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Challenges in the Transition to a Low-Carbon Economy for Developing Countries

Estimating Capital-Use Matrices and Imported Needs

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Challenges in the Transition to a Low-Carbon Economy for Developing Countries

Estimating Capital-Use Matrices and Imported Needs

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Abstract

The low-carbon transition in developing countries requires large investments in new technologies. However, since capital goods production is concentrated mostly in more advanced economies, this transition will generate a high demand for imported Machinery and equipment in these countries, leading to a higher demand for foreign exchange and potentially creating negative macroeconomic pressures. To account for the important role of capital goods in this transition process, we endogenize fixed capital in the input-output (IO) framework, estimating capital use matrices for six developing and emerging countries in Latin America and the Caribbean within the Gloria sectoral framework from 1990 to 2020. Based on these estimates, we show how the endogenization of capital can offer a nuanced sectoral perspective on the multidimensional challenges faced by developing countries during their low-carbon transition, including the external and socio-economic dimensions. Our findings suggest that the inclusion of capital in the IO framework reveals a substantial deepening of the external constraint for developing countries.

We find that for every dollar invested solely to maintain current productive capacity, on average more than 45% leaks directly and indirectly to foreign producers through imports. Some socio-economic benefits of green investment, such as employment generation, are absorbed by the rest of the world, rather than fostering domestic job creation. Essentially, with the growing demand for foreign-produced capital goods generated by the low-carbon transition, developing countries will face an increased external constraint and substantial socio-economic imbalances as they embark on their low-carbon trajectory.

Keywords

Low-carbon transition, Macroeconomic challenges, Gross fixed capital formation, Input-output

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Résumé
La transition vers une économie à faibles émissions de carbone dans les pays en développement nécessite d'importants investissements dans les nouvelles technologies. Cependant, comme la production de biens d'équipement est principalement concentrée dans les économies plus avancées, cette transition générera une forte demande de machines et d'équipements importés dans ces pays, ce qui entraînera une hausse de la demande de devises et créera potentiellement des pressions macroéconomiques négatives. Pour tenir compte du rôle important des biens d'équipement dans ce processus de transition, nous endogénéisons le capital fixe dans le cadre des entrées sorties (IO), en estimant les matrices capital-utilisation pour six pays en développement et émergents d'Amérique latine et des Caraïbes dans le cadre sectoriel de Gloria de 1990 à 2020. Sur la base de ces estimations, nous montrons comment l'endogénéisation du capital peut offrir une perspective sectorielle nuancée sur les défis multidimensionnels auxquels sont confrontés les pays en développement au cours de leur transition vers une économie à faibles émissions de carbone, y compris les dimensions externes et socio-économiques. Nos résultats suggèrent que l'inclusion du capital dans le cadre des entrées-sorties révèle une aggravation substantielle de la contrainte extérieure pour les pays en développement. Nous constatons que pour chaque dollar investi uniquement pour maintenir la capacité de production actuelle, plus de 45% en moyenne fuient directement et indirectement vers les producteurs étrangers par le biais des importations. Certains avantages socio-économiques des investissements verts, tels que la création d'emplois, sont absorbés par le reste du monde, au lieu de favoriser la création d'emplois au niveau national. Essentiellement, avec la demande croissante de biens d'équipement produits à l'étranger générée par la transition vers une économie à faibles émissions de carbone, les pays en développement seront confrontés à une contrainte extérieure accrue et à des déséquilibres socio-économiques substantiels alors qu'ils s'engagent sur la voie d'une économie à faibles émissions de carbone.

Mots-clés
Transition bas carbone,
Défis macroéconomiques,
Formation brute de capital fixe,
Input-output

1. Introduction

With the signing of the Paris agreement in 2015, the international community collectively recognized the increasingly destructive impacts of human activity on our ecosystems (Persson et al., 2022; Ripple et al., 2020), committing 196 countries to limit global warming to below 2.0 degrees Celcius compared to preindustrial levels (UNFCCC, 2015). To abide by this target, countries are increasingly adopting Nationally Determined Contributions (NDC), fostering technological change and promoting the decarbonization of the economy (UNCTAD, 2021). However, in an international world system that must be viewed as fundamentally asymmetric with developing countries occupying a subordinated position both in technological and productive capacities, in the international financial system and in the hierarchy of environmental transformation, this transition will confront developing countries with yet another set of multi-dimensional challenges (Gramkow and Porcile, 2022; Magacho et al., 2023).

In order to achieve a successful decarbonization of their economy countries depend on advanced capital goods and inputs (Hidalgo, 2021). However, with capital goods production being concentrated mostly in advanced countries (Mutreja et al., 2014), this process generates a high demand for imported capital goods, such as Machinery& Equipment, Software Equipment, and other specialized capital goods. At the same time, this transition will be accompanied by a profound restructuring of the labour market, requiring a substantial reallocation and re-training of workers with uncertain socio-economic impacts (Saget et al., 2020). However, with a growing demand for foreign-produced capital goods produced by the decarbonization and green transition strategies, socio-economic benefits are absorbed by those countries that produce these capital goods, rather than fostering domestic employment creation. Thus, in particular for developing countries, who tend to be positioned far from the technological frontier and characterized by a productive structure concentrated in low value-added industries, this dynamic will likely produce external and socioeconomic imbalances.

In this context, Input-Output (IO) analysis (Leontief, 1936, 1941) has proven to be a useful tool to model dynamics of the low-carbon transition such as the environmental footprint of economic activity (Lenzen et al., 2022; Wiedmann and Lenzen, 2018; Wiedmann et al., 2015) or the multidimensional sectoral risks that may emerge during this transition (Magacho et al., 2023, 2024). Despite its comprehensibility, versatility, and high level of detail, one of the fundamental shortcomings of IO analysis concerns the accounting of capital. Given that most IO tables are constructed from supply and use tables on the basis of national accounts, capital assets are treated as exogenous to the model (Södersten et al., 2018a,b). Hence, in the context of the pivotal role of capital goods for the decarbonization strategies of developing countries, the IO system that focuses exclusively on inputs may underestimate the degree to which a country's productive capacity depends on the import of capital goods, hence underestimating the challenges faced by developing countries during their low-carbon transition.

While endogenizing capital in IO models is gaining attention, previous studies have focused almost exclusively on the assessment of the environmental footprint of fixed capital and have done so largely in the context of developed countries. Therefore, this paper aims to contribute to the recent methodological developments within input-output analysis by building on the method developed by Södersten et al. (2018b). We propose an adjusted flow-matrix method to estimate capital-use matrices for six developing and emerging countries in Latin America and the Caribbean (i.e., Colombia, Costa Rica, Dominican Republic, Honduras, Mexico, and Peru) within the Gloria (Lenzen et al., 2022, 2017) sectoral framework from 1990 to 2020.[1] The selection of these six countries is based on the data availability in the LA KLEMS database, preventing us from including additional countries at this time.[2]

Based on these estimates, we show how the endogenization of capital in the IO framework can offer a nuanced sectoral perspective on the multi-dimensional challenges faced by developing countries during their low-carbon transition, including the external and the socio-economic dimension. First, we find substantial differences across sectors in terms of their capital intensities, with Government Services, Construction, Transportation, and Utilities, including Electricity, being the most capital-intensive sectors. Moreover, we find substantial differences regarding the respective sectoral investment needs in terms of their capital assets distribution with some sectors (i.e., Government Services, Utilities) relying primarily on Building and Civil Engineering Construction, while others such as Manufacturing, Telecommunications, Transportation, and Construction rely primarily on Machinery& Equipement.

In addition, our findings suggest that the inclusion of capital in the IO framework reveals a substantial deepening of the external constraint for the six analyzed countries. With a substantial share of capital goods being imported, our results suggest that the decarbonization strategies and the associated replacement of productive capacity[3] in developing countries will be strongly constrained by their dependence on foreign-produced capital goods. In fact, for every dollar invested to maintain current productive capacity, on average more than 45% leak directly and indirectly to foreign producers with sectoral leakages reaching almost 80%. While the inclusion of capital had a positive effect on employment multipliers across the economy, our findings suggest that the need for imports can create constraints from a balance-of-payments perspective. Although new investments may increase production and create jobs, because a relevant share of this demand leaks to other countries, the most prominent impact of an increase in investment is the increase in demand for foreign exchange. Finally, we show that sectors that tend to be key for the low-carbon transition, such as Utilities (i.e., Waste, Water, Gas, Electricity), Transportation, Telecommunications, and Information Services tend to be not only very capital-intensive, but also extremely import-intensive with only limited positive effects on employment multipliers. In this context, our findings exemplify the multi-dimensional and multi-sectoral challenges faced by developing countries during their low-carbon transition.

The structure of the article is as follows. In the next section, we will provide a detailed literature review on the role of capital goods in the sustainable development trajectory of developing

[1]Note that we compute a time-series of capital matrices from 1990-2020, with differing time series across countries, due to data availability. However, for visualization purposes we present the results only for 2015.

[2]Note that, because of data limitations, we exclude Chile and El Salvador from our analysis, despite the fact that data is available in the LA KLEMS database.

[3]Note that for the purpose of this paper, using *accumulation of productive capacity* refers to the investment that is necessary to replace the existing capital stock and maintain current production. In this sense, it does not include the investment necessary to build-up new productive capacity.

countries. In section 3, we will present our methodology on the construction of capital-use matrices. Section 4 will then present our results, showing the impact of the capital-endogenization on import dependencies and employment multipliers. The final section will then discuss these results by relating them to the sustainable development strategies, the challenges faced by developing countries during their low-carbon transition and the methodological developments in the field of input-output analysis.

2. Literature review

2.1. The external constraint of developing countries

The technological and productive asymmetries of the international world system materialize themselves in the pattern of specialization of developed and developing countries respectively (Porcile, 2019; Dosi et al., 2022). While developed countries specialize in technology-intensive industries, developing countries tend to rely on their static competitive advantage and specialize in low-value-added – either primary commodity or low-skilled labour intensive – industries (Cimoli and Katz, 2003; Cimoli et al., 2019). Thus, with a productive structure concentrated in low-tech and natural resource-intensive industries, developing countries generate a very high demand for imported inputs and capital goods as they pursue economic growth and accumulate productive capacity (Porcile, 2024). This means that they are characterized by a high income elasticity of demand for imports (Romero and McCombie, 2018). On the contrary, given that they export primarily low-technology goods, whose demand is relatively weak in the global market, a faster growth on the world level does not increases developing countries' exports proportionally (Araujo and Lima, 2007; Spinola, 2020). Thus, developing countries are not only characterized by a high import-elasticity, but also by a low export-elasticity. This dynamic has been prominently analysed by Raul Prebisch (1951, 1950), who argued that developing countries are thus faced with deteriorating terms of trade and an ever increasing need for exports to obtain an equal amount of imports.

Moreover, given the asymmetries of the international financial system and the fact that developing countries occupy a subordinated position in the hierarchy of currencies (Conti and Prates, 2018; Fritz et al., 2017), they cannot rely on foreign savings to settle the payments for their imports. Ultimately, while developed countries enjoy the "exorbitant privilege" (Eichengreen, 2019) with a high international demand for their currency, developing countries faces a hard "survival constraint" (Aglietta and Coudert, 2019; Minsky, 1976) with the constant need to attract capital inflows to pay for their imports. In this context, financial globalisation, characterized by excessive international trade and free capital flows acts as a multipliers of these asymmetries and dependencies (Kaltenbrunner and Painceira, 2015).

Building on the interrelation between structural and financial dynamics, Thirlwall (1979) and Thirlwall and Hussain (1982) formally theorized this constraint in his model of balance-of-payment constrained growth and what has become later known as "Thirwall's Law". It postulates that the long-run equilibrium growth rate consistent with the balance of payment equilibrium equates the ratio of the long-run growth rate of exports to the income elasticity of demand for imports. Thus, the structure of exports and imports determines a countries long-term growth rates, as foreign capital could not indefinitely finance deficits (McCombie and Thirlwall, 2016; Thirlwall, 2012; Yilmaz and Godin, 2021).

2.2. Challenges of the low-carbon transition for developing countries

In addition to these socio-economic and financial asymmetries, the low-carbon transition will confront developing countries with one of the most transformative challenge of economic restructuring, including the eminent need to reduce the environmental footprint of current and future production processes. It will be led by the scaling-up of investment to both green the existing production process and ensure the accumulation of new green productive capacity. In this context, the structure of investment and the sectoral investment needs in terms of capital goods emerge as pivotal to attain an equitable decarbonization in developing countries.

The production of capital goods is concentrated in only a few developed countries, with 80% of capital goods being produced by only 10 countries (Mutreja et al., 2014). Moreover, green capital goods that are essential to achieve the decarbonization of the economy tend to be those with a higher technological content (Mealy and Teytelboym, 2022). Thus, given their specialization in low value-added industries, developing economies are less diversified and less competitive in the production of these high-technology, green products (Boleti et al., 2021; Hidalgo, 2021). Hence, in order to replace existing or accumulate new green productive capacity, they depend on the import of high-tech capital goods such as Machinery, Transport Equipment, Software, and other specialized capital goods (Hoyos et al., 2021; Gisbert, 2023). In addition, the decarbonization of the economy requires a substantial greening of the Construction sector with large infrastructural and building investments necessary. While Construction is largely produced domestically, the inputs and capital goods necessary for the production of the Construction sector tend to be technology- and thus import-intensive.

Thus, as developing countries embark on their low-carbon trajectory, they create a high demand for imported inputs and capital goods that are necessary, not only to green future production processes, but also to reduce the environmental footprint of current production activities (Magacho et al., 2023). In this context, the low-carbon transition and the related replacement and accumulation of green productive capacity will be accompanied by substantial dependence on imported inputs and capital goods, potentially leading to an increased pressure on the balance-of-payment.

From a socio-economic perspective, decarbonization strategies in developing countries will be accompanied by a profound restructuring of the labour market with important employment and distributional effects.

First of all, Pollin (2020) point out that the transition will require a profound restructuring of the labour market including a substantial re-allocation and re-training of workers. With a concentrated and undiversified production structure and a large pool of workers employed in low-skilled industries or even informal activities, this process will be profoundly more challenging for developing countries. The concentrated and undiversified production structure (Hartmann et al., 2017) will also constrain the ability of developing countries to redistribute the income generated by the positive effects of employment. Rosemberg (2010) further argues that the transition will likely be associated with a decline in living standards due to its impact on high job destruction and low job creation, particularly in developing economies that depend on carbon-intensive industries. It has been frequently argued that the accumulation of green investment is generally associated with an increase in employment, in particular if it is directed to sectors with lower import propensities (Perrier and Quirion, 2018). However, with a growing demand of investment for foreign-produced capital goods, socio-economic benefits tend to be absorbed by the rest of world, rather than creating employment domestically. While the transition's net impact on employment may be positive, it is likely that the dependence of investment on foreign-produced capital goods will produce socio-economic imbalances (Saget et al., 2020).

