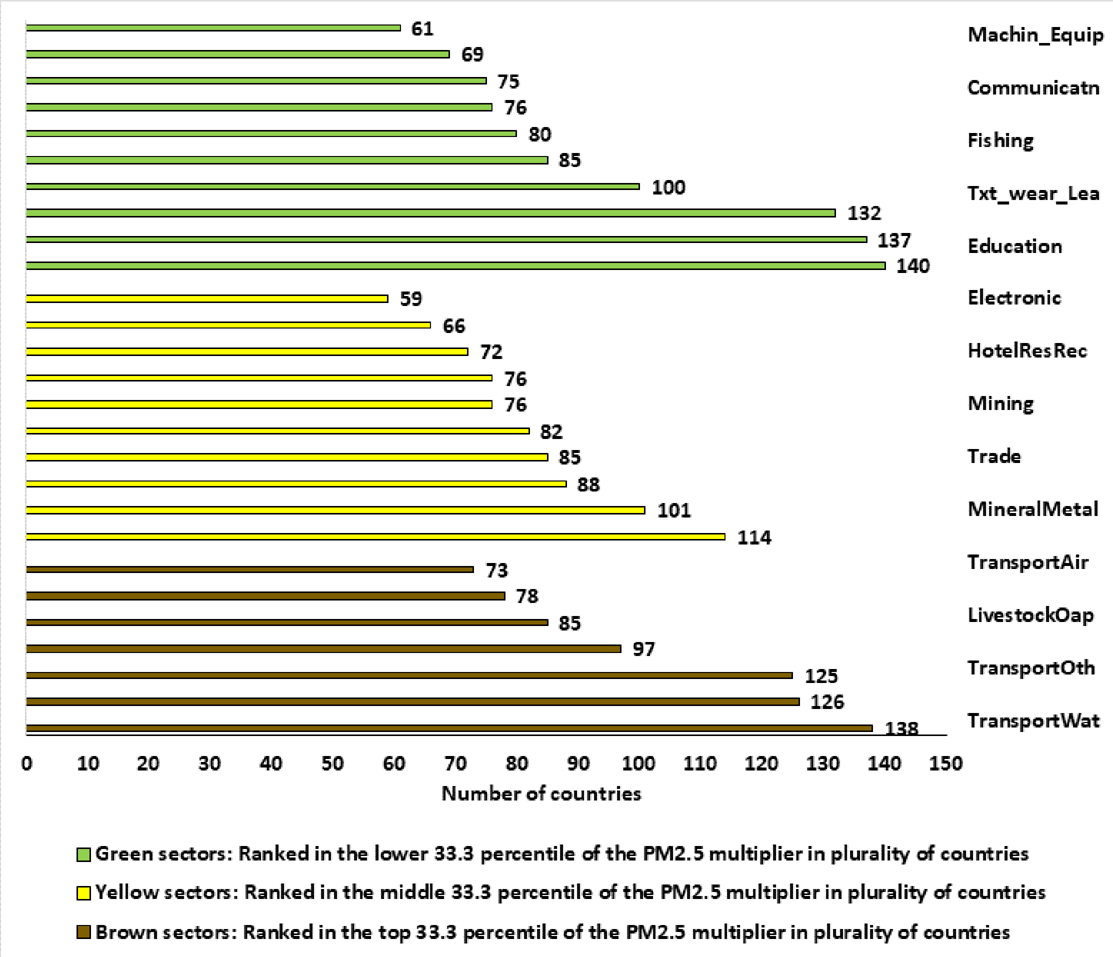

Figure 3. A global ranking of economic activities based on their PM2.5 multipliers: Figures on the bars represent the number of countries fall in each category for each sector

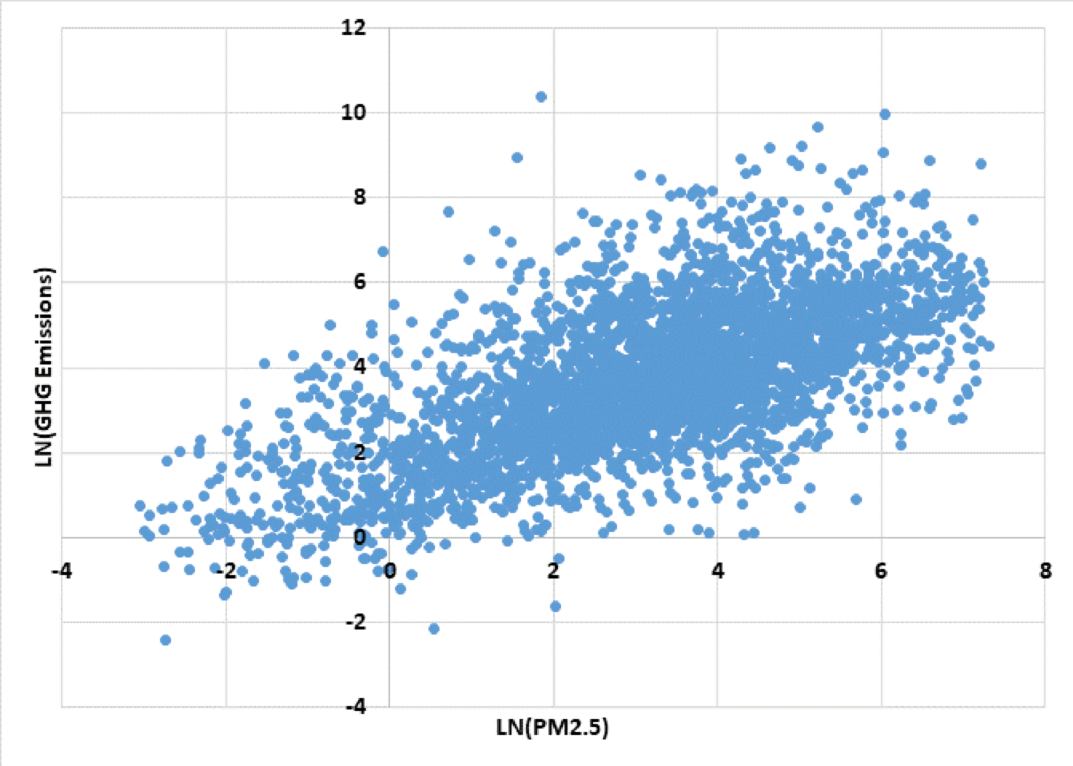

Figure 4. Correlation between the PM2.5 and GHG emissions multipliers

Employment multipliers

Figure 5 divides the non-energy sectors into terciles of the employment multipliers labeled as High, Medium, and Low. There are 12 sectors in the top tercile with high employment multipliers, with significant majorities in Finance-Insurance, Health, Education, and Rice sectors. Seven sectors form the Medium category and includes Warehousing with 95 countries in the upper bound of this category and Mining with only 62 countries in the lower bound. There is much variation in the employment multiplier across countries in the intermediate multiplier sectors. Finally, there are eight sectors in the low employment multiplier category. Electronics in the upper bound with 117 countries and Wood-Paper with 79 countries are the lower bound of this class of employment.

The variation in employment multipliers across countries in a given sector often reflects differences in industry structure and technology. For instance, the Textile-Wearing-Leather sector falls in the Low employment multiplier category in a majority of 95 countries out of 141 countries, where the sector is found to be relatively capital intensive according to the GTAP database. Conversely, in 5 countries the sector is relatively labor intensive with High employment multipliers and is in the intermediate range in 40 countries.

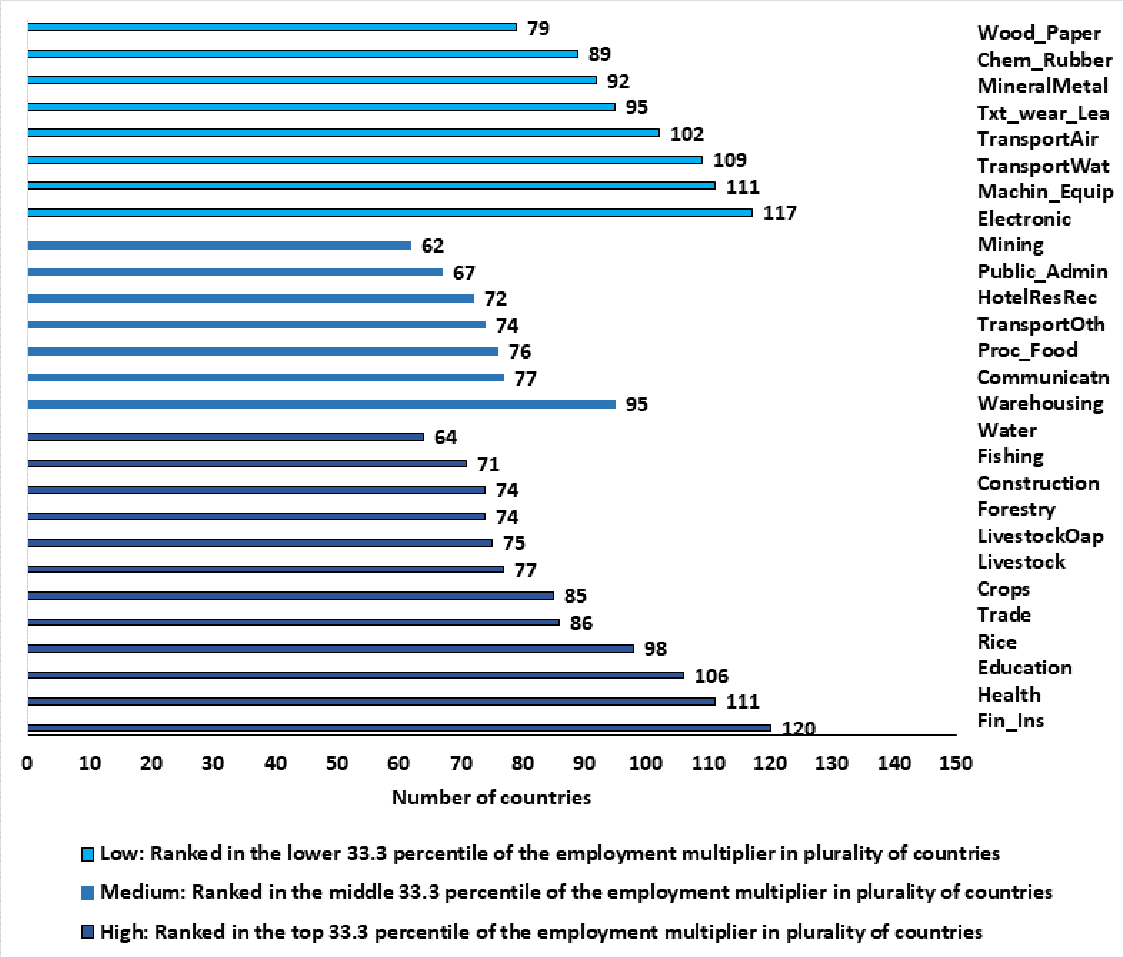

Figure 5. A global ranking of economic activities based on their employment multipliers: Figures on the bars represent the number of countries fall in each class for each sector

Intersection between GHG and employment multipliers

Table 1 presents the joint distribution of the GHG and employment multiplier rankings as a general guide for fiscal stimulus packages that aim to maximize employment while controlling GHG emissions. It also points to sectors which have high job creation potential, but where attention may be needed to reduce pollution or greenhouse gas emissions, so that short-term efforts of recovery are not pursued at the cost of long-term sustainability.

Table 1. Joint impacts of sectoral investment: Green versus Employment

Description		GHG emissions		
		Brown	Yellow	Green
Employment multiplier	Low	Transport-Air, Transport-Water	Chem-Rubber, Electronic, Mineral-Metal	Machin-Equip, Txt-wear-Lea, Wood Paper
	Medium	Transport-Other	Hotel-Res-Rec, Mining, Proc-Food, Warehousing	Communication, Public-Admin

	High	Livestock, Livestock-Oap, Rice, Water-Treat	Crops, Fin-Ins, Trade	Construction, Education, Fishing, Forestry, Health

The Air and Water Transportation sectors occupy the least attractive spot of this table in the Low-Brown cell which represents low employment and high GHG categories. On the other side sectors such as Construction, Education, Fishing, Forestry,[13] and Health lie in the "sweet spot" of High employment and Greener multipliers in a large number of countries.[14] Other sectors such as Hotel-Restaurant-Recreation, Mining, Processed Food, and Warehousing fall in the middle ranges of the joint distributions of employment and GHG multipliers, or the edges of Table 1 which represent various mixes of employment and GHG categories.

Gender and skills in employment

While the total job creation potential of an investment is important, governments may also be concerned about the distributional consequences and the impact on female labor force participation rates. Figure 6 presents the share of female labor in the employment multiplier, at the global scale (the red line) averaged across sectors and in each sector, mapped on to the GHG classification presented in Figure 1. On average the share of female labor in the employment multiplier is about 37% globally with significant variation ranging from a low of about 12% in construction to around 65% in the health sector. An especially notable feature is that the sectoral share of female labor is above the global average mainly in some of the Yellow and Green categories including Trade; Financial and insurance; Processed food; Hotels, Restaurants, and Recreational Activities; Health; Education; and Textile-Wearing-Leather sectors. Thus, when designing labor policies which emphasize the importance of female labor, one could unintentionally also generate environmental co-benefits.

[13] See footnote 11 regarding the forestry sector.

[14] It is important to emphasize that "Green" here is defined as having low GHG emissions multipliers, as defined based on Scope 3 emissions in GTAP. It would not, for example, take into account emissions that could result from induced land use changes resulting from construction sector activity or emissions / loss of carbon sinks that could result from unsustainable management of forests and fisheries.