3. Methods and data

3.1. Method

Input-output analysis, initially conceived by Wassily (Leontief, 1936, 1941), is an important tool to analyse the interdependence of industries within and across economies (Miller and Blair, 2009). Basic IO tables are built from observed data, often on the country level, providing information about the intersectoral productive relations of a country (Miller and Blair, 2009). Multi-regional IO tables were further developed to account for the interrelation between sectors in different regions or countries, including the interdependence of global supply chains and the accounting for multilateral trade (Wiedmann et al., 2011).

One of the fundamental shortcomings of the IO framework concerns the accounting of capital (Södersten et al., 2018b). In the IO framework, fixed capital is treated as an exogenous variable denoted either as gross fixed capital formation (GFCF) or as the consumption of fixed capital (CFC): the GFCF is usually presented as a column-vector within the final demand, while the CFC is integrated as a row-vector as part of value-added (Södersten and Lenzen, 2020). The GFCF constitutes the flow of long-term investment designated to maintain, replace, or build-up production capacity (OECD and UN, 2009). The CFC constitutes the consumption of fixed capital, which represents the expected decline of the current value of the capital stock during the accounting period as a consequence of physical deterioration, normal obsolescence and normal accidental damage (OECD and UN, 2009).[4] Given that both of these measures are available only in a one-dimensional form, aggregated by product (for GFCF) and industry (for CFC), there is no information on the inter-industrial use of capital in the IO framework. The structure of IO databases treats capital goods not as inputs to the production system, but as goods destined for final consumption, disregarding the fact that capital goods are predominately purchased to be used repeatedly in production

[4]Thus, the CFC is used interchangeably with the economic concept of depreciation serving as a measure of the consumption of the in-use capital stock (Shreyer, 2009).

processes (Södersten et al., 2020; Ye et al., 2021; Wu et al., 2021a).

Given the high data requirements on the use of capital by industry and asset type, only a limited amount of studies have attempted to endogenize capital in the MRIO framework. The two most prominent methods that emerged were the augmentation method and the flow matrix method (Lenzen and Treloar, 2004). With the augmentation method, fixed capital is incorporated as a separate sector of homogeneous capital goods that is added to the intersectoral matrix. This sector is constructed by using the GFCF vector as producing and the CFC vector as consuming industries. The flow-matrix method on the other hand relies on the disaggregation of capital by sector and asset type to produce a separate capital-flow matrix, which is added to the regular intersectoral flow matrix forming a total flow matrix, which incorporates both fixed capital flows and intermediate inputs (Södersten et al., 2018b; Ye et al., 2023). Upon a comparison of these two methods, Lenzen and Treloar (2004) conclude that, while the augmentation method is easier to implement, its application produces substantial and systematic distortions of the factor multipliers, which is largely due to the uncertainties in the allocation of fixed capital. On the other hand, the flow-matrix method produces much more accurate and reliable results, is however constrained by its high data requirement on product-by-industry capital flows.

Owing to the development of external databases such as EU KLEMS, World KLEMS, or Penn World Tables that provide detailed data on capital stocks by industry and asset type (Södersten et al., 2020, 2018b,a; Vivanco, 2020; Wu et al., 2021b; Ye et al., 2023), scholars no longer had to resort to endogenize either GCFC or CFCF of the MRIO databases. Instead by relying on these external databases, they were able to estimate detailed capital use-matrices, which substantially improved the accuracy, reliability, and predictive capacity of capital endogenization in MRIO analysis.

On the basis of these methodological developments, multiple studies have started to endogenize capital in IO analysis. However, they have focused almost exclusively on the associated environmental impact of fixed capital in developed countries, with only a few studies specifically discussing the environmental footprint of fixed capital in developing countries (Chen et al., 2018; Wu et al., 2021a). Consistently, these studies show that the endogenization of capital in MRIO models has led to a substantial increase in the consumption and production-based emissions as well as a significant redistribution of environmental impacts across industries and countries (Ye et al., 2021, 2023; Södersten et al., 2020, 2018a,b; Xu et al., 2023; Hertwich and Wood, 2018).[5]

3.2. Data

Following the objective of this study, namely to provide a method to estimate capital-use matrices for developing countries, we rely on the GLORIA global multi-region input-output (MRIO) database (Lenzen et al., 2022, 2017). Contrary to most databases such as WIOD and Exiobase, which offer a high sectoral resolution only for a limited amount of developed countries, the GLORIA database covers 120 sectors for 164 countries accounting for more than 99% of the world's GDP and the bulk of global supply-chains.

[5] For a detailed review, see Appendix A.

Given that data on capital stock by industry and asset is not available within the MRIO database, we rely on the external database LA KLEMS (Gu and Hofman, 2021; Fernández-Arias et al., 2021) to complement our analysis. The LA KLEMS Growth and Productivity Accounts are a set of databases that contain inputs and outputs of capital, labor, energy, materials, and services for eight developing countries in Latin America and the Caribbean (LAC). They provide information on the purchase of different capital assets, making it a useful and valuable complement to Gloria. While databases such as EU KLEMS or World KLEMS provide highly aggregated capital formation matrices, the LA KLEMS database had to settle for a lower level of industry and asset type detail. Moreover, the data availability and consistency differs substantially across countries.

Given these variations in data availability, we rely on two different methods to extract the capital accounts from the external databases. For Peru and Colombia, for which data on GFCF (by asset k and sector s) was equally detailed as data on capital stock (by asset k and sector s), we rely on the capital stock data from KLEMS.[6] For Mexico, Costa Rica, Honduras, and the Dominican Republic, for which data on GFCF was available with a higher level of sectoral disaggregation, we estimate the capital stock using the time series of gross fixed capital formation in volumes, applying the permanent inventory method (PIM) with the depreciation rates provided by the LA KLEMS database (see (Fernández-Arias et al., 2021).

Table 1: Data availability by asset and sector for each country

Country	Assets x Sectors	Database	Extraction Method
Colombia	8x9	LA KLEMS	DCS
Costa Rica	8x9	LA KLEMS	PIM
Dominican Republic	6x9	LA KLEMS	PIM
Honduras	5x9	LA KLEMS	PIM
Mexico	9x25	LA KLEMS	PIM
Peru	7x9	LA KLEMS	DCS

3.3. Estimating Capital-Use Matrices in GLORIA

As indicated above, the concept of capital endogenization in IO tables is not a novelty in itself (Södersten et al., 2018a), however most studies have conducted this task only for countries for which high-resolution data is readily available. Given the discrepancies in data availability between the countries used in the analysis, we modify our methodology for each country to account for these differences. Here, modifications are justified both on a qualitative and quantitative basis and indicated when needed.

Following the comparison by Lenzen and Treloar (2004) and building on the method developed by Södersten et al. (2018a), we propose an adjusted flow-matrix methodology to estimate the capital-use matrix for six developing countries, available in the LA KLEMS database, in the Gloria MRIO framework. [7]

[6] Note that we refer to this method as *Direct Capital Stock* method (DCS).
[7] The countries include Colombia, Costa Rica, Dominican Republic, Honduras, Mexico, and Peru.

Therefore, in order to combine the capital accounts provided by LA KLEMS with the detailed sectoral and environmental accounts of Gloria, we adjust and expand the KLEMS capital accounts to make them compatible with Gloria. Before that, we execute some modifications to the existing data structure to guarantee the compatability with the IO tables.

First, we separate the asset *Residential Investment* from the original KLEMS capital-use matrices. In cases where *Residential Investment* is consumed by multiple sectors, we extract the value for *Residential Investment* consumed by the Construction sector k_{ri}^{con} and aggregate *Residential Investment* and *Non-Residential Investment*. This is justified for two reasons. First, given that the sectoral classification of Gloria entails both Building Construction and Civil Engineering Construction, while the KLEMS dataset only provides one Construction sector, the exclusion of *Residential Investment* allows us to differentiate between the two. Secondly, we argue that the *Property and Real Estate* sector is almost exclusively consuming *Residential Investment* and in order to account for this dynamic, we have to seperate residential and non-residential capital assets. Moreover, we aggregate the KLEMS assets *Computer equipment* and *Communication equipment* as both assets match to only one Gloria sector. Furthermore, we seperate the cell that specifies the *Cultivable Assets* consumed by the Agricultural sector k_{ca}^{agr}. We then distribute k_{ca}^{agr} diagonally across all of the Agricultural sectors in GLORIA to account for the fact that each capital asset produced by the Agricultural Sector is uniquely consumed by the same Agricultural sector (see Equation 8 below. Finally, we distribute the KLEMS assets *Computer equipment, Communication equipment, Software, Transport equipment* and *Transport equipment* across the seven Trade and Transport sectors of the Gloria database to account for differences in trade and transport margins, as the KLEMS data is provided in purchasing prices and GLORIA in basic prices. We use their total capital stock values from the KLEMS data as a distribution proxy. Finally, this yields our modified initial KLEMS-based capital matrix $\tilde{\tilde{\mathbf{K}}}_{k,s}$ with *k* assets in rows and *s* sectors in columns with differing dimensions across countries (see Table 1)

After these initial modifications, we aim to expand the KLEMS-based capital matrix to the GLORIA structure. To do so, we first disaggregate the *k* asset types into the 120 sector categories of Gloria, using a basic concordance matrix $\mathbf{G}_{k,j}$ matching KLEMS assets k (rows) to Gloria sectors j (columns). The matrix contains ones for the corresponding KLEMS-asset to Gloria-sector combinations and zeros for the rest. For the resulting matrix, there is no rule for rows summation, but columns should sum-up to one. When KLEMS-asset match to more than one Gloria sector, the values are disaggregated and distributed among the sectors using a proxy vector $\mathbf{p}_i$. The weighted correspondence matrix is thus given by

$$\mathbf{G} = (\widehat{\tilde{\mathbf{G}}\mathbf{p}})^{-1}\tilde{\mathbf{G}}\hat{\mathbf{p}} \tag{1}$$

where the proxy $\mathbf{p}$ is the column-vector of GFCF of the domestically produced and imported goods, obtained from GLORIA, hats indicate vector diagonlization and $(\widehat{\tilde{\mathbf{G}}\mathbf{p}})^{-1}$ denotes matrix inversion of $(\widehat{\tilde{\mathbf{G}}\mathbf{p}})$. Note that we normalize the concordance matrix, such that rows sum-up to one, while columns cannot sum up to more than one. This avoids double counting as the sum of the shares that each KLEMS asset assigns to the Gloria sectors amounts to one.

Conversely, to disagregate the KLEMS sectors into the Gloria sectors we rely on a second concordance matrix $\mathbf{H}_{j,s}$ that matches KLEMS sectors *s* (columns) to Gloria sectors *j* (rows). As above, the matrix contains ones for the corresponding KLEMS-sector to Gloria-sector combinations and zeros for the rest. All rows should sum-up to one with no rule for row-summation. As above, when KLEMS-sectors match to more than one Gloria sector, the values are disaggregated and distributed among the sectors using a proxy vector $\mathbf{d}_j$. The weighted correspondence matrix is thus given by

$$\mathbf{H} = \widehat{\mathbf{d}}\tilde{\mathbf{H}}(\widehat{\mathbf{d}\tilde{\mathbf{H}}})^{-1} \tag{2}$$

where the proxy vector **d** is the row-vector of CFC obtained from GLORIA. As above, the concordance matrix is normalized to avoid double-counting such that all columns should sum-up to one, while rows cannot sum up to more than one. Thus, the KLEMS based capital-use matrix $\tilde{\tilde{\mathbf{K}}}_{k,s}$ can be opened into a Gloria structure to yield a new capital-use matrix $\overline{\mathbf{K}}_{i,j}$ as

$$\overline{\mathbf{K}} = \mathbf{G}'\tilde{\tilde{\mathbf{K}}}\mathbf{H}' \tag{3}$$

where $\mathbf{G}_{k,j}$ and $\mathbf{H}_{i,s}$ refer to the corresponding concordance matrices, $\tilde{\tilde{\mathbf{K}}}_{k,s}$ to the original KLEMS capital matrix, and ′ indicates matrix transposition. Following its initial removal, the value for the consumption of *Cultivable Assets* by the Agricultural sector denoted as k_{ca}^{agr} is distributed diagonally across the Agricultural sector based on the proxy $\mathbf{p}^{agr}$, which considers only the Agricultural sector of the GFCF column-vector of the domestically produced and imported goods. This yields the new capital-stock matrix $\overline{\mathbf{K}}_{i,j}^{agr}$ of the agricultural sector with weighted values in the diagonal only for the Agricultural Sector and zeros for the rest.

$$\overline{\mathbf{K}}^{agr} = k_{ca}^{agr} \begin{bmatrix} \widehat{\mathbf{p}^{agr}} \\ 0 \end{bmatrix} \tag{4}$$

Thus, the capital-use matrix, denoted as $\overline{\overline{\mathbf{K}}}_{i,j}$ is obtained as the summation of these two matrices and the matrix of residential investment, $\overline{\mathbf{K}}_{i,j}^{res}$, which is a matrix of zeros for all cells except the one for Building Construction production (row) for Property and Real Estate consumption (column) given by k_{ri}^{con}.

$$\overline{\overline{\mathbf{K}}} = \overline{\mathbf{K}} + \overline{\mathbf{K}}^{agr} + \overline{\mathbf{K}}^{res} \tag{5}$$

In order to ensure consistency between the CFC data of Gloria and the obtained data on capital stock from KLEMS, we first transform the KLEMS depreciation matrix $\delta_{k,s}$ to the Gloria structure, by using the same concordance matrices $\tilde{\mathbf{H}}_{i,s}$ and $\tilde{\mathbf{G}}_{k,j}$ to obtain a new depreciation matrix $\delta_{i,j}$. Note that the cell corresponding to Construction production (row) for Property and Real Estate consumption (column) is replaced by the depreciation value of residential assets $\tilde{\delta}_{pre}^{con}$.

$$\delta = \tilde{\mathbf{H}}\tilde{\delta}\tilde{\mathbf{G}} \tag{6}$$

We then estimate a hypothetical CFC based on the previously obtained $\bar{\bar{\mathbf{K}}}$ using this newly obtained depreciation matrix $\delta_{i,j}$ by

$$\bar{\mathbf{d}} = \iota'[\delta' \odot \bar{\bar{\mathbf{K}}}] \tag{7}$$

where ι is the summation column-vector. We then calculate an adjustment matrix $\tilde{\mathbf{d}}_{i,j}$ for the CFC given by

$$\tilde{\mathbf{d}} = \widehat{\mathbf{d} \oslash \bar{\mathbf{d}}} \tag{8}$$

where $\oslash$ is the element-wise division. The final time series of the capital-stock matrix $\mathbf{K}_{i,j,t}$ adjusted to be coherent with CFC data from Gloria with assets i in rows and sectors j in columns is obtained as follows:

$$\mathbf{K} = \bar{\bar{\mathbf{K}}}\tilde{\mathbf{d}} \tag{9}$$

To obtain a capital *requirement* matrix **B**, we proceed similarly as when calculating the matrix of technical input coefficients $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$. Thus, the matrix of capital requirements to produce one unit of output is obtained as

$$\breve{\mathbf{B}} = \mathbf{K}\hat{\mathbf{x}}^{-1} \tag{10}$$

where **x** is the output column-vector and **K** our newly obtained Gloria-based capital matrix. $\breve{\mathbf{B}}$ is thus the matrix of direct capital coefficients, where each element $b_i^j = b_i^j / x_i^j$ represents the direct capital requirement from sector *i* per unit of total output for sector *j* and where the horizontal vector of the row-sums represents the capital-output ratio by sector *j*.