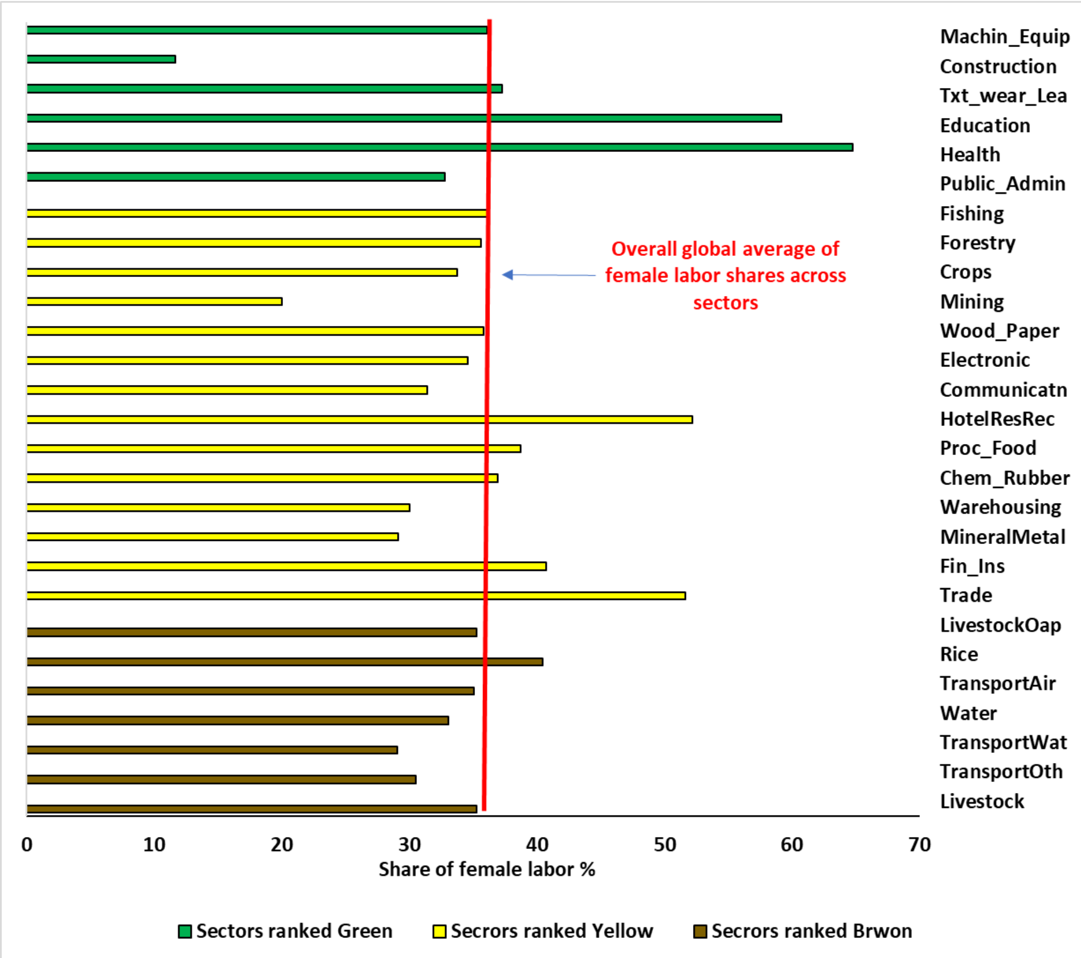

Figure 6. Share of female labor in employment multiplier at the global scale and by sector. The overall global average represents the simple average of female labor shares over sectors and countries. The bars represent the simple average of female shares over countries for each sector. The Brown, Yellow, and Green classes represent the GHG classification of Figure 1.

Next, Figure 7 replaces the share of female labor with the share of unskilled labor. The results indicate that on average the share of unskilled labor in the employment multiplier is about 71% at the global scale (indicated by the blue line). As one might expect, Figure 7 shows that the share of unskilled labor is significantly lower than the global average in sectors such as Education, Health, and Public Administration (about 41%). On the other hand, this share is considerably higher than the global average in the Crops and Livestock industries (87% in Livestock and 90% in Crops). The share of unskilled labor is usually close to the global average in many industries that fall in the Yellow category.

A comparison between Figure 6 and Figure 7 indicates that the shares of female labor and unskilled labor in the overall employment multiplier do not coincide in many sectors at the global scale, suggesting that policy makers may face trade-offs between jobs that promote gender parity and those that promote employment amongst the lower skilled.

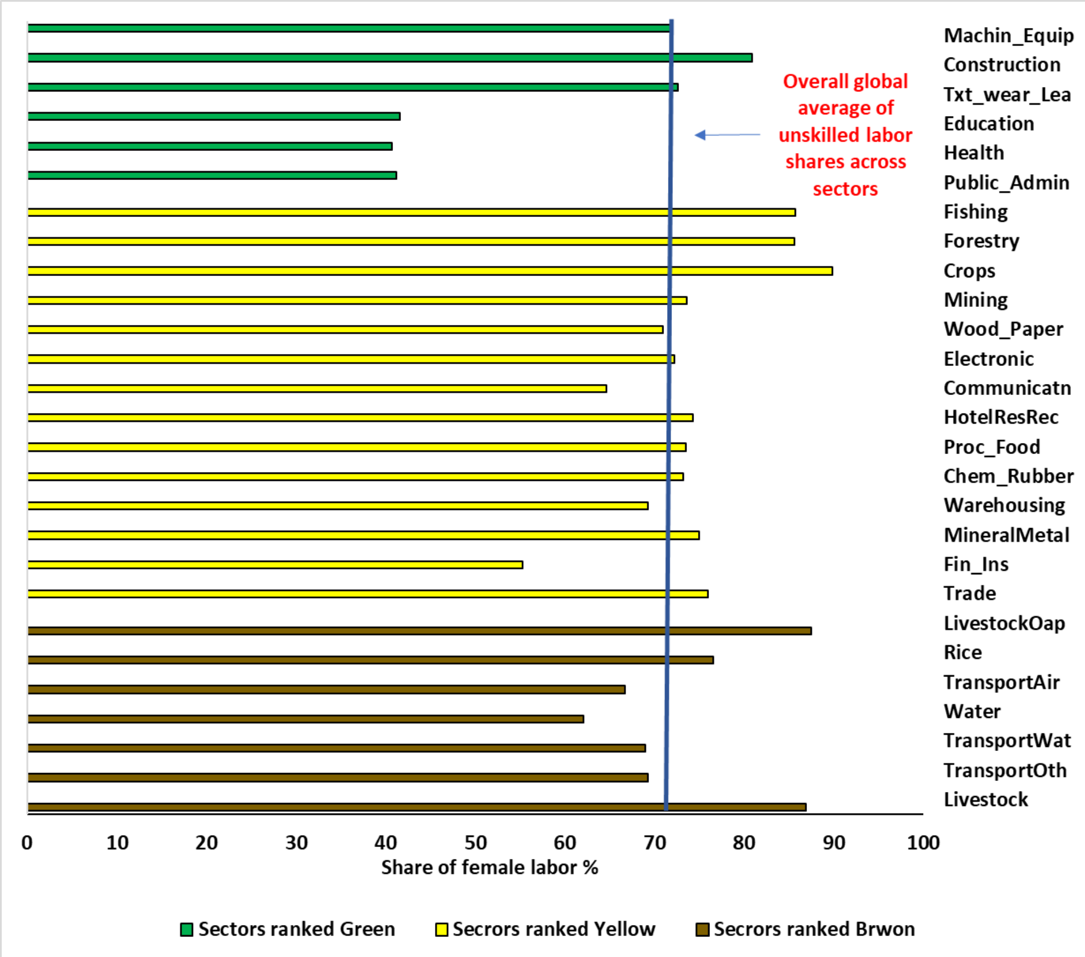

Figure 7. Share of unskilled labor in employment multiplier at the global scale and by sector. The overall global average represents the simple average of unskilled labor shares over sectors and countries. The bars represent the simple average of unskilled labor shares over countries for each sector. The Brown, Yellow, and Green classes represent the GHG

3.2. Cardinal ranking of GHG emissions and employment

The ordinal rankings provided thus far are useful but ignore the distance between sectors across the employment and GHG indices. The subsection seeks to address this issue by providing measures that facilitate comparisons by normalizing the indices to account for differences in the size of economies. A one million dollar stimulus will have negligible employment effects in a large country than in would in (say) a small island economy. To allow for meaningful cardinal comparisons across countries this subsection standardizes the multiplier in terms of the emissions per unit employment and emissions per unit value added. The results suggest that the employment and value-added multipliers often diverge implying that there are trade-offs not only between economic and environmental objectives but at times also between growth and employment priorities.

We define the *GHG intensity of the employment multiplier* (henceforth *GHGEMP*), as the ratio of the GHG multiplier to the employment multiplier. It provides a metric, normalized by employment, of the relative "greenness" of job creation in a sector. In general, a smaller ratio is desirable as it indicates lower emissions per job created for a given investment in the sector.

We report four measures across the distribution to compare sector performance – an overall average as well as the low, middle, and high terciles of the *GHGEMP* index. Figure 8 summarizes the results:

- Panel A shows sectors with the smallest overall average of GHGEMP. The index ranges from 0.76 to 4.9 metric tons of GHG per unit of employment in Panel A (see the green bars). This group mainly contains services sectors and a few industries (e.g., Hotels and Recreation), that have low GHG emissions per unit of employment.
- Panel B represents the intermediate sectors. The overall GHGEMP ranges from 5.9 to 23.6 metric tons of GHG per unit of employment (see the yellow bars). This group is dominated by industries and a few service sectors with significantly higher values of the index than in Panel A.
- Panel C shows sectors with the worst performance (see the brown bars). This group comprises the dirtiest industries and services, with GHGEMP values that are extremely large, and significantly higher than the values of the other two groups.

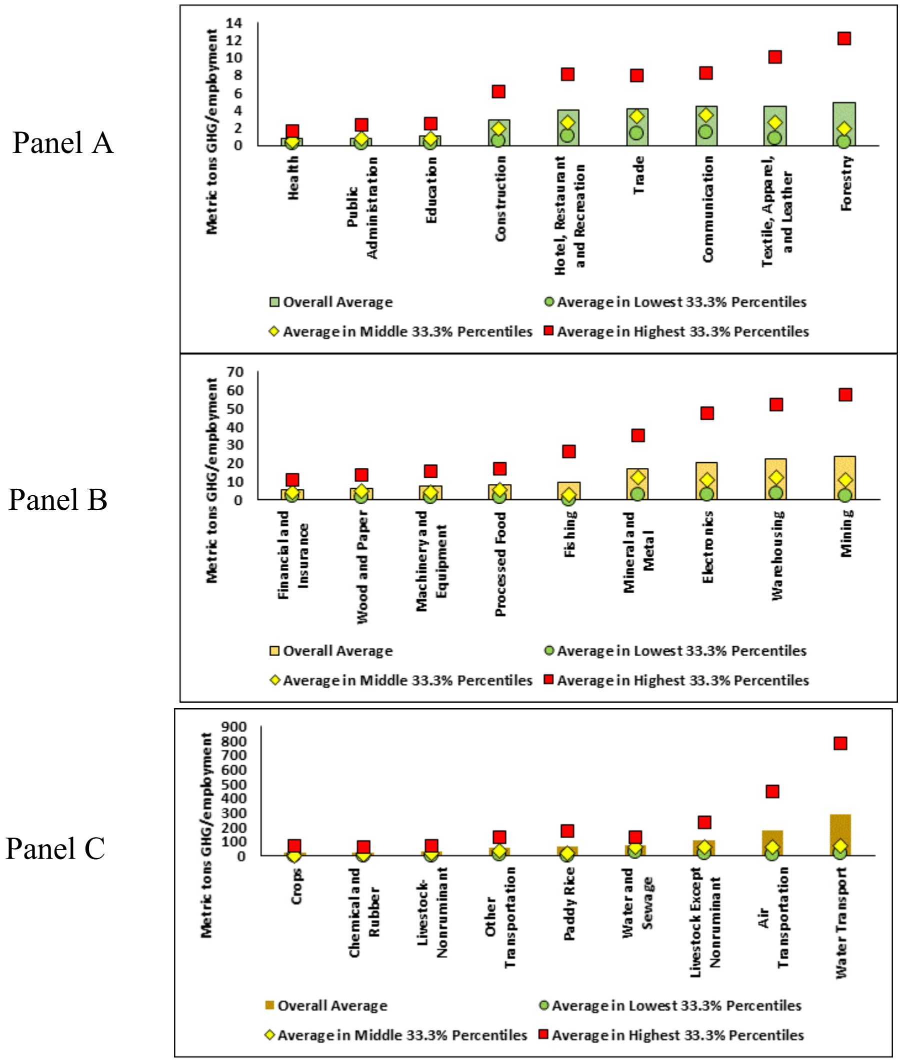

Figure 8. Global ranking of non-energy sectors based on generated GHG emissions per employment due to sectoral investment by $1 million

In summary, the cardinal rankings provided in Figure 8, identify a wide class of sectors that generate low GHG emissions for a given employment multiplier. These include Health, Public Administration, Education, Construction, Hotel-Restaurant-Recreation, Trade, Communication, Textile-Wearing-Leather, and Forestry. At the other extreme lie sectors such as Crops, Chemical-Rubber, Non-Ruminant Livestock, Other Transportation, Paddy Rice, Water-Sewage, Air Transportation, and Water Transportation that have the largest emissions for a given employment multiplier. It is also notable that many of the low emission sectors are also more gender neutral in their employment creation potential, whereas the "browner" sectors, tend to be in agriculture and the traditional industries that generate more employment for lower skilled males.

The heterogeneity of performance across countries shown in Figure 8 could be explained by various factors such as variations in capital intensity, differences in wage rates and prices across countries, variations in production technology, and different energy mixes. These sources of heterogeneity highlight potential opportunities for countries to shift towards cleaner production processes. It also suggests that proper trade policies could limit global emissions by directing demand towards countries with lower emission intensities. Annex II provides some additional discussion on emission and employment multipliers by selected sectors are regions.

3.3 Cardinal ranking of GHG emissions and value added

Investments that have relatively high employment multipliers may not necessarily have high value-added (income) multipliers. To further explore this relationship, we develop a new index comprising the ratio of GHG emissions to value-added multipliers (henceforth *GHGVAL*). Analogous to the previous case, we report: the overall global average for each sector, and averages across terciles in the first, second and third 33.3 percentiles. Figure 9 summarizes the outcomes shows these indices by sector in three panels:

- Panel A shows sectors with the smallest overall average value which ranges from 0.06 to 0.37 kilograms (Kg) of GHG per $ of value-added generated (see the green bars). This group includes service sector industries such as public administration and health that could be expected to have low emission to value-added multiplier ratios and the same industries as identified in the previous ranking of GHGEMP.
- In Panel B the intermediate range is dominated by industries with relatively low GHG emissions per unit of value-added, but significantly larger than the values of lowest group presented in Panel A.
- Panel C comprising the relatively "dirtiest" industries have GHGVAL values that are significantly higher than in the preceding groups. These are the sectors that may warrant priority investments in pollution abatement.