Note however, that this matrix indicates the depreciated capital-stock and does not take into account the capital stock necessary to maintain productive capacity at its current level. Thus, we adjust our newly obtained $\breve{\mathbf{B}}$ matrix by an adjustment vector to build a capital-stock matrix that captures the capital-stock needed to sustain productive capacity.

To compute this adjustment vector, we first calculate a hypothetical Investment matrix $\bar{\mathbf{I}}$ that captures the investment necessary to replace depreciation, using the following formula and the newly obtained matrix $\breve{\mathbf{B}}$ as

$$\bar{\mathbf{I}} = \hat{\delta}\breve{\mathbf{B}}\mathbf{x} + \breve{\mathbf{B}}\dot{\mathbf{x}} \tag{11}$$

where $\dot{\mathbf{x}} = g\mathbf{x}$ with *g* being a scalar representing the desired growth rate, which is given by the average long-term logarithmic growth rate. Conversely, the investment necessary to replace the existing capital stock is given by $\mathbf{I} = \hat{\delta}\mathbf{B}\mathbf{x} + \mathbf{B}\dot{\mathbf{x}}$, where **B** represents the matrix of the new capital stock to be estimated. Given that **I** is equal to gross fixed capital formation, it is given by the GFCF-vector **p** of the IO table. Using this vector, we are able to calculate an adjustment vector β that indicates the difference between the capital stock necessary to replace the depreciated capital and the capital stock needed to sustain productive capacity. Thus, since $\mathbf{I} = \widehat{\beta}\bar{\mathbf{I}}$, where **I** is given by **p**, the adjustment vector β is calculated by

$$\beta = \mathbf{I} \oslash \bar{\mathbf{I}} \tag{12}$$

Using this adjustment vector, we can calculate the new B matrix that considers the capital stock needed to maintain productive capacity at a given desired growth rate g:

$$\mathbf{B} = \widehat{\beta}\breve{\mathbf{B}} \tag{13}$$

Ultimately, the sum of **A** and **B** shows the total production requirements of capital and non-capital goods, which allows us to calculate a new Leontief inverse as

$$\mathbf{L}^{K} = (\mathbf{I} - (\mathbf{A} + \widehat{\delta}\mathbf{B}))^{-1} \tag{14}$$

whose element $l^{k}_{i,j}$ denotes not only the the direct and indirect inputs, but also the direct and indirect capital assets of sector *i* needed by sector *j* to produce one unit of industry *j* output. Note that **B** is multiplied by the matrix of annual depreciation rates $\delta_{i,j}$. Note that the interpretation of this new Leontief Inverse differs from the common Leontief matrix as it includes not only the embodied inputs, but also the direct and indirect capital goods required to produce both inputs and capital goods (Södersten et al., 2018a).

4. Results

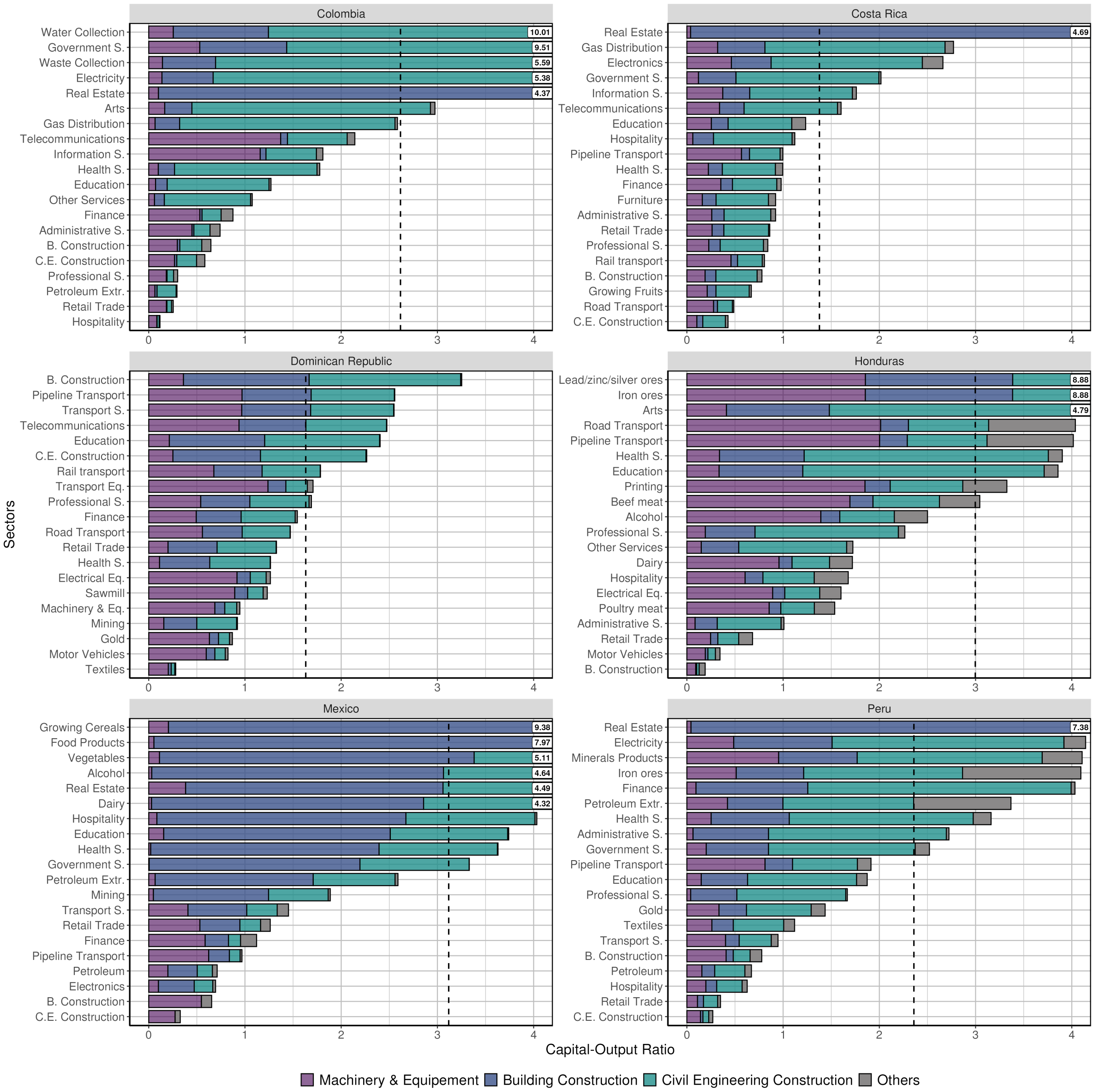
4.1. Sectoral investment requirements

The endogenization of capital into the IO system allows us to understand sectoral differences, not only in terms of their respective capital-output ratios, but also in terms of their disaggregated investment needs in terms of capital asset. To provide a more accurate account of these sectoral differences, Figure 1 compares the sectoral capital-output ratios of the 20 largest sectors (in terms of total capital stock) of each country disaggregated by four primary asset types *Machinery& Equipment, Building Construction, Civil Engineering Construction*, and *Others*. More specifically, it presents the sectoral investment disaggregated by asset type that is necessary to maintain the current productive capacity in this sector.

In accordance with the literature, we find the capital-output ratios of the six analyzed countries to vary between 1.4 (Costa Rica) and 3.1 (Mexico) with Dominican Republic (1.6), Colombia (2.6), Peru (2.4), and Honduras (3.0) falling within this range (Feenstra et al., 2015; Inklaar et al., 2019).[8]

[8]Note that these studies find slightly higher capital-to-output ratios as they use GDP as a measure of output, which discounts intermediate consumption as opposed to our measure of output that includes intermediate consumption.

Figure 1: Sectoral Capital-Output Ratios by Asset



Note: The black dashed line represents the average capital-output ratio across the largest 20 sectors (in terms of total capital-stock).

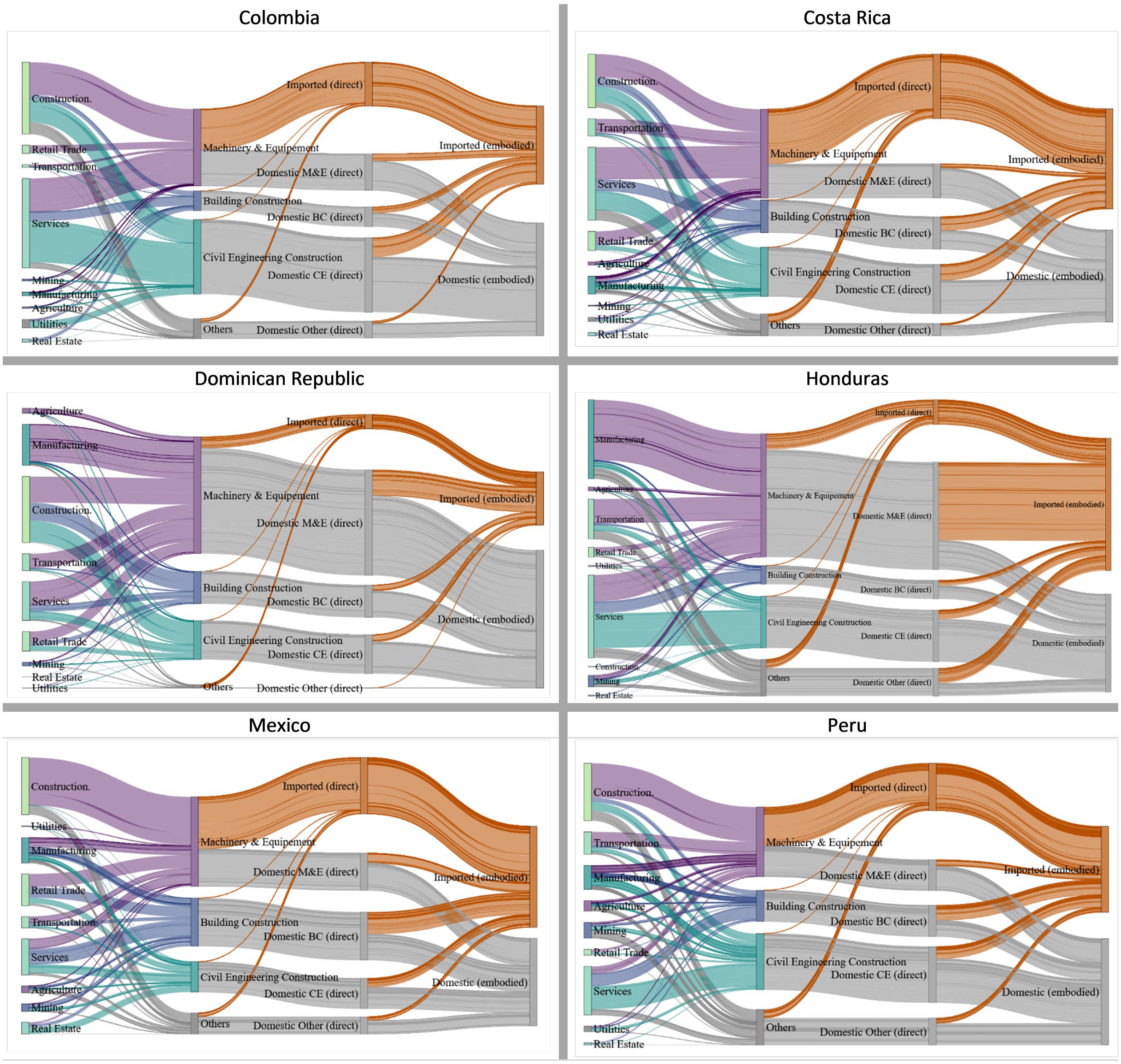
We further find the capital-output ratios to vary substantially between sectors within the same country. In particular, sectors such as Utilities (i.e., Waste, Water, Gas, Electricity), Transportation, ICTs (Telecommunications, Information Services, Electronics) and Education tend to have high capital-output ratios across countries, suggesting that they are capital-intensive sectors. Large sectors (in terms of monetary output) such as Motor Vehicles, Construction, or Retail Trade tend to have lower capital-intensities across countries, requiring less capital to produce an equivalent unit of output. Nevertheless, we find that similar sectors have very different capital-output ratios across sectors. For example, Petroleum Extraction in Mexico (2.6) and Peru (3.4) has a relatively high capital-output ratio, while for Colombia it has a very low capital-output ratio (0.25). Conversely, while Arts ranks among the more capital-intensive sectors in Colombia (4.37) and Honduras (4.79), it is much less capital-intensive in other the other countries. In addition, food producing sectors such as Growing Cereals, food Products, Vegetables, Dairy, and Alcohol are very capital-intensive in Mexico (4.32-9.38), while for the rest of the countries, similar sectors tend to be less capital-intensive.

Figure 1 also demonstrates large differences across sectors and countries in terms of their respective investment structures, as the capital assets that are required to maintain productive capacity in the respective sector differ between sectors. While Service Industries, Agricultural Industries, and Utilities depend largely on Building and Civil Engineering Construction, sectors such as ICT's, Manufacturing, Transportation, and Construction tend to be much more dependent on Machinery& Equipment. Furthermore, it becomes apparent that the structure of investment of the most capital-intensive sectors differs between countries. For example, while Machinery& Equipment plays an important role in Honduras and the Dominican Republic, Mexico and Costa Rica tend to be more dependent on Construction, with Colombia and Peru's investment structure being relatively balanced across capital assets.

4.2. The import-intensity of investment

Underlying these sectoral investment needs are monetary capital flows that start from capital-investing sectors undertaking the investment to build up their capital stock, to capital producing sectors that provide the necessary capital assets. These flows are then either captured by foreign producers (i.e., through imported capital goods) or by domestic producers (i.e., through domestically produced capital goods). They also flow indirectly to foreign and domestic producers who produce the necessary inputs and capital goods that are required to produce the domestic capital goods. Given developing countries' dependence on the import of foreign technology, in particular capital goods, the objective is to understand how the endogenization of the capital stock into the IO system may reveal an increased dependence on imported capital goods, that may be underestimated by previous IO analyses that focused exclusively on inputs. To this end Figure 2 plots Sankey Diagrams for each country, presenting their direct and embodied sectoral dependence on imported inputs and capital goods. The first flow represents the investment allocation ($\mathbf{K}$) from the capital-demanding to the capital-producing sector. The second flow represents the origin of the capital supply, distinguishing between the imported ($\mathbf{K}^M$ in orange) and the domestic ($\mathbf{K}^D$ in grey) investment allocation, with the domestic investment requirements being disaggregated by asset type. The final flow describes the origin of the embodied inputs and capital goods in capital, differentiating between the imported ($\mathbf{L}^{K^m}$ in orange) and the domestic ($\mathbf{L}^{K^d}$ in grey) content of domestic production.

Figure 2: Comparing Monetary Flows of Capital Goods Demand



First, coherent with Figure 1, we observe that across countries, Manufacturing is a large capital-investing sector, investing predominately in Machinery& Equipment. In particular for Honduras, Mexico, and Dominican Republic, the Manufacturing sector, but also the Transportation sector, have high capital requirements, despite accounting for only a small share in total output. Apart from Services, who rely predominately on Construction with Machinery& Equipment playing a supplementary role across countries, we observe substantial variations across countries in terms of their sectoral investment needs.

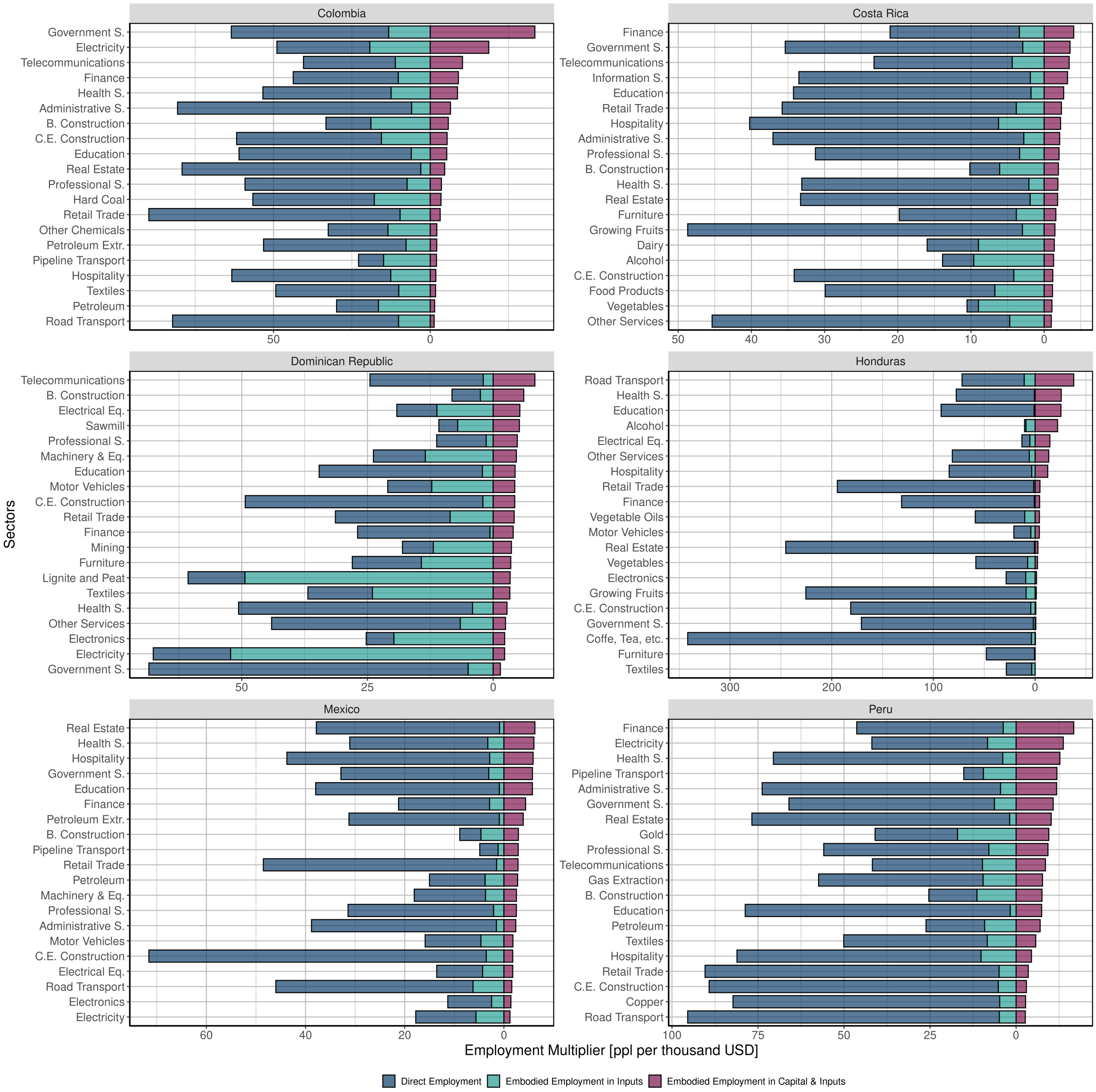
Analyzing the monetary flows necessary related to this capital-stock reveals that more than 50% of Machinery& Equipment are directly imported. This means that for every dollar spent on Machinery& Equipment more than half leak to foreign producers through imports. On the contrary, Building Construction and Civil Engineering Construction are primarily produced domestically with, more than 99% originating from domestic production and negligible shares being directly imported. On the contrary, across countries, Other capital assets, such as Cultivable Assets and other Manufactured capital goods, despite constituting a minor share in total consumption, present non-negligible levels of direct imports of between 15% and 20%.

However, when considering the embodied imports, namely the imported inputs and capital goods necessary to produce the domestic capital stock, we observe that the country's dependence on foreign produced capital goods increases significantly. Figure 2 reveals that across countries a substantial share of the domestic production of capital goods and inputs depends on the import of inputs and capital goods. For most countries up to 50% (Honduras) of the domestically produced capital stock are indirectly imported. Accordingly, when considering the direct and indirect embodied inputs and capital goods, countries import on average of 45.8% with countries like Honduras (55.8%), Mexico (53.6%), and Costa Rica (52.1%) being even more import-dependent and the Dominican Republic being less import constraint than the other countries (27.8%). This suggests that for every dollar invested to sustain productive capacity, more than 45% of the monetary flows leak directly and indirectly to foreign producers. Note that this share varies substantially, depending on the capital-investing sector and the capital-asset used with Machinery& Equipment being much more import intensive than Building Construction and Civil Engineering Construction., suggesting that the replacement of productive capacity in Machinery& Equipment-intensive sectors is more import-intensive than in Building Construction- or Civil Engineering Construction-intensive sectors.

4.3. The employment-intensity of investment

While the endogenization of fixed capital into the IO system reveals positive multiplier affects across the economy, the strong dependence on foreign produced capital goods suggests that socio-economic benefits (e.g., employment) are predominately absorbed by foreign producers. To this end, Figure 3 compares the direct employment ($\mathbf{n}$), the embodied employment in inputs ($\mathbf{nL}$) and the embodied employment in capital goods ($\mathbf{nL}^K$) of the 20 largest sectors in terms of monetary output (see Appendix B for explanations on the equations).

Figure 3: Comparing Employment Multipliers



Note: The grey dashed line represents the average direct and indirect employment in inputs, while the black dashed line represents the average embodied employment in capital goods.

As above, we observe substantial differences across countries and sectors, with respect to the employment multiplier effects embodied in capital goods (see Figure 3). Importantly, across countries, while direct employment intensities are largest across most sectors, embodied employment in capital tends to be equal or larger than embodied employment in inputs. Moreover, we observe substantial differences across countries, as capital-intensive sectors such as ICTs, Government Services, Finance, Electricity have high employment multipliers embodied in capital in Colombia, Costa Rica, and Peru, but low employment multipliers embodied in capital in Mexico and the Dominican Republic. On the contrary, sectors such as Transportation and Retail Trade have very low employment multipliers embodied in capital in Mexico, Peru, and Colombia, but very high multipliers in Costa Rica or Honduras.

Note further that while for Peru, Mexico and the Dominican Republic, and Costa Rica employment embodied in capital is relatively well distributed across industries, for Honduras and Colombia, employment is concentrated in only a few leading sectors with the rest of the sectors having comparably low employment multipliers.

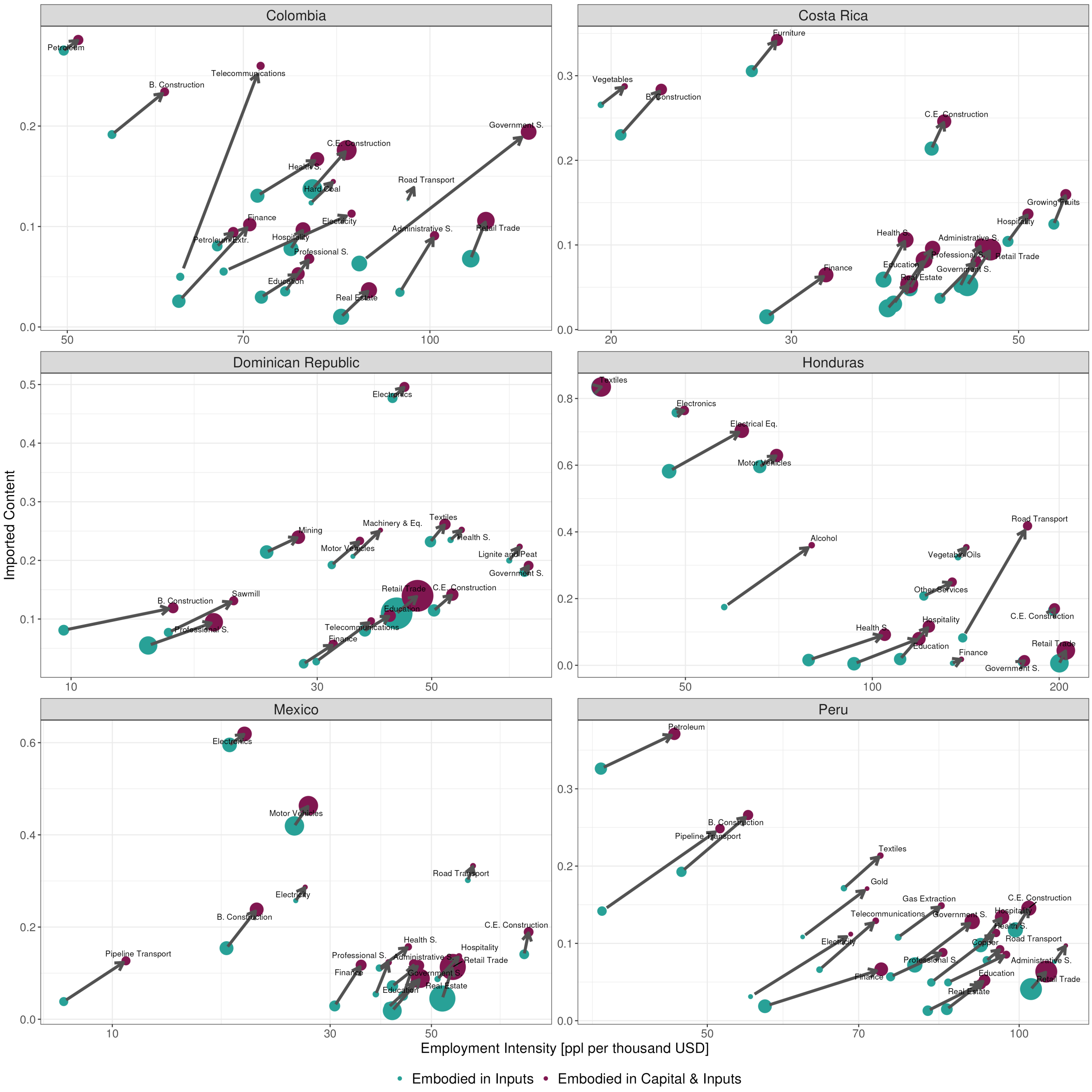
4.4. The multi-dimensional challenge of investment

The previous sections have highlighted that capital goods such as Machinery& Equipment and indirectly also Construction are very import intensive, as the analyzed countries do not have the productive capacities to produce these capital goods domestically. While the build up the of the capital-stock is dependent on foreign capital goods, suggesting low employment generation, Figure 3 has shown that investment directed at replacing the existing capital stock entails positive employment effects across the economy. To understand the respective degree of both effects Figure 4 maps a country's multidimensional impact by considering not only the embodied imports in capital, but also the employment embodied in capital of the country's leading economic sectors.

It is evident that the endogenization of fixed capital in the IO system reveals an increase in both employment and imported content for most of the leading sectors of the economy. While the average imported content of the economy, as shown in Figure 2 reveals a high import-dependency of roughly 45%, the sectoral perspective suggests that import-intensive sectors such as Electrical Equipment or Electronics import up to 80% and generally more than 45% of their investment. The comparison of sectors within countries suggests that both the imported content and the embodied employment increased strongest for high-technology sectors such as Telecommunication, Electrical Equipment, Electronics, and Transport sectors, as well as capital-intensive sectors such as Building and Civil Engineering Construction.

For example, the imported content of the Telecommunication sector in Colombia increased almost four-fold and the Road Transport sector in Honduras almost seven-fold following the inclusion of fixed capital. On the contrary the impact on employment of the same sectors was rather small with increases of 1.1 and 1.4 respectively. The impact of the inclusion of fixed capital was smallest for Electronics, which is nonetheless characterized by very high import-needs and very low employment generation.

Figure 4: Comparing Imported Content and Output Multipliers



Note: The length of the arrow suggests the total increase accruing from the inclusion of capital. The size of the points refers to the share in total output.