Notably, both rankings (GHGEMP and GHGVAL) identify similar industries in the three blocks. Health, Public Administration, Education, Construction, Hotel-Restaurant-Recreation, Trade, Communication, Textile-Wearing-Leather, and Forestry generate lowest GHG emissions per unit of employment and value-added. On the other hand, Crops excluding Paddy Rice, Chemical-Rubber, Non-Ruminant Livestock, Other Transportation, Paddy Rice, Water-Sewage, Livestock excluding Non-Ruminant, Air Transportation, and Water Transportation generate the largest emissions per job created and value-added generated. The implication for policy makers is that when there is a desire to limit GHGs within a constrained fiscal envelope, selecting amongst sectors with low GHGEMP and GHGVAL ratios may provide a useful way of delivering on both growth and environmental objectives. Fortunately, there is convergence across sectors with high employment potential and high value-added multipliers, easing somewhat the trade-offs between these economic policy objectives. However, as the graphs suggest, heterogeneity across countries is significant, necessitating more detailed analyses. Additional discussion on selected sectors and regional dimensions are included in Annex III.

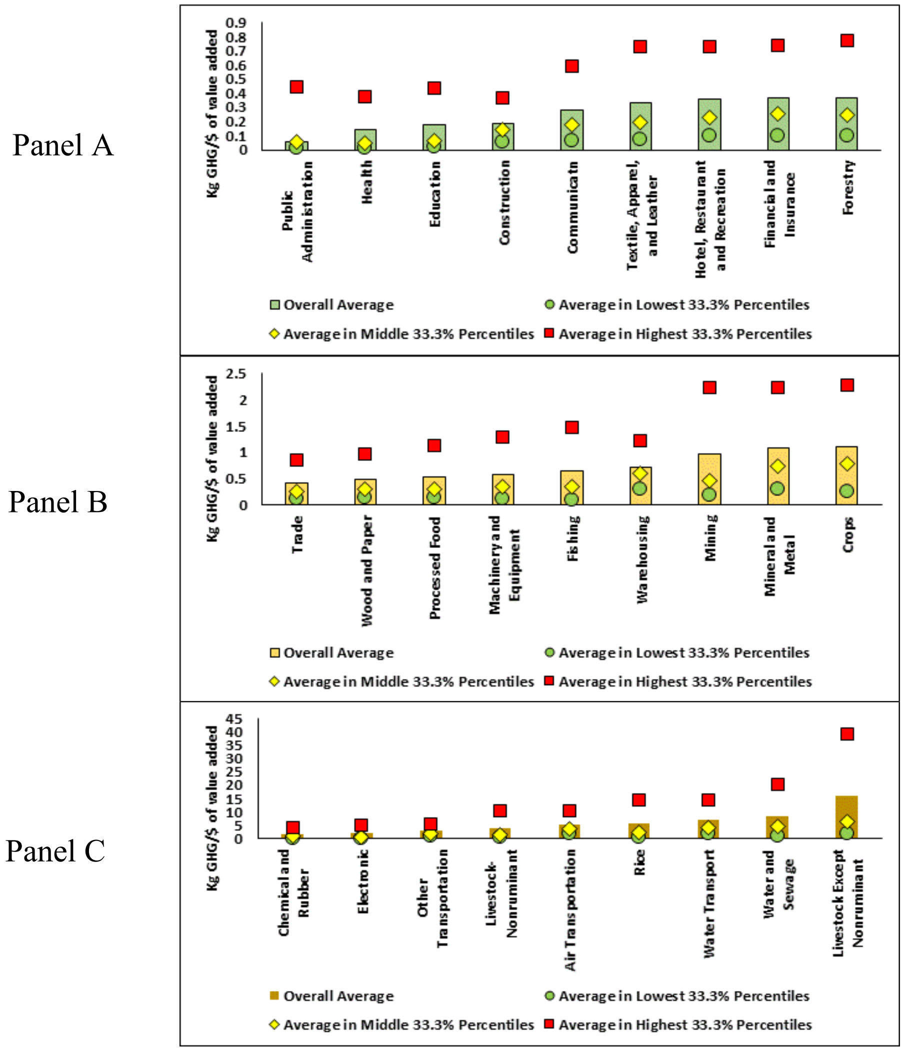

Figure 9. Global ranking of non-energy sectors based on generated GHG emissions per generated value-added due to sectoral investment by $1 million

4. Conclusions

As countries seek to restore economic growth and employment in a context of mounting debt and limited fiscal space, they confront difficult choices on ways to spend scarce budgets to achieve multiple goals. This paper presents data that could inform these decisions and help identify when spending entails sharp trade-offs between economic objectives and wider development benefits such as the social impacts (e.g., the gender or skill distribution of jobs) and environmental objectives (e.g., greenhouse gases and local air pollutants). Three broad conclusions emerge from the results of the I-O analysis presented in this paper.

First, the analysis finds, perhaps predictably, that many of the traditional sectors in agriculture and industry have large employment multipliers, but also generate male dominant, lower skill employment, and tend to have higher emissions multipliers. It is in economies dominated by these sectors that trade-offs to a “greener” transition will emerge most sharply. The good news is that even in these economies, there exist other sectors with high employment multipliers and low emissions, including sectors that are more conducive to female employment. In sum, there are opportunities in most economies to choose policy options that can stimulate the economy without worsening social outcomes (such as inequality and female employment) and environmental objectives. In the long term, thinking about greening and strengthening inclusion in sectors with high job multiplier potential may be important.

Second, the results suggest that meeting multiple objectives with a limited budget will typically entail making different choices than would eventuate with a single objective – such as maximizing employment or minimizing GHGs. The simulations involving GHGEMP and GHGVAL suggest that recovery programs designed to promote job creation may come at a cost of higher GHG emissions and local pollutants. Countries where sectors show systematically high emissions multipliers will face more difficult choices. When such trade-offs are found and cannot be avoided by a different set of policies or investments, choices will likely be based on value judgments and ideally made in a way that commands broad support.

Finally, the results uncover significant heterogeneity across countries, especially across the emissions multipliers and the gender distribution of employment. This implies that there may be scope for countries that lag in these dimensions to significantly improve their performance over time by emulating those that lead. Indeed, this heterogeneity suggests the choices and trade-offs noted in the previous paragraph may not necessarily be binding, at least over the medium term.

Achieving ‘catch-up’ may require some combination of adopting new technologies and business models and making progress on the supply side of the labor market. Most notably, many countries can close the gap by changing their underlying energy mix, which directly affects GHG multipliers without otherwise changing the production structure of downstream industries. This is particularly the case for many countries in EAP and ECA, regions which are relatively ‘brown’ and remain heavily reliant on coal for energy production. In these countries, shifting away from fossil fuels can avoid the need to trade off job creation and sustainability. The extent to which changing the energy mix, and more broadly achieving ‘catch up’ is feasible over the medium term will depend on country capacity, technical endowments, and comparative advantages, as well as domestic political economy. Beyond this, trade may offer a way to promote convergence to a more desirable equilibrium, with the right incentives.

The I-O modeling framework used in this paper provides a straightforward way to capture and analyze the forward and backward relationships among producers, consumers, and owners of the primary inputs, and their interactions in an economy. However, the approach is not without limitations. An important caveat is the fixed coefficient property which precludes substitutions that could happen in production, consumption, and trade relationships in the long run. Hence, the outcomes may not represent potential changes that could occur in the long run, particularly due to technological progress. Additionally, since the Social Accounting Matrixes (SAMs) that provide the data for the model are updated by countries with varying frequency, the analysis may not represent the most recent data for each country. In particular, the recent attempts to shift the energy mix towards renewables may not be fully reflected in the analysis due to time lags in the updating of SAMs.