5. Discussion and Conclusion

5.1. Summary of Results

In this study we built on Södersten et al. (2018a) and applied the flow matrix method to endogenize capital in the IO framework for six LAC countries. We analyzed how the endogenization of investment impacts developing countries' dependence on imported capital goods as well as its impact on employment multipliers.

Our results suggest that the endogenization of capital had a substantial effect on the external constraint of developing countries with an average of up to 45% of inputs and capital goods being directly or indirectly imported for every dollar invested. Sectoral leakages for import-intensive sectors such as Telecommunication, Transportation, Construction, or Electronics are even stronger with values as high as 80%. This implies that developing countries, being far from the technological frontier, do not possess the productive capabilities to produce the capital goods such as ICTs, Machinery& Equipment, Transport Equipment, Electronics, and other specialized capital goods. Furthermore, our results suggest that the inclusion of capital has a positive effect on employment multipliers across most of the leading sectors. However, our findings suggest that, given very high levels of imported content, most of the demand for capital goods is leaking to foreign producers such that the positive socio-economic effects produced by the domestic employment generation are limited.

Lastly, we find substantial differences across sectors in terms of their capital intensities, their sectoral import dependencies on capital goods, as well as the sectoral employment multipliers. Sectors, such as Utilities (i.e., Waste, Water, Gas, Electricity), Transportation, ICTs (Telecommunications, Information Services), and Education tend to be not only very capital-intensive, but also very import-intensive. Moreover, we find substantial differences regarding the respective sectoral investment needs in terms of their capital assets distribution with some sectors (i.e., Real Estate, Utilities) relying primarily on Building and Civil Engineering Construction, while others such as Manufacturing, Transportation, Telecommunication, and Construction rely strongly on Machinery& Equipment. As such, we find substantial differences with respect to sectoral import dependencies, as sectors that rely predominately on Machinery& Equipment tend to be more import-intensive than sectors that rely primarily on Building Construction and Civil Engineering Construction.

Interestingly, we find that similar sectors have very different capital intensities and investment requirements in terms of capital assets across countries. Explanations for these differences can be given both on a methodological and qualitative basis. From a methodological perspective, it can be argued that the construction of the capital-use matrices is sensitive to the values of the CFC from Gloria, which are subject to uncertainty. Hence, for example the surprisingly high capital-output ratio of the Art sector in Colombia and Peru can be partially explained by the very high CFC values of this sector obtained from Gloria. On the other hand, the differences across countries in terms of sectors can also be explained using a more qualitative, country-contextual perspective. First of all, the different structures of private and state-owned companies across countries have important implications for the sectoral investment structures. For example, Mexico's state-owned oil company PEMEX is a major investor and plays an important role for domestic redistribution (ECLAC, 2022), while Colombia is running its state-owned Petroleum company Ecopetrol almost as a private company, with a large share of private, especially foreign investment (Ocampo et al., 2017; Braga and Campos, 2012; Heigl, 2011), which can explain some of the observed differences in capital structures of the Petroleum sector across the two countries. Overall, the extent to which countries generate favourable conditions for capital inflows such as foreign direct investment (FDI) has important implications for the domestic capital stock. In particular for developing countries, it has been shown that countries (or sectors) that allow for a greater share of FDI tend to have a higher domestic capital stock (Desai et al., 2005; Delgado and McCloud, 2017), which may also be reflected in a higher share of technology-intensive capital goods such as Machinery and equipment (Newman et al., 2015). Another important factor that explains the differences observed across similar sectors is the period in which the investment was conducted. As countries experience episodes of sustained capital accumulation often referred to as "investment surges" (Hoyos et al., 2021; Libman et al., 2019) during different time periods, the capital structure of similar sectors at a specific point in time (e.g., 2015) may reflect very different capital intensities and requirements in terms of capital assets. This also means that the extent to which the existing capital stock is already depreciated differs across countries, which will also be reflected in the structure of the investment. Moreover, different capital stock compositions can also be explained based on the general capital accumulation rates, as fast-developing countries tend to have more capital-intensive production structures (Chen et al., 2018), resulting in different capital-to-output ratios for similar sectors across countries. Finally, different capital-output ratios can further be explained based on different investment efficiencies across countries, which may, among other things mentioned above, explain the relatively high average capital-to-output ratios observed in Mexico and Honduras (Ibarra and Ros, 2019; Flegl et al., 2022). These sectoral differences highlight once again the importance of bringing a detailed sectoral approach to the analysis of investment, but also the shortcomings and limitations of aggregating or uniformly distributing capital requirements across regions, sectors, or assets.

5.2. The role of investment for the low-carbon transition in developing countries

The findings of our study are crucial for understanding the trajectory of the low-carbon transition in developing countries. This transition will confront developing countries with the profound challenge not only to achieve a successful decarbonization of their economy, but with the need to master this process with growing equality and a reduction in the asymmetries of the international system (Gramkow and Porcile, 2022). Central to this transition is the investment that is necessary to green the economy, reduce the environmental footprint of current production processes, generate employment and income, promote structural and technological change, as well as close the gap in GDP per capita between the developing and the developed world.

However, the nature and composition of green investment is complex, encompassing both sophisticated manufactured capital goods with a high technological content such as Machinery& Equipment and Software Equipment and on the other hand green infrastructural investments, composed primarily of capital assets such as Construction. Conversely, the impact of the decarbonization efforts in developing countries on sectors such as Agriculture, Energy, Electricity, Transportation, Telecommunication, and Water will be much more transformative than on other sectors of the economy (ECLAC, 2023, 2022). For example, the Agricultural sector, with both one of the highest climate and biodiversity impacts faces the two-fold challenge of providing affordable food for a growing population, while simultaneously reducing its environmental impact by reducing its GHG emissions and limiting its land-use (FAO, 2017; Vos and Bellù, 2019). In this context, sophisticated capital goods to reduce or replace chemical fertilizers and infrastructural investments to promote agroforestry practices and silvpasture systems are indispensable for a sustainable transition (Searchinger et al., 2019; Bhattacharya et al., 2019). In the Energy sector, the transition to renewable energy sources such as solar power, green hydrogen, and wind energy necessitates high-tech capital goods, while substantial infrastructure investments are needed to support the generation, transmission, and distribution, of green electricity and natural gas, which will require the construction of renewable energy plants, grid upgrades, and energy storage systems (Grottera, 2022; IEA, 2024b). Conversely, in the Transport sector, the shift towards electrification, particularly through an increased production of electric vehicles, demands advanced capital goods. On the other hand, the scaling up of public transportation infrastructure, the expansion of rail networks, and emission-reductions in the road, maritime, and air transport sectors necessitate substantial infrastructural investments (Zhang and Fujimori, 2020; IEA, 2024a; Bataille et al., 2020). Moreover, in the context of the digital transition and the servicification of the economy, the Telecommunication sectors requires sophisticated capital goods alongside a substantial need for infrastructural investments to ensure comprehensive coverage across urban and rural areas (ECLAC, 2022). Finally, investments in high-tech machinery to enhance water security and equitable access to clean water, as well as substantial infrastructure investments for managing extreme weather events such as floods and droughts are indispensable to ensure a successful decarbonization of the economy (Rozenberg and Fay, 2019).

Thus, the very nature of green capital goods and the associated green investment requirements necessary to master the low-carbon transition are diverse, sector specific and carry with them a multi-facet set of challenges depending on the sector's role during the transition and its associated investment needs.

Our findings suggest that as countries embark on their low-carbon trajectory and pressure to transform the key sectors of the economy will increase, they will create a large demand for imported capital goods - both in the case of advanced capital goods, as well as in the case of green infrastructural capital goods. In the former case, this occurs directly through the import dependence on foreign-produced, high-technology capital goods. In the latter case, it occurs indirectly, since green infrastructural goods, despite being primarily produced domestically, rely indirectly on the import of advanced capital goods. Ultimately, with a strong import dependency of investment and capital goods, developing countries face an increased balance-of-payment constraint, with domestic capital accumulation being suppressed by the the constant need to attract foreign currency that is necessary to pay for foreign-produced capital goods. This pushes developing countries to rely on their static competitive advantage and intensify their production and exportation of primary commodity, low-value added, and often emission-intensive products to ensure the necessary capital inflows. One the other hand, as the accumulation of the capital stock is strongly dependent on foreign-produced capital goods, the socio-economic benefits of investment are largely captured by foreign producers, leading to low domestic employment generation. While green investment projects are likely to have a positive effect on employment, the associated creation of employment in low-emitting (sunrise) and the destruction of employment in high-emitting (sunset) industries, may create socio-economic imbalances (Saget et al., 2020). Thus, as developing countries transition toward a low-carbon economy, they face severe challenges with their dependence on foreign-produced capital goods not only delaying the decarbonization process, but possibly hampering employment generation and the associated distribution of income across society.

The capacity of to overcome both the resulting balance-of-payment constraint and attain sufficient employment generation crucially depends on the different strategies adopted by countries to master the low-carbon transition. Evidently, it would be fatal for developing countries to continue to their reliance on static competitive advantages by intensifying the export of primary, resource-intensive commodities. As most of the leading export industries tend to be very emission-intensive, an intensification in these industries may perpetuate existing environmental inequalities (Althouse et al., 2020) and substantially delay the decarbonzation process, risking permanent environmental damage, lock-in of polluting socio-technical pathways, socio-economic and financial losses caused by stranded assets (Pegels and Altenburg, 2020). Moreover, it will neither reduce the dependency on imported inputs and capital goods, nor address the underemployment, structural heterogeneity and the fragmentation of the labor market, originally produced by the adaptation of these strategies (Porcile, 2024).

On the contrary, our results suggest that policies that promote sustainable development in developing countries should be aimed both at reducing import elasticity of demand by reducing the dependence on foreign-produced inputs and capital goods or at increasing export elasticity by raising the degree of sophistication of the export basket. Lowering import dependency on foreign-produced inputs and capital goods implies the promotion of industrialisation and structural change to develop the productive capabilities necessary to produce domestically the investment and capital goods necessary for the transition (Mealy and Teytelboym, 2022). However, with 80% of capital goods production being concentrated in only 10 countries (Mutreja et al., 2014), even in developed countries, the replacement and accumulation of productive capacity is constrained by a strong dependence on foreign-produced capital goods, making the decoupling of investment from imported capital goods hardly achievable.[9] In fact, the fundamental difference is that developed countries export high-technology and high value-added goods, which enjoy a higher export elasticity, enabling them to replace existing productive capacity without facing balance-of-payment constraints.

In this context, technological transfers through channels such as trade, FDI, licensing, migra-

[9] Note however, that Brazil has successfully managed to increase its productive and export capacity of manufactured and agricultural equipment, despite the fact that its integration in the global capital goods trade network is still low (Ruffoni and Reichert, 2022; Wang et al., 2021).

tion or re-expatriation has often been proposed as a useful tool to mitigate capital imports for developing countries (UNCTAD, 2014, 2023; Kirchherr and Urban, 2018). However, our results suggest that technological transfer through positive spillover effects from the import of capital goods (e.g. technological transfer through trade) increases developing countries' structural dependence by deepening their external constraints, rather than allowing them to develop the necessary capacities to produce these advanced capital goods. Moreover, the penetration of new technology and its diffusion tends to be concentrated predominately in export industries, recording little spillover effects toward other industries (Prebisch, 1976; Pinto, 1970). Importantly, for technological transfer to be successful, the capacity on the side of the receiving country to adapt and adopt the transferred technology is pivotal (Arocena and Suetz, 2016) and can only be achieved if domestic supply capabilities and sufficient backward linkages exist (Hirschman, 1970). Moreover, technological capabilities are predominately tacit, as they cannot be transferred as a blueprint, but are acquired and developed through sector-specific experiences and routines. It follows that technological transfer must be viewed as a step-by-step process in which a country slowly develops the capabilities to adapt and absorb the foreign technology, moving the economy towards a lower technological gap, a more diversified pattern of specialization, higher economic growth and ultimately a more sustainable productive structure (Porcile, 2019; Cimoli and Katz, 2003). As such, a successful process of technological transfer can move developing countries toward a higher Green Complexity with strengthened capabilities to competitively export green, technology-intensive inputs and capital goods (Mealy and Teytelboym, 2022).

Thus, successful transition strategies in developing countries must be primarily directed toward increasing the export elasticity. Rather than using the revenues accruing from the exportation of emission-intensive industries to intensify production in those industries, countries should direct the revenues to diversify, green, and increase the degree of sophistication of their export structure (Gala et al., 2018). Such strategies are inevitable for developing countries to achieve sustainable development and build a resilient economy that can address the challenges produced by the low-carbon transition. First, with the exportation of goods that enjoy a higher demand on the international market, developing countries can ensure sufficient capital inflows to pay for the foreign-produced capital goods, with the potential to increase the balance-of-payment constrained growth rate. This may hold, despite the fact that building-up new export industries and increasing export complexity will drive demand for foreign-produced capital goods, which increases import elasticity and thus lowers the balance-of-payment constrained growth rate. Secondly, the build-up of new export industries with higher levels of productivity may increase employment, and promote the establishment of a resilient labor market that can absorb the profound restructuring produced by the transition (Pollin, 2020; Saget et al., 2020). Third, directing resources away from emission-intensive industries will increase environmental sustainability and reduce the socio-economic, fiscal, and external dependence on emission-intensive industries (Magacho et al., 2023). Importantly, it will allow countries to build a resilient economy, preparing its economy for the declining demand for fossil-fuels and other emission-intensive industries, with the potential to increase its productive capacity in low-emission industries and boost technical change and non-price competitiveness in green industries (Porcile, 2024).

5.3. Contributions and Limitations

Our study address the well-known limitations of capital accounting in IO analysis, which treats fixed capital as an exogenous category of final demand. Despite the development of sophisticated capital-use databases such as the KLEMS project, previous studies on capital endogenization have focused almost exclusively on developed countries, estimating capital-use matrices only for a limited amount of mostly developed countries available in the MRIO database Exiobase. On the contrary, by combining the LA KLEMS capital-use tables with the Gloria MRIO database, we propose a refined and integrated approach of estimating capital-use matrices for developing countries for which data is not as readily available, hereby filling an important research gap.

As opposed to previous studies on capital endogenization, who focus on the depreciation of the capital stock currently in use, we chose to adjust our capital requirement matrix to account for the capital-stock that is necessary to sustain productive capacity given a desired growth rate of the economy. This allows us to integrate sectoral investment needs and analyze the import and employment dynamics that are associated with the investment that is necessary to maintain the current productive capacity, which is crucial for designing explicit transition strategies. Hereby, we are not only contributing to the ongoing debate on sustainable development in developing countries, but we are also moving beyond existing studies on capital endogenization that focused almost exclusively on the environmental footprint of fixed capital.