Finally, it is important to note that the modeling is focused on a narrow subset of environmental concerns relating mainly to air pollution and climate change. We are unable at this stage to account for impacts on habitat loss and the contribution of the different sectors to the global biodiversity crisis. In particular it is known that roads that cut through natural habitats are typically the precursors of species extirpation and the extensification of agriculture, especially for commodities such as soy, beef and palm oil, are implicated in much habitat loss (Ceia-Hasse et al. 2017, Tollefson 2019). Exploring the differential impacts of sectoral investments on land-use change remains an urgent issue for consideration in future research, especially in the globally significant biodiversity hotspots.

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Annex I – Sectoral aggregation

Number	Code	Description (Detailed Sector Breakdown)	Aggregated sectors
1	pdr	Paddy rice	Rice
2	wht	Wheat	Crops
3	gro	Cereal grains nec	Crops
4	v_f	Vegetables, fruit, nuts	Crops
5	osd	Oil seeds	Crops
6	c_b	Sugar cane, sugar beet	Crops
7	pfb	Plant-based fibers	Crops
8	ocr	Crops nec	Crops
9	ctl	Bovine cattle, sheep and goats, horses	Livestock
10	oap	Animal products nec	Livestock Oap
11	rmk	Raw milk	Livestock
12	wol	Wool, silk-worm cocoons	Livestock
13	frs	Forestry	Forestry
14	fsh	Fishing	Fishing
15	coa	Coal	Fossil fuels
16	oil	Oil	Fossil fuels
17	gas	Gas	Fossil fuels
18	oxt	Other Extraction (formerly omn Minerals nec)	Mining
19	cmt	Bovine meat products	Processed food
20	omt	Meat products nec	Processed food
21	vol	Vegetable oils and fats	Processed food
22	mil	Dairy products	Processed food
23	pcr	Processed rice	Processed food
24	sgr	Sugar	Processed food
25	ofd	Food products nec	Processed food
26	b_t	Beverages and tobacco products	Processed food
27	tex	Textiles	Textile, wear, lea
28	wap	Wearing apparel	Textile, wear, lea
29	lea	Leather products	Textile, wear, lea
30	lum	Wood products	Wood, paper
31	ppp	Paper products, publishing	Wood, Paper
32	p_c	Petroleum, coal products	Petroleum
33	chm	Chemical products	Chem Rubber
34	bph	Basic pharmaceutical products	Chem Rubber
35	rpp	Rubber and plastic products	Chem Rubber
36	nmm	Mineral products nec	Mineral Metal
37	i_s	Ferrous metals	Mineral Metal
38	nfm	Metals nec	Mineral Metal
39	fmp	Metal products	Mineral Metal
Number	Code in GTAP	Description (Detailed Sector Breakdown)	Aggregated sectors
40	ele	Computer, electronic and optical products	Electronics

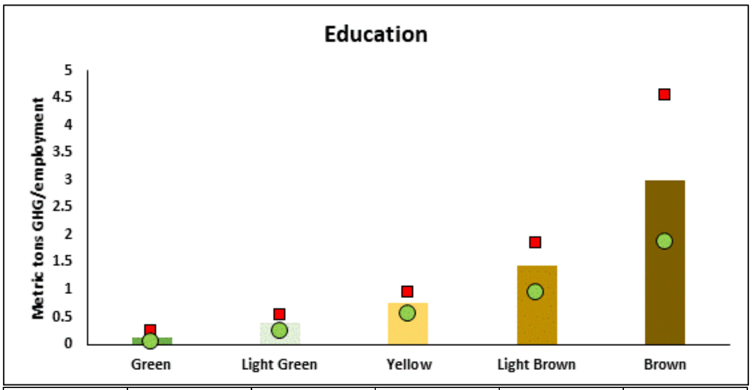
41	eeq	Electrical equipment	Electronics
42	ome	Machinery and equipment nec	Machin Equip
43	mvh	Motor vehicles and parts	Machin Equip
44	otn	Transport equipment nec	Machin Equip
45	omf	Manufactures nec	Machin Equip
46	TnD	Electricity Transition	Elec Transition
47	NuclearBL	Electricity Nuclear Base Load	Elec Other
48	CoalBL	Electricity Coal Base Load	Elec Coal
49	GasBL	Electricity Gas Base Load	Elec Gas
50	WindBL	Electricity Wind Base Load	Elec Sol Win
51	HydroBL	Electricity Hydro Base Load	Elec Other
52	OilBL	Electricity Oil Base Load	Elec Other
53	OtherBL	Electricity Other Base Load	Elec Other
54	GasP	Electricity Gas Pick	Elec Gas
55	HydroP	Electricity Hydro Pick	Elec Other
56	OilP	Electricity Oil Pick	Elec Other
57	Solar	Electricity Solar	Elec Sol Win
58	gdt	Gas manufacture, distribution	Gas
59	wtr	Water	Water
60	cns	Construction	Construction
61	trd	Trade	Trade
62	afs	Accommodation, Food and service activities	Hotels Res Rec
63	otp	Transport nec	Transport Other
64	wtp	Water transport	Transport Water
65	atp	Air transport	Transport Air
66	whs	Warehousing and support activities	Warehousing
67	cmn	Communication	Communication
68	ofi	Financial services nec	Fin-Ins
69	ins	Insurance (formerly isr)	Fin-Ins
70	rsa	Real estate activities	Fin-Ins
71	obs	Business services nec	Fin-Ins
72	ros	Recreational and other services	Hotels Res Rec
73	osg	Public Administration and defense	Public admin
74	edu	Education	Education
75	hht	Human health and social work activities	Health
76	dwe	Dwellings	Dwelling

Annex II - Emissions versus employment by sector and region

Here we provide a sector-by-sector analysis of the relationship between the GHGs and employment multipliers by region. To accomplish this task, we continue to use the index of GHGEMP by sector and country. To highlight regional differences, we divide the whole world into 7 regions of EAP, ECA, LAC, MENA, NAM, SAS, and SSA following the World Bank's definitions. For each sector, this analysis divides countries into 5 categories of Green (first 20 percentile), Light Green (second 20 percentile), Yellow (third 20 percentile), Light Brown (fourth 20 percentile), and Brown (fifth 20 percentile) based on their GHGEMP index. The analysis concentrates on three measures of GHGRMP in each sector: the Maximum, Minimum and Average values for each percentile category. This Annex depicts a figure for each sector representing these data items plus number of countries falling into each percentile by the regional aggregation mentioned above. In what follows, we analyze the results for three representative sectors, one from each panel of Figure 8: Education from Panel A, Processed food from Panel B, and Air Transportation from Panel C. The education sector represents a very low GHG intensity of the employment multiplier with a large direct employment effect and low employment spill over impacts on the rest of economy. It has a large female employment share as well. On the other hand, the food processing sector which belongs to the middle tier of GHG intensity of the employment multiplier has strong forward and backward links to other activities, make moderate to strong spill over employment in particular for female employment. Finally, the air transportation sector has a very large GHG intensity of the employment multiplier, very strong forward and backward links to other sector, major spill over employment effect, generating more indirect employment than direct employment.

Education

Figure II1 shows the information for the education sector which has a small overall global average of 1.1 metric tons of GHG emissions per unit of generated employment. The min, max, and average values are below 0.5 metric tons per employment in the first two categories of Green and Light Green. Members of LAC, MENA, and SSA mostly fall in these two categories. For example, 10 members of LAC, 5 members of MENA, and 7 members of SSA fall in the Green category.