Furthermore, by adjusting for the CFC data of Gloria, we ensure that potential data limitations produced by the LA KLEMS database are accounted for and consistency across different data sources is ensured. However, this approach includes several limitations. First of all, our results are very sensitive to sectoral CFC values from Gloria. Secondly, using CFC as a proxy for the physical use of capital is highly debated given that it remains an economic concept designed to describe the estimated loss in value as a result of use and obsolescence (Södersten et al., 2018a). It has been previously suggested to use capital services as a more adequate measure for capital stock as inputs to production, however their estimation is highly debated and sectoral data for many countries remains scarce (Ahmad, 2004; Oulton and Srinivasan, 2003; Jorgenson, 1999).

In addition, for our study, we rely on the depreciation rates published by the LA KLEMS database (Gu and Hofman, 2021), who rely on the same depreciation rates as the PWT and the EU KLEMS database that are based on the official estimates of US Bureau of Economic Analysis (Fraumeni). As such, we implicitly assume that depreciation rates are uniform across countries and most importantly that they are similar between developed and developing countries. This has been contested both on empirical and theoretical grounds. While some studies simply suggest that depreciation rates are generally higher in developing countries (Bu, 2006; Schündeln, 2013), other studies suggest that high-technology capital assets such as ICTs, Transport Equipment or Machinery & Equipment have lower depreciation rates in developing countries, while durable capital assets such as Construction goods tend to have higher depreciation rates (Pyo; Yilmaz and Kiliç, 2021). This implies that our results may overestimate the role of Construction goods and underestimate the role of Machinery

& Equipment in the capital stock structure of the analyzed countries. This in turn may cause us to underestimate the external constraint of the analyzed countries, as advanced capital goods such as Machinery & Equipment are much more import-intensive than Construction goods. In addition, the sensitivity of capital-stock estimates to the implicit assumptions made about the depreciation rates used to construct the capital-stock (Pritchett, 1999; OECD, 2023) raises important questions about the accuracy and predictability of capital-stock estimates in the context of capital endogenization. It also restates the eminent need to construct robust measures of depreciation rates across different regions of the world.

Finally, our study fails to address the inter-temporal feature of the capital-stock. As capital goods are bought to be used repeatedly in production processes, the existing capital-stock is ultimately the product of a historic accumulation process (Keynes, 1936). Effectively, we assume that the capital-stock of today was produced using today's technology, today's production structure and paid for by today's money. However, hereby, we ignore the fact that the current capital stock has already been paid for and was produced using different technologies during different age cohorts and on the basis of different productive structures (Wu et al., 2021b). This is particularly biased when interpreting the indirect impacts on employment and imports, as we attribute these impacts to a capital stock that has already been produced, and thus already been imported or generated employment. While we cannot fully abstract from these assumptions, as the structure of the input-output framework (e.g., data published on an annual basis) does not allow us to capture the historical dynamics of the capital stock, they have to be taken into account when interpreting the results.

In fact, with these limitations being largely attributed to data availability, this study exemplifies the need to develop new and more integrate measures of the sectoral investment accounts (i.e., both capital production and consumption) that allow researchers to expand and build upon these methodological developments. A more comprehensive collection of capital-use data would allow researchers to conduct dynamic modelling exercises of sectoral trends, including the determination of transition trajectories under different economic and ecological scenarios. Moreover, by relying on the external database LA KLEMS to estimate capital-use matrices for six LAC countries within the Gloria framework, further work could include the integration of other capital-stock databases such as EU KLEMS, World KLEMS, Asia KLEMS, or national capital-stock data to develop a global multi-regional capital-use table for the Gloria framework. Such methodological developments would further allow for a more comprehensive comparison between developed and developing countries, regarding their respective transition dynamics and extend previous works on the environmental footprint accounting of fixed capital to a wide range of developing countries.

References

M. Aglietta and V. Coudert. The dollar and the Transition to Sustainable Development: From Key Currency to Multilateralism. CEPII Policy Brief 2019-26, CEPII Research Center, 2019.

N. Ahmad. In Introducing Capital Services into the Production Account. Technical report, Meeting of the Advisory Expert Group on National Accounts, 2004.

J. Althouse, G. Guarini, and J. Gabriel Porcile. Ecological macroeconomics in the open economy: Sustainability, unequal exchange and policy coordination in a center-periphery model. *Ecological Economics*, 172: 106628, 2020.

R. A. Araujo and G. T. Lima. A structural economic dynamics approach to balance-of-payments-constrained growth. *Cambridge Journal of Economics*, 31(5):755–774, 2007.

R. Arocena and J. Suetz. Reading Freeman when ladders for development are gone. In E. S. Reinert, J. Ghosh, and R. Kattel, editors, *Handbook of Alternative Theories of Economic Development*. Edward Elgar Publishing, 2016.

C. Bataille, H. Waisman, Y. Briand, J. Svensson, A. Vogt-Schilb, M. Jaramillo, R. Delgado, R. Arguello, L. Clarke, T. Wild, F. Lallana, G. Bravo, G. Nadal, G. Le Treut, G. Godinez, J. Quiros-Tortos, E. Pereira, M. Howells, D. Buira, J. Tovilla, J. Farbes, J. Ryan, D. De La Torre Ugarte, M. Collado, F. Requejo, X. Gomez, R. Soria, D. Villamar, P. Rochedo, and M. Imperio. Net-zero deep decarbonization pathways in Latin America: Challenges and opportunities. *Energy Strategy Reviews*, 30, 2020.

P. Berrill, T. R. Miller, Y. Kondo, and E. G. Hertwich. Capital in the American carbon, energy, and material footprint. *Journal of Industrial Ecology*, 24(3):589–600, 2020.

A. Bhattacharya, G. G. Watkins, C. C. Casado, M. C. S. Zuniga, M. Jeong, and A.-L. Amin. Attributes and Framework for Sustainable Infrastructure. *IDB Publications*, 2019.

E. Boleti, A. Garas, A. Kyriakou, and A. Lapatinas. Economic Complexity and Environmental Performance: Evidence from a World Sample. *Environmental Modeling & Assessment*, 26(3): 251–270, 2021.

F. Bontadini, C. Corrado, J. Haskel, M. Iommi, and C. Jona-Lasinio. EUKLEMS & INTANProd: Industry productivity accounts with intangibles - Sources of growth and productivity trends: Methods and main measurement challenges. Technical report, LUISS Lab of European Economics, 2023.

L. P. Braga and T. N. Campos. A comparative study of bidding models adopted by Brazil, Peru, Colombia and Uruguay for granting petroleum exploration and production rights. *The Journal of World Energy Law & Business*, 5(2): 94–112, 2012.

Y. Bu. Fixed capital stock depreciation in developing countries: Some evidence from firm level data. *The Journal of Development Studies*, 42(5):881–901, 2006.

M. Cao, W. Kang, Q. Cao, and M. J. Sajid. Estimating Chinese rural and urban residents' carbon consumption and its drivers: Considering capital formation as a productive input. *Environment,* *Development and Sustainability*, 22(6):5443–5464, 2020.

Q. Cao, W. Kang, S. Xu, M. Sajid, and M. Cao. Estimation and decomposition analysis of carbon emissions from the entire production cycle for Chinese household consumption. *Journal of Environmental Management*, 247:525–537, 2019.

X. Chen, Y. Zhen, and Z. Chen. Household Carbon Footprint Characteristics and Driving Factors: A Global Comparison Based on a Dynamic Input–Output Model. *Energies*, 16(9): 3884, 2023.

Z.-M. Chen, S. Ohshita, M. Lenzen, T. Wiedmann, M. Jiborn, B. Chen, L. Lester, D. Guan, J. Meng, S. Xu, G. Chen, X. Zheng, J. Xue, A. Alsaedi, T. Hayat, and Z. Liu. Consumption-based greenhouse gas emissions accounting with capital stock change highlights dynamics of fast-developing countries. *Nature Communications*, 9(1):3581, 2018.

Z.-M. Chen, P. Chen, M. Lenzen, B. Xiao, and A. Malik. Global Embodied Energy Flow and Stock Analysis with Endogeneous Fixed Capital. *Environmental Science & Technology*, 56 (23):17197–17205, 2022.

M. Cimoli and J. Katz. Structural reforms, technological gaps and economic development: A Latin American perspective. *Industrial and Corporate Change*, 12 (2):387–411, 2003.

M. Cimoli, J. B. Pereima, and G. Porcile. A technology gap interpretation of growth paths in Asia and Latin America. *Research Policy*, 48(1):125–136, 2019.

B. D. Conti and D. M. Prates. The international monetary system hierarchy: Current configuration and determinants. In *The 28th Annual EAEPE Conference Manchester*, volume 3 of 5, page 47, UK, 2018.

M. S. Delgado and N. McCloud. Foreign direct investment and the domestic capital stock: The good–bad role of higher institutional quality. *Empirical Economics*, 53 (4):1587–1637, 2017.

M. A. Desai, C. F. Foley, and J. R. Hines Jr. Foreign Direct Investment and the Domestic Capital Stock. *American Economic Review*, 95(2):33–38, 2005.

G. Dosi, F. Riccio, and M. E. Virgillito. Specialize or diversify? And in What? Trade composition, quality of specialization, and persistent growth. *Industrial and Corporate Change*, 31 (2):301–337, 2022.

ECLAC. Economic Survey of Latin America and the Carribbean: Trends and challenges of investing for a sustainable and inclusive recovery. Technical Report LC/PUB.2022/9-P/Rev.1, United Nations, Santiago, Chile, 2022.

ECLAC. Economic Survey of Latin America and the Carribbean: Financing a sustainable transition: Investment for growth and climate change action. Technical Report LC/PUB.2022/9-P/Rev.1, United Nations, Santiago, Chile, 2023.

B. J. Eichengreen. *Globalizing Capital: A History of the International Monetary System*. Princeton University Press, Princeton ; Oxford, third edition edition, 2019.

FAO. *The Future of Food and Agriculture: Trends and Challenges*. Food and Agriculture Organization of the United Nations, Rome, 2017.

R. C. Feenstra, R. Inklaar, and M. P. Timmer. The Next Generation of the Penn

World Table. *American Economic Review*, 105(10): 3150–3182, 2015.

E. Fernández-Arias, A. Hofman, and T. Gàlvez. Latin America and the Carribean (LA KLEMS) Overview of Methodology and Database. Technical report, Universidad de Santiago de Chile, 2021.

M. Flegl, C. A. Jiménez-Bandala, I. Sánchez-Juárez, and E. Matus. Analysis of production and investment efficiency in the Mexican food industry: Application of two-stage DEA. *Czech Journal of Food Sciences*, 40(2): 109–117, 2022.

B. M. Fraumeni. The Measurement of Depreciation in the U.S. National Income and Product Accounts.

B. Fritz, L. F. de Paula, and D. M. Prates. Keynes at the periphery: Currency hierarchy and challenges for economic policy in emerging economies. *Journal of Post Keynesian Economics*, 40(2):183–202, 2017.

P. Gala, I. Rocha, and G. Magacho. The structuralist revenge: Economic complexity as an important dimension to evaluate growth and development. *Brazilian Journal of Political Economy*, 38(2):219–236, 2018.

O. Gisbert. A description of mature and catching-up economies: A bottom-up approach from trade specialization data. *Structural Change and Economic Dynamics*, 67:193–210, 2023.

C. Gramkow and G. Porcile. Un modelo de tres brechas. *El Trimestre Económico*, 89(353):197–227, 2022.

C. Grottera. Reducing emissions from the energy sector for a more resilient and low-carbon post-pandemic recovery in Latin America and the Caribbean. Technical Report LC/TS.2022/17, ECLAC, Santiago, 2022.

W. Gu and A. Hofman. LA KLEMS Productivity Level Database: Methodology for Estimating Purchasing Power Parities of Output and Inputs and Relative Productivity Levels in Latin America. Technical report, LA KLEMS, 2021.

D. Hartmann, M. R. Guevara, C. Jara-Figueroa, M. Aristarán, and C. A. Hidalgo. Linking Economic Complexity, Institutions, and Income Inequality. *World Development*, 93: 75–93, 2017.

S. Hata, K. Nansai, and K. Nakajima. Fixed-capital formation for services in Japan incurs substantial carbon-intensive material consumption. *Resources, Conservation and Recycling*, 182:106334, 2022.

K. He and E. G. Hertwich. The flow of embodied carbon through the economies of China, the European Union, and the United States. *Resources, Conservation and Recycling*, 145:190–198, 2019.

M. C. Heigl. An Operationalization of the Strategic-Relational Approach: The Contested Privatization of the Mexican Oil Sector (1982–2006). *Globalizations*, 8(1): 81–96, 2011.

E. G. Hertwich. Increased carbon footprint of materials production driven by rise in investments. *Nature Geoscience*, 14(3):151–155, 2021.

E. G. Hertwich and R. Wood. The growing importance of scope 3 greenhouse gas emissions from industry. *Environmental Research Letters*, 13(10): 104013, 2018.

C. A. Hidalgo. Economic complexity theory and applications. *Nature Reviews Physics*, 3(2):92–113, 2021.

A. O. Hirschman. *Exit, Voice, and Loyalty: Responses to Decline in Firms, Organiza-*

tions, and States. Harvard University Press, 1970.

M. Hoyos, E. Libman, and A. Razmi. The structural outcomes of investment surges. *Structural Change and Economic Dynamics*, 58:245–255, 2021.

C. A. Ibarra and J. Ros. Profitability and capital accumulation in Mexico: A first look at tradables and non-tradables based on KLEMS. *International Review of Applied Economics*, 33(3):426–452, 2019.

IEA. Net Zero by 2050: A Roadmap for the Global Energy Sector. Technical report, IEA, Paris, 2024a.

IEA. World Energy Investment 2024. Technical report, IEA, Paris, 2024b.

R. Inklaar, D. Gallardo Albarrán, and P. Woltjer. The Composition of Capital and Cross-country Productivity Comparisons. *International Productivity Monitor*, 36(36):34–52, 2019.

D. W. Jorgenson. New Methods for Measuring Capital. Technical report, Canberra Group on Capital Stock Statistics, Washington DC, 1999.

A. Kaltenbrunner and J. P. Painceira. Developing countries' changing nature of financial integration and new forms of external vulnerability: The Brazilian experience. *Cambridge Journal of Economics*, 39(5):1281–1306, 2015.