EAP	1	6	1	2	10
ECA	2	3	14	17	9
LAC	10	11	2	0	1
MENA	5	4	4	1	1
NAM	0	0	0	0	3
SAS	4	0	0	1	1
SSA	7	4	7	7	3

Figure II1. Sector of Education: Index of GHGEMP- Bars represent average values, red squares show maximum values, green circle demonstrate minimum values, and numbers in the table show number of countries in each category.

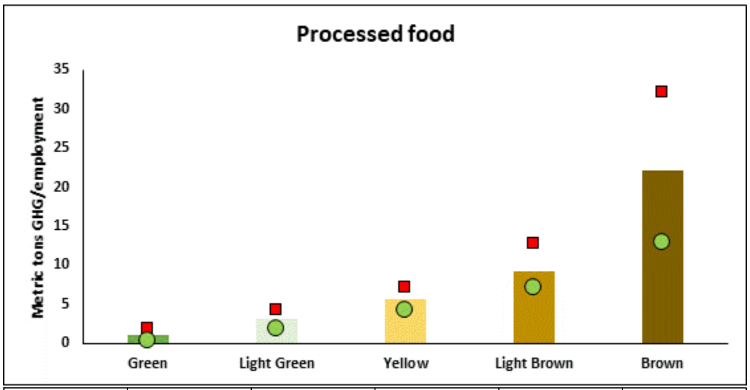
As shown in Figure II1, the average of GHGEMP in the Yellow category is about 0.75 metric tons of GHG emissions per employment (see the yellow bar). In this category, 14 and 7 countries are members of ECA and SSA, respectively. Only 4 members of MENA region fall in this category. The average of GHGEMP increases to 1.4 metric tons of GHG emissions per employment in the Light Brown category and most members of this category are from ECA region (17 countries) or SSA region (7 members). Moving from the Light Brown category to Brown category, the average GHG emissions per employment increases sharply from 1.4 to 3. Most members of the brown category are from EAP (10 members) or ECA (9 members).

Figure II1 also shows that as we move from the Green to Brown, the max value of GHEMP increases sharply. For example, the max value in the Brown category reaches to 4.5 metric tons per employment, 1.5 times higher than the average of this category.

In summary, for the sector of Education, the members of LAC, MENA, and SAS fall in the low percentiles of the GHGEMP index, while members of EAP and ECA belong to the higher percentiles of this index. Members of SSA appear in all most categories from the Green to Brown. There is a wide range and a large number of countries in EAP and ECA representing considerable higher GHG intensity of the employment multiplier in the sector. In some of these countries the energy intensity of education is higher than other countries. On the other hand, more coal used the mix of consumed energy in some these countries and that leads to higher GHG emissions. Finally, it is important to reemphasize even the GHG intensity of employment multiplier is significantly low for the education sector, even in the countries that fall in the top percentile.

Processed food

From the second panel of Figure 8, we further analyze the sector of Processed Food. Figure II2 shows the information for this sector which has a relatively moderate overall global average of 8.2 metric tons of GHG emissions per generated employment. For this sector, the min, max, and average values are below 4.2 metric tons per employment in the first two categories of Green and Light Green. Members of SSA (16 countries), SAS (4 countries), and LCA (4 countries) are the dominate members of Green category of this sector, while members of the Light Green category scattered around the aggregated regions.



EAP	2	5	2	6	5
ECA	2	6	9	13	15
LAC	4	6	11	1	2
MENA	1	5	3	2	4
NAM	0	0	0	1	2
SAS	4	1	1	0	0
SSA	16	5	2	5	0

Figure II2. Sector of Processed food: Index of GHGEMP- Bars represent average values, red squares show maximum values, green circle demonstrate minimum values, and numbers in the table show number of countries in each category.

As shown in Figure II2, the average of GHGEMP in the Yellow category of this industry is about 5.7 metric tons of GHG emissions per employment (see the yellow bar). In this category, 11 and 9 countries are members of LAC and ECA, respectively. Only 3 members of MENA region fall in this category. The average of GHGEMP increases to 9.2 metric tons of GHG emissions per employment in the Light Brown category and most members of this category are from ECA region (13 countries), EAP region (6 members). Moving from the Light Brown category to Brown category, the average GHG emissions per employment increases sharply from 9.2 to 22.2. In this sector, most members of the brown category are from ECA (15 members) or EAP (5 members). In this category, 4 countries are from LAC.

Figure II2 also shows that as we move from the Green to Brown, the max value of GHEMP increases sharply. For example, the max value in the Brown category reaches to 32.1 metric tons per employment, about 1.5 times higher than the average of this category.

In summary, for the sector of Processed food, the members of SSA, LAC, MENA, and SAS fall in the low percentiles of the GHGEMP index, while members of EAP and ECA belong to the higher percentiles of this index.

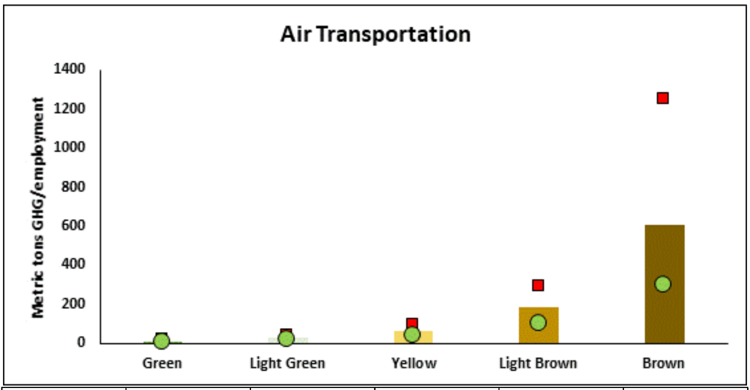
Air Transportation

Finally, from the third panel of Figure 8, we further analyze the sector of Air transportation. Figure II3 shows the information for this sector which has a large overall global average of 176.5 metric tons of GHG emissions per generated employment. For this sector, the min, max, and average values are below 40 metric tons per employment in the first two categories of Green and Light Green. Members of SSA (17 countries) and LCA (7 countries) are the dominate members of Green category of this sector, while members of the Light Green category scattered around the aggregated regions.

As shown in Figure II3, the average of GHGEMP in the Yellow category of this industry is about 59.9 metric tons of GHG emissions per employment (see the yellow bar). In this category, 10 and 6 countries are members of LAC and ECA, respectively. Only 4 members of MENA region fall in this category. The average of GHGEMP increases to 187.1 metric tons of GHG emissions per employment in the Light Brown category and most members of this category are from ECA region (12 countries), EAP region (5 members), and MENA (6 countries). Moving from the Light Brown category to Brown category, the average GHG emissions per employment increases sharply from 187.1 to 604.4. In this sector, most members of the brown category are from ECA (19 countries) and EAP (5 countries).

Figure II3 also shows that as we move from the Green to Brown, the max value of GHEMP increases sharply. For example, the max value in the Brown category reaches to 1249.3 metric tons per employment, more than twice of the average of this category.

In summary, for the sector of Air transportation, the members of SSA and LAC fall in the low percentiles of the GHGEMP index, while members of EAP, and ECA, belong to the higher percentiles of this index and MENA countries across all categories except the lowest tier.