J. M. Keynes. *The General Theory of Employment, Interest, and Money*. Palgrave Macmillan, New York, USA, 1936.

J. Kirchherr and F. Urban. Technology transfer and cooperation for low carbon energy technology: Analysing 30 years of scholarship and proposing a research agenda. *Energy Policy*, 119: 600–609, 2018.

M. Lenzen and G. Treloar. Endogenising capital: A comparison of two methods. *Input-output analysis*, 10:1–11, 2004.

M. Lenzen, A. Geschke, M. D. Abd Rahman, Y. Xiao, J. Fry, R. Reyes, E. Dietzenbacher, S. Inomata, K. Kanemoto, B. Los, D. Moran, H. Schulte In Den Bäumen, A. Tukker, T. Walmsley, T. Wiedmann, R. Wood, and N. Yamano. The Global MRIO Lab – charting the world economy. *Economic Systems Research*, 29(2): 158–186, 2017.

M. Lenzen, A. Geschke, J. West, J. Fry, A. Malik, S. Giljum, L. Milà i Canals, P. Piñero, S. Lutter, T. Wiedmann, M. Li, M. Sevenster, J. Potočnik, I. Teixeira, M. Van Voore, K. Nansai, and H. Schandl. Implementing the material footprint to measure progress towards Sustainable Development Goals 8 and 12. *Nature Sustainability*, 5 (2):157–166, 2022.

W. W. Leontief. Quantitative Input and Output Relations in the Economic Systems of the United States. *The Review of Economics and Statistics*, 18(3):105, 1936.

W. W. Leontief. *The Structure of the American Economy*. Havard University Press, 1941.

E. Libman, J. A. Montecino, and A. Razmi. Sustained investment surges. *Oxford Economic Papers*, 71 (4):1071–1095, 2019.

G. Magacho, E. Espagne, A. Godin, A. Mantes, and D. Yilmaz. Macroeconomic exposure of developing economies to low-carbon transition. *World Development*, 167:106231, 2023.

G. Magacho, E. Espagne, and A. Godin. Impacts of the CBAM on EU trade partners: Consequences for developing countries. *Climate Policy*, 24(2):243–259, 2024.

J. McCombie and A. P. Thirlwall. *Economic Growth and the Balance-of-Payments Constraint*. Springer, 2016.

P. Mealy and A. Teytelboym. Economic complexity and the green economy. *Research Policy*, 51 (8):103948, 2022.

R. E. Miller and P. D. Blair. *Input-Output Analysis: Foundations and Extensions*. Cambridge University Press, 2 edition, 2009.

T. R. Miller, P. Berrill, P. Wolfram, R. Wang, Y. Kim, X. Zheng, and E. G. Hertwich. Method for endogenizing capital in the United States Environmentally-Extended Input-Output model. *Journal of Industrial Ecology*, 23(6):1410–1424, 2019.

H. P. Minsky. *John Maynard Keynes*. Springer, 1976.

P. Mutreja, B. Ravikumar, and M. Sposi. Capital Goods Trade and Economic Development. Working Paper 2014-012A, Federal Reserve Bank of St. Louis, St. Louis, 2014.

C. Newman, J. Rand, T. Talbot, and F. Tarp. Technology transfers, foreign investment and productivity spillovers. *European Economic Review*, 76:168–187, 2015.

J. V. Ocampo, K. Govindan, M. A. G. Perez, and C. H. Cano. Nationalisation and privatisation in state-owned oil multilatinas. *International Journal of Business and Emerging Markets*, 9(3):302, 2017.

OECD. Sensitivity of capital and MFP measurement to asset depreciation patterns and initial capital stock estimates. OECD Statistics Working Papers 2023/01, 2023.

OECD and UN. System of National Accounts, 2009. Technical report, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank, New York, 2009.

N. Oulton and S. Srinivasan. Capital Stocks, Capital Services, and Depreciation: An Integrated Framework, 2003.

A. Pegels and T. Altenburg. Latecomer development in a "greening" world: Introduction to the Special Issue. *World Development*, 135:105084, 2020.

Q. Perrier and P. Quirion. How shifting investment towards low-carbon sectors impacts employment: Three determinants under scrutiny. *Energy Economics*, 75:464–483, 2018.

L. Persson, B. M. Carney Almroth, C. D. Collins, S. Cornell, C. A. de Wit, M. L. Diamond, P. Fantke, M. Hassellöv, M. MacLeod, M. W. Ryberg, P. Søgaard Jørgensen, P. Villarrubia-Gómez, Z. Wang, and M. Z. Hauschild. Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. *Environmental Science & Technology*, 56(3):1510–1521, 2022.

A. Pinto. Naturaleza E Implicaciones De La "Heterogeneidad Estructural" De La América Latina. *El Trimestre Económico*, 37 (145(1)):83–100, 1970.

R. Pollin. Green Economics and Decent Work: A Viable Unified Framework. *Development and Change*, 51 (2):711–726, 2020.

G. Porcile. *Latin American Structuralism and Neo-structuralism*, pages 50–71. Oxford University Press, 2019.

G. Porcile. Sustainable development in a center-periphery model. LEM Working Paper Serues 2024/10, Scuola Superiore Sant'Anna, Pisa, Italy, 2024.

R. Prebisch. The economic development of Latin America and its principal problems. *Economic Comission for Latin America*, 1950.

R. Prebisch. Crecimiento, desequilibrio y disparidades: una interpretación del proceso de desarrollo, Estudio económico de A.L. Technical report, ECLAC, Santiago, 1973, 1951.

R. Prebisch. A critique of peripheral capitalism. *CEPAL Review*, 1:9–76, 1976.

L. Pritchett. *The Tyranny of Concepts: CUDIE (Cumulated, Depreciated Investment Effort) Is Not Capital*. Policy Research Working Papers. The World Bank, 1999.

H. K. Pyo. The Estimation of Industry-level Capital Stock for Emerging-Market and Transition Economies.

W. J. Ripple, C. Wolf, T. M. Newsome, P. Barnard, W. R. Moomaw, and P. Grandcolas. World Scientists' Warning of a Climate Emergency. *BioScience*, 70(1):8–12, 2020.

J. P. Romero and J. S. L. McCombie. Thirlwall's law and the specification of export and import functions. *Metroeconomica*, 69 (2):366–395, 2018.

A. Rosemberg. Building a Just Transition: The linkages between climate change and employment. In *Climate Change and Labour: The Need for a "Just Transition": International Journal of Labour Research, Vol. 2, Issue 2*, pages 125–162. International Labour Office, 2010.

J. Rozenberg and M. Fay, editors. *Beyond the Gap: How Countries Can Afford the Infrastructure They Need While Protecting the Planet*. Sustainable Infrastructure References. World Bank, Washington, DC, 2019.

E. P. Ruffoni and F. M. Reichert. Capabilities and Innovative Performance in the Brazilian Agricultural Machinery Industry. *Revista Brasileira de Gestão de Negócios*, 24:275–293, 2022.

C. Saget, A. Vogt-Schilb, and T. Luu. Jobs in a Net Zero Emissions Future in Latin America and the Caribbean. Technical report, Inter-American Development Bank and International Labour Organization, Washington D.C. and Geneva, 2020.

M. J. Sajid, H. Niu, Zijing Liang, J. Xie, and M. H. Ur Rahman. Final consumer embedded carbon emissions and externalities: A case of Chinese consumers. *Environmental Development*, 39:100642, 2021.

M. Schündeln. Appreciating depreciation: Physical capital depreciation in a developing country. *Empirical Economics*, 44(3): 1277–1290, 2013.

T. Searchinger, R. Waite, C. Hanson, J. Ranganathan, P. Dumas, and E. Mathews. Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050. Technical report, World Resources Institute, Washington DC, 2019.

M. Shahbaz, I. Ozturk, T. Afza, and A. Ali. Revisiting the environmental Kuznets curve in a global economy. *Renewable and Sustainable Energy Reviews*, 25:494–502, 2013.

P. Shreyer. *Measuring Capital - OECD Manual 2009: Second Edition*. OECD, Paris, 2009.

C.-J. Södersten and M. Lenzen. A supply-use approach to capital endogenization in input–output analysis. *Economic Systems Research*, 32(4): 451–475, 2020.

C.-J. Södersten, R. Wood, and E. G. Hertwich. Endogenizing Capital in MRIO Models: The Implications for Consumption-Based Accounting. *Environmental Science & Technology*, 52(22): 13250–13259, 2018a.

C.-J. Södersten, R. Wood, and E. G. Hertwich. Environmental Impacts of Capital Formation. *Journal of Industrial Ecology*, 22(1):55–67, 2018b.

C.-J. Södersten, R. Wood, and T. Wiedmann. The capital load of global material footprints. *Resources, Conservation and Recycling*, 158:104811, 2020.

D. Spinola. Uneven development and the balance of payments constrained model: Terms of trade, economic cycles, and productivity catching-up. *Structural Change and Economic Dynamics*, 54:220–232, 2020.

A. P. Thirlwall. The Balance of Payments Constraint as an Explanation of International Growth Rate Differences. *BNL Quarterly Review, Banca Nazionale del Lavoro*, 32(128):45–53, 1979.

A. P. Thirlwall. Balance of Payments Constrained Growth Models: History and Overview. In E. Soukiazis and P. A. Cerqueira, editors, *Models of Balance of Payments Constrained Growth*, pages 11–49. Palgrave Macmillan UK, London, 2012.

A. P. Thirlwall and M. N. Hussain. The Balance of Payments Constraint, Capital Flows and Growth Rate Differences between Developing Countries. *Oxford Economic Papers*, 34(3): 498–510, 1982.

M. P. Timmer, M. O'Mahony, and B. van Ark. Growth and Productivity Accounts from Eu Klems: An Overview. *National Institute Economic Review*, (200):64–78, 2007.

UNCTAD. Studies in technology transfer. Technical Report UNCTAD/DTL/STICT/2013/7, UNCTAD, Geneva, 2014.

UNCTAD. Climate change, green recovery and trade. Technical report, United Nations, Geneva, 2021.

UNCTAD. Technology and Innovation Report 2023. Technical Report UNCTAD/TIR/2022, UNCTAD, Geneva, 2023.

UNFCCC. Paris Agreement to the United Nations Framework Convention on Climate Change. Technical report, United Nations, Paris, 2015.

D. F. Vivanco. The role of services and capital in footprint modelling. *The International Journal of Life Cycle Assessment*, 25(2): 280–293, 2020.

R. Vos and L. G. Bellù. Global Trends and Challenges to Food and Agriculture into the 21st Century. In C. Campanhola and S. Pandey, editors, *Sustainable Food and Agriculture*, pages 11–30. Academic Press, 2019.

Y. Wang, Z. Wang, and H. Zameer. Structural characteristics and evolution of the "international trade-carbon emissions" network in equipment manufacturing industry: International evidence in the perspective of global value chains. *Environmental Science and Pollution Research*, 28 (20):25886–25905, 2021.

T. Wiedmann and M. Lenzen. Environmental and social footprints of international trade. *Nature Geoscience*, 11(5):314–321, 2018.

T. Wiedmann, H. C. Wilting, M. Lenzen, S. Lutter, and V. Palm. Quo Vadis MRIO?

Methodological, data and institutional requirements for multi-region input–output analysis. *Ecological Economics*, 70(11):1937–1945, 2011.

T. O. Wiedmann, H. Schandl, M. Lenzen, D. Moran, S. Suh, J. West, and K. Kanemoto. The material footprint of nations. *Proceedings of the National Academy of Sciences*, 112(20):6271–6276, 2015.

X. Wu, C. Li, J. Guo, X. Wu, J. Meng, and G. Chen. Extended carbon footprint and emission transfer of world regions: With both primary and intermediate inputs into account. *Science of The Total Environment*, 775:145578, 2021a.

Z. Wu, M. Wang, and Q. Ye. Integrating the inter- and intra-annual dynamic features of capital into environmental footprint assessment: Revisiting China's greenhouse gas footprints, 1995-2015. *Science of The Total Environment*, 801:149629, 2021b.

D. Xu, Y. Zhang, and Z. Yang. From Geospatial to Temporal Separation: A Review on Carbon Accounting Endogenizing Fixed Capital. *Ecosystem Health and Sustainability*, 9:0002, 2023.

Q. Ye, E. G. Hertwich, M. S. Krol, D. Font Vivanco, A. W. Lounsbury, X. Zheng, A. Y. Hoekstra, Y. Wang, and R. Wang. Linking the Environmental Pressures of China's Capital Development to Global Final Consumption of the Past Decades and into the Future. *Environmental Science & Technology*, 55 (9):6421–6429, 2021.

Q. Ye, M. S. Krol, Y. Shan, J. F. Schyns, M. Berger, and K. Hubacek. Allocating capital-associated CO2 emissions along the full lifespan of capital investments helps diffuse emission responsibility. *Nature Communications*, 14(1):2727, 2023.

D. Yilmaz and A. Godin. A Stock-Flow Consistent Prototype Growth Model.pdf. AFD Working Paper 125, Agence Française de Dévéloppement, Paris, France, 2021.

E. Yilmaz and İ. E. Kiliç. Estimating Firm-Level Capital Stock: The Evidence From Turkey. *The Developing Economies*, 59(4):371–404, 2021.

R. Zhang and S. Fujimori. The role of transport electrification in global climate change mitigation scenarios. *Environmental Research Letters*, 15(3): 034019, 2020.

A. Appendix: Reviewing studies on capital endogenization

A.1. The Capital-Augmented Environmental Footprint

One the basis of the methodological developments mentioned above, multiple studies have started to endogenize capital in MRIO analysis, focusing predominately and almost exclusively on the associated environmental impact of fixed capital.

Initial studies focused primarily on the augmentation method both on a global (Hertwich and Wood, 2018; He and Hertwich, 2019) and national level (Cao et al., 2019; Hata et al., 2022; Cao et al., 2020; Sajid et al., 2021) to quantify the carbon (Wu et al., 2021a) and the material-related carbon footprint (Hertwich, 2021) of countries. Considering that the productive services of fixed capital extend over more than one year and are formed in previous years, some scholars criticized that these static IO models ignore the intertemporal feature of fixed capital. Therefore, in an attempt to address this shortcoming, subsequent studies started to apply the augmentation method in a dynamic framework assessing the temporal deviation between the current carbon (Chen et al., 2018, 2023) or energy footprint (Chen et al., 2022) and future consumption. Besides the general methodological limitations of the augmentation method presented above, it was further argued that these studies treat fixed capital as a homogeneous commodity. Hereby, they ignore the considerable differences between different types of capital assets and their respective differences in environmental impacts (Xu et al., 2023). Consequently, as pointed out by (He and Hertwich, 2019), these studies may overestimate the carbon footprint of services, while underestimating that of transportation, raising important methodological questions of the aforementioned studies (see also (Berrill et al., 2020).