EAP	2	3	5	5	5
ECA	1	7	6	12	19
LAC	7	4	10	1	2
MENA	0	3	4	6	2
NAM	0	0	0	3	0
SAS	2	3	1	0	0
SSA	17	8	2	1	0

Figure II3. Sector of Air transportation: Index of GHGEMP- Bars represent average values, red squares show maximum values, green circle demonstrate minimum values, and numbers in the table show number of countries in each category.

Similar graphs are available for other sectors upon the request

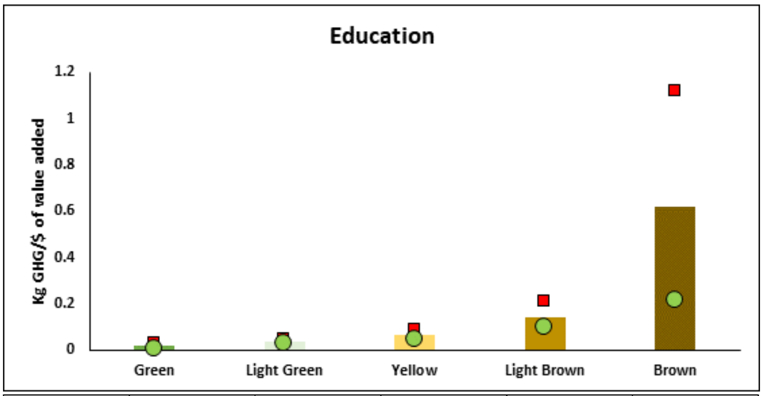
Annex III - Emissions versus value added by sector and region

Here we provide a sector-by-sector analysis of the relationship between the GHG and value-added multipliers using the index of GHGVAL. To accomplish this task, we follow the set up defined in section 3 for the case of GHGEMP. This Annex depicts a figure for each sector representing these data items. In what follows, similar to the case of GHGEMP index, we analyze the results for the three representative sectors of Education, Processed food, and Air Transportation.

Education

Figure III1 shows the information for the sector of education which has a small overall global average of 0.17 Kg of GHG emissions per generated value-added. For this sector, the min value is tiny (about 0.005 Kg/$) but the max value is significantly larger (1.12 Kg/$).

The average value of GHGVAL for the first four categories of Green, Light Green, Yellow, and Light Brown remains under 0.14 Kg/$. However, the average value of GHGVAL suddenly increases to the value of 0.62 Kg/$ in the Brown category. That is basically due to higher values of GHGVAL among the members of SSA region, as shown in Figure III1. This figure shows that most members of SSA falls in the Light Brown and Brown categories of GHGVAL. The size of this index in the SSA region is high due to low wage rates. Most members of LAC and MENA regions fall in the Green, Light Green, and Yellow categories of education, while the members of EAC region scattered across all various categories of Green to Brown.

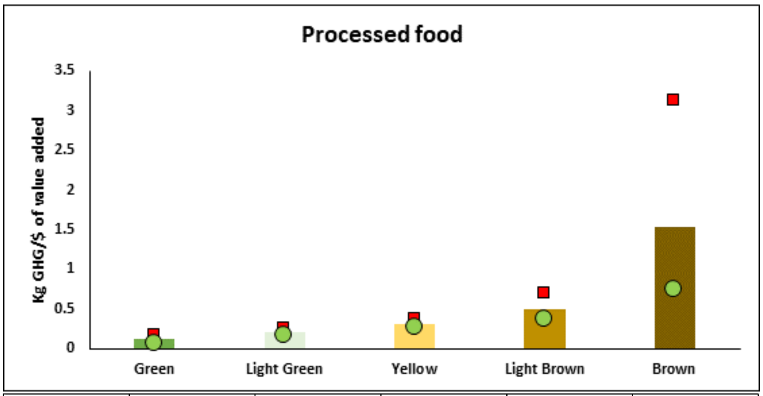


EAP	2	4	4	5	5
ECA	6	10	11	12	6
LAC	8	8	6	2	0
MENA	8	2	1	3	1
NAM	0	1	2	0	0
SAS	2	1	1	1	1
SSA	3	2	3	5	15

Figure III1. Sector of Education: Index of GHGVAL- Bars represent average values, red squares show maximum values, green circle demonstrate minimum values, and numbers in the table show number of countries in each category.

Processed food

Figure III2 shows the information for the processed food sector which has a relatively small overall global average of 0.53 Kg of GHG per $ of value-added generated. For this sector, the min value of GHGVAL is very limited (0.066 KG/$), but the max value is significantly larger (3.11 Kg/$) compared with the mean value. In this sector the mean value increases gradually from 0.12 Kg/$ for the Green category to 0.5 Kg/S for the Light Brown category and then it suddenly jumps to 1.52 Kg/$ in the Brown category. This jump is basically due to low wage rates in several countries in the SSA, SAS, MENA, and EAP regions.

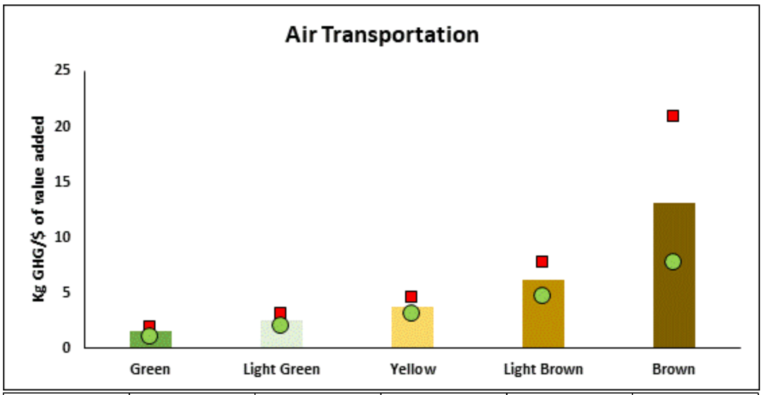


EAP	2	4	4	4	6
ECA	6	15	10	10	4
LAC	7	4	5	5	3
MENA	5	2	1	2	5
NAM	1	0	2	0	0
SAS	1	1	1	1	2
SSA	7	2	5	6	8

Figure III2. Sector of Processed food: Index of GHGVAL- Bars represent average values, red squares show maximum values, green circle demonstrate minimum values, and numbers in the table show number of countries in each category.

Air Transportation

Finally, Figure III3 shows the information for the air transportation sector which has a large overall global average of 5.4 of GHG per $ of value-added generated. For this sector, the min value of GHGVAL index is low (0.97 Kg/$). However, its max value is significantly larger (20.86 Kg/$). The mean value of this index for the categories of Green, Light Green, and Yellow remains under 3.7 Kg/$, but it increases to 6.2 Kg/$ in the Light Bwown category and then sharply elevates to 13.1 Kg/$ in the Brown category. As shown in Figure III2 many members of the ECA regions falls in these two high emissions categories. This figure indicates that 10 members of the ECA region belong to the Light Brown category and 14 of them fit in the Brown category. Figure III3 also shows that 12 members of the EAP region fall in the Light Brown and Brown categories.



EAP	6	0	2	6	6
ECA	6	7	8	10	14
LAC	8	5	5	4	2
MENA	1	6	3	2	3
NAM	0	2	1	0	0
SAS	2	1	1	2	0
SSA	6	7	8	4	3

Figure III3. Sector of Air transportation: Index of GHGVAL- Bars represent average values, red squares show maximum values, green circle demonstrate minimum values, and numbers in the table show number of countries in each category.

Similar graphs are available for other sectors upon the request