As a consequence more recent studies, relied on the flow-matrix method to assess the environmental impacts of capital stock. Given the initial lack of high-precision data on capital stock by sector and asset, studies focused primarily on the United States for which data was readily available. For example, (Miller et al., 2019) distinguished between three types of capital assets, concluding that housing was predominately consuming structures, transport was mainly consuming equipment, while information industries consumed predominately intellectual property products. Similar results were also found by (Berrill et al., 2020) in a follow-up study that distinguished between 9 capital assets. As noted above, With the emergence of the KLEMS project (see (Timmer et al., 2007; Bontadini et al., 2023), global data availability on capital stock by industry and asset type increased substantially. This led to new methodological developments that allowed for capital endogenization and the associated assessment of environmental impacts for different types of fixed capital on a global scale.

While these studies substantially advanced the literature on capital endogenization, some scholars have recently argued that the extended footprints based on the static MRIO models fail to account for the intertemporal feature of fixed capital. That is, it fails to capture that capital goods are produced in different age cohorts with different technologies, which affect the retrospective distribution of historical resource extractions and emissions (Wu et al., 2021b). Instead, these methods assume that the capital consumed today was produced by today's technology. Consequently, a few recent studies restored to assessing the dynamic footprint of fixed capital using the production structure and the environmental intensities of the production year of the fixed capital to quantify the historical emissions for a target year (Ye et al., 2021; Wu et al., 2021b). For example, (Ye et al., 2021) quantify the past and future linkages of China's capital formation for six environmental pressures and (Wu et al., 2021b) further extended this dynamic model by integrating the inter- and intra-annual dynamic features of capital to assess environmental footprints.

A.2. The Sectoral, Geospatial, and Temporal Resdistribution of Capital's Environmental Impact

Consistently, these studies show that the endogenization of capital in MRIO models has led to a substantial increase in the consumption and production-based emissions as well as a significant redistribution of environmental impacts across industries and countries.

For example, (Södersten et al., 2018a) endogenized capital transactions using Exiobase to allocate emissions from eight different capital goods to final consumption, concluding that the endogenizing of capital increased the global carbon footprint of final consumption by up to 57% (see also (Södersten et al., 2018b). Moreover, they show that global emissions embodied in trade increased by up to 11% and that the increase in emissions was strongest for sectors with low initial multipliers (e.g. Services and Government sectors). Similarly, (Hertwich and Wood, 2018) show that the inclusion of capital predominately increased the carbon footprint of Services, including Real Estate Services, Rental Machineryand Equipment, Education and Health Care (see also (Cao et al., 2019), while the material footprint increased primarily for Construction and Machinery& Equipment (Hertwich, 2021). This is further argued by (Södersten et al., 2020) who introduce the capital-augmented material footprint (CAMF)[10], showing that Construction was the largest intermediate capital good for the material footprint accounting for almost 80% of global material flows. Moreover, they show that for mineral use, between 50-60% of the total footprint of final consumption is embedded in capital goods. In terms of energy, (Berrill et al., 2020) show that capital consumption accounted for 19% of total energy footprints in the US in 2012, while (Chen et al., 2022) show that in 2014 three times the world's direct energy use was stored in global fixed capital stock.

In terms of geospatial redistribution, most of these studies show that the inclusion of capital had a stronger impact on the carbon (Chen et al., 2018; He and Hertwich, 2019; Wu et al., 2021a), the material-related carbon footprint (Södersten et al., 2020), and the energy footprint (Chen et al., 2022) of developing countries. In particular, it is argued that the impact was strongest for fast-developing countries, highlighting the recent capital stock expansions in those regions, but also the fact that developing countries use capital investments to build up capacity, while developed countries use capital investment to replace the existing depreciated capital (Chen et al., 2022, 2018).[11] Accordingly, several studies confirmed that

[10] The CAMF is a new indicator that includes all the materials embedded in capital goods

[11] Other studies have further attributed this dynamic to the high population growth and foreseeable urbanization in some fast-developing countries (Hertwich, 2021), as well as the increased production capacities required to fulfill

this increase was strongest for China, driven by the renewed capital stock that had been heavily invested in over the last 20 years (He and Hertwich, 2019). Moreover, (Södersten et al., 2018a) argue that, while overall emission multipliers decreased, indicating that production processes have become cleaner, this trend was less profound in developing countries, suggesting that developing countries still have a larger share of dirty assets embodied in their capital stock (Shahbaz et al., 2013). In addition, by allowing for the distinction between capital assets, these studies were able to show that developing countries tend to invest in more resource-intensive assets, such as infrastructure and Machinery, while developed countries invest in less-resource intensive assets such as computers, software, and services (Ye et al., 2023).

In terms of temporal redistribution, it is important to note that studies focusing on the dynamic environmental footprint demonstrate that the dynamic footprint tends to be smaller than the traditional footprint, as dynamic models allocate emissions embodied in fixed capital formation to future consumption (see (Ye et al., 2023; Chen et al., 2018, 2023; Wu et al., 2021a). In particular (Ye et al., 2023) argue that the traditional footprint tends to overestimate environmental impacts by up to 114% for the case of China, while (Wu et al., 2021b) argue that 8% of GHG footprints would still be overestimated if the intra-annual dynamics were not considered. Note further that this difference was generally found to be smaller for developing countries, further underlining their high capital requirements and the recent capital stock expansion dynamics indicated above.

B. Appendix: Methodology

B.1. Constructing the Time-Series of Capital Stock

Given that we rely on the GFCF data ($\tilde{\mathbf{I}}_{k,s}$) in constant prices, we adjust the price level by $\beta_t = \frac{\pi_{n_t}}{\pi_{r_t}}$. Thus, the time-series of GFCF $\mathbf{I}_{k,s}$ in current prices by asset type k and sector s is thus obtained by:

$$\mathbf{I}_t = \tilde{\mathbf{I}}_t \odot \boldsymbol{\beta}_t \tag{15}$$

We first calculate the matrix of the initial capital stock $\mathbf{K}^i_{k,s}$ for each KLEMS asset type *k* in KLEMS sector *s*. To do so, we first calculate the average GFCF matrix (by asset *k* and sector *s*) for the first five years, indicated by $\tilde{\mathbf{J}}_{k,s}$ as follows

$$\tilde{\mathbf{J}} = \frac{\sum_{i=1}^{n=5} \mathbf{J}}{n} \tag{16}$$

The initial capital stock matrix is then calculated as

$$\mathbf{K}^i = \frac{\tilde{\mathbf{J}}}{(\delta + \bar{\mathbf{g}})} \tag{17}$$

the surging export demand in those regions (Södersten et al., 2018a).

where δ represents the matrix of the annual depreciation rate by industry and asset and $\bar{\mathbf{g}} = \frac{ln(\mathbf{J}_n)-ln(\mathbf{J}_{t_0})}{n}$ indicates the matrix of the long-term average logarithmic growth rate of GFCF by industry and asset. Subsequently, the time series of the capital stock is calculated sequentially as

$$\tilde{\mathbf{K}}_{t+1} = \tilde{\mathbf{K}}_t(1-\boldsymbol{\delta}) + \mathbf{J}_t \tag{18}$$

Given this method, we are able to obtain detailed capital stock data for 7 LA and CA countries, each with a different level of detail with respect to assets and sectors (see 1).

B.2. The Capital-Augmented IO model

After having constructed our capital-flow matrix, we are able to construct an input-output framework with capital endogenization. Following (Miller and Blair, 2009), one can obtain the Multiregional Leontief matrix by considering that total production by industry and country is given by the summation of the columnvector of intermediate inputs and the column-vector of final demand (**y**). Intermediate inputs are given by the multiplication of the technical coefficient matrix **A** and the column-vector of total production (**x**):

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \tag{19}$$

Alternatively, the basic IO accounting equation can be rewritten as

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{20}$$

where $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief matrix denoting the direct and indirect inputs necessary to produce one unit of industry output. To obtain a capital *requirement* matrix **B**, we proceed similarly as when calculating the matrix of technical input coefficients $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$. Thus, the matrix of capital requirements to produce one unit of output is obtained as

$$\breve{\mathbf{B}} = \mathbf{K}\hat{\mathbf{x}}^{-1} \tag{21}$$

where **x** is the output column-vector and **K** our newly obtained Gloria-based capital matrix. $\breve{\mathbf{B}}$ is thus the matrix of direct capital coefficients, where each element $b_i^j = b_i^j/x_i^j$ represents the direct capital requirement from sector *i* per unit of total output for sector *j* and where the horizontal vector of the row-sums represents the capital-output ratio by sector *j*.

Note however, that this matrix indicates the depreciated capital-stock and does not take into account the capital stock necessary to maintain productive capacity. Thus, we adjust our newly obtained $\breve{\mathbf{B}}$ matrix by an adjustment vector to build a capital-stock matrix that captures the capital-stock needed to maintain productive capacity (see also Section 3.2).

$$\mathbf{B} = \hat{\beta}\breve{\mathbf{B}} \tag{22}$$

Ultimately, the sum of **A** and **B** shows the total production requirements of capital and non-capital goods, which allows us to calculate a new Leontief inverse as

$$\mathbf{L}^{\mathrm{K}} = (\mathbf{I} - (\mathbf{A} + \delta\mathbf{B}))^{-1} \tag{23}$$

$$\mathbf{G}^{\mathrm{K}} = (\mathbf{I} - (\mathbf{D} + \delta\mathbf{B}))^{-1} \tag{24}$$

whose element lk_i^j denotes not only the the direct and indirect inputs, but also the direct and indirect capital assets of sector *i* needed by sector *j* to produce one unit of industry output. Note that **B** is multiplied by the matrix of annual depreciation rates $\delta_{i,j}$. Thus, one must bear in mind that the interpretation of this new Leontief Inverse differs from the common Leontief matrix as it also includes the direct and indirect capital requirements.

B.3. Calculating the Import-Intensities of Capital Goods

In a second step, the goal is to understand how the endogenization of capital impacts the import dependency of developing countries. In order to provide a full account of this dynamic, we need to account for the direct and indirect inputs and capital goods necessary to produce both domestic inputs and capital goods. To achieve this, we first calculate the matrix of direct imported inputs as

$$\mathbf{A}^{\mathrm{M}} = \mathbf{A} \odot (1 - \mathbf{M}) \tag{25}$$

where **M** is a dummy matrix of ones in the within countries' sectoral relations and zeros in the trade flows (imports and exports) of the Gloria MRIO database. We then separate our capital-use matrix **B** in a domestic ($\mathbf{B}^{\mathrm{D}}$) and an imported ($\mathbf{B}^{\mathrm{M}}$) capital-use matrix as follows

$$\mathbf{B}^{\mathrm{D}} = \mathbf{D}\mathbf{ps}^{d} \tag{26}$$

$$\mathbf{B}^{\mathrm{M}} = \mathbf{D}(1 - \mathbf{ps}^{d}) \tag{27}$$

where $\mathbf{D} = \delta\mathbf{B}$ and $\mathbf{ps}^{\mathrm{d}}$ is a distribution vector indicating the share of domestic GFCF by sector. $\mathbf{ps}^{\mathrm{d}}$ is calculated by dividing the domestic GFCF vector $\mathbf{p}^{\mathrm{d}}$ by the vector of total GFCF **p**. Note that the matrix of capital stocks **K** is separated accordingly into a domestic ($\mathbf{K}^{\mathrm{D}}$) and an imported capital stock matrix ($\mathbf{K}^{\mathrm{M}}$) using the same method.

Building on that, we calculate the matrix of direct and indirect embodied imported inputs for domestic production excluding capital

$$\mathbf{A}^{\mathrm{ML}} = \mathbf{A}^{\mathrm{M}}\mathbf{L}^{\mathrm{M}} \tag{28}$$

where $\mathbf{L}^{\mathrm{M}} = \mathbf{L} \odot (1 - \mathbf{M})$ represents the imported Leontief matrix. Ultimately, the matrix of direct and indirect embodied imported inputs and capital goods necessary to produce both domestic inputs and capital goods is given by

$$\mathbf{L}^{\mathrm{MK}} = (\mathbf{A}^{\mathrm{M}} + \mathbf{B}^{\mathrm{M}})\mathbf{L}^{\mathrm{K}} \tag{29}$$

As a final step, we calculate the indirectly imported inputs and capital goods necessary to produce the domestically produced capital stock by

$$\mathbf{L}^{\mathrm{K^m}} = \mathbf{E}^{\mathrm{D}} \odot \sum_{j=1}^{i} \mathbf{L}^{\mathrm{MK}} \tag{30}$$

where $\mathbf{E}^{\mathrm{M}} = \delta\mathbf{K}^{\mathrm{D}}$ represents the domestically produced depreciated capital stock. Consequently, the domestically produced inputs and capital goods necessary to produce domestically capital goods are calculated as a residual by

$$\mathbf{L}^{\mathrm{K^d}} = \mathbf{E}^{\mathrm{D}} - \mathbf{L}^{\mathrm{K^m}} \tag{31}$$

B.4. Calculating the Employment-Intensities of Capital Goods

Lastly, we estimate the direct and indirect employment generated by each sector in the economy, both including and excluding capital.

Denoting the direct total employment vector by industry as $\mathbf{q}_{\mathrm{j}}$, where each element q_i represents the total direct employment generated by industry *i*, we can calculate the direct employment intensity vector **n** by

$$\mathbf{n} = \mathbf{q}\hat{\mathbf{x}}^{-1} \tag{32}$$

where **x** is the industries' total output. Given the employment intensity vector **n** and the newly constructed capital-augmented Leontief inverse $\mathbf{L}^{\mathrm{K}}$ we can calculate the direct and indirect employment intensities $\mathbf{N}^{\mathrm{K}}$ by

$$\mathbf{N}^{\mathrm{K}} = \hat{\mathbf{n}}\mathbf{L}^{\mathrm{K}} \tag{33}$$

where each element n_i^j denotes the amount of employment *q* that is generated by the total upstream inputs and upstream capital assets from industry *i*, required for the production of industry *j*'s output. Conversely, we calculate the direct and indirect employment intensities without capital endogenization **N** by:

$$\mathbf{N} = \hat{\mathbf{n}}\mathbf{L} \tag{34}$$

C. Appendix: Additional Results

Figure 1: Sectoral Imported Content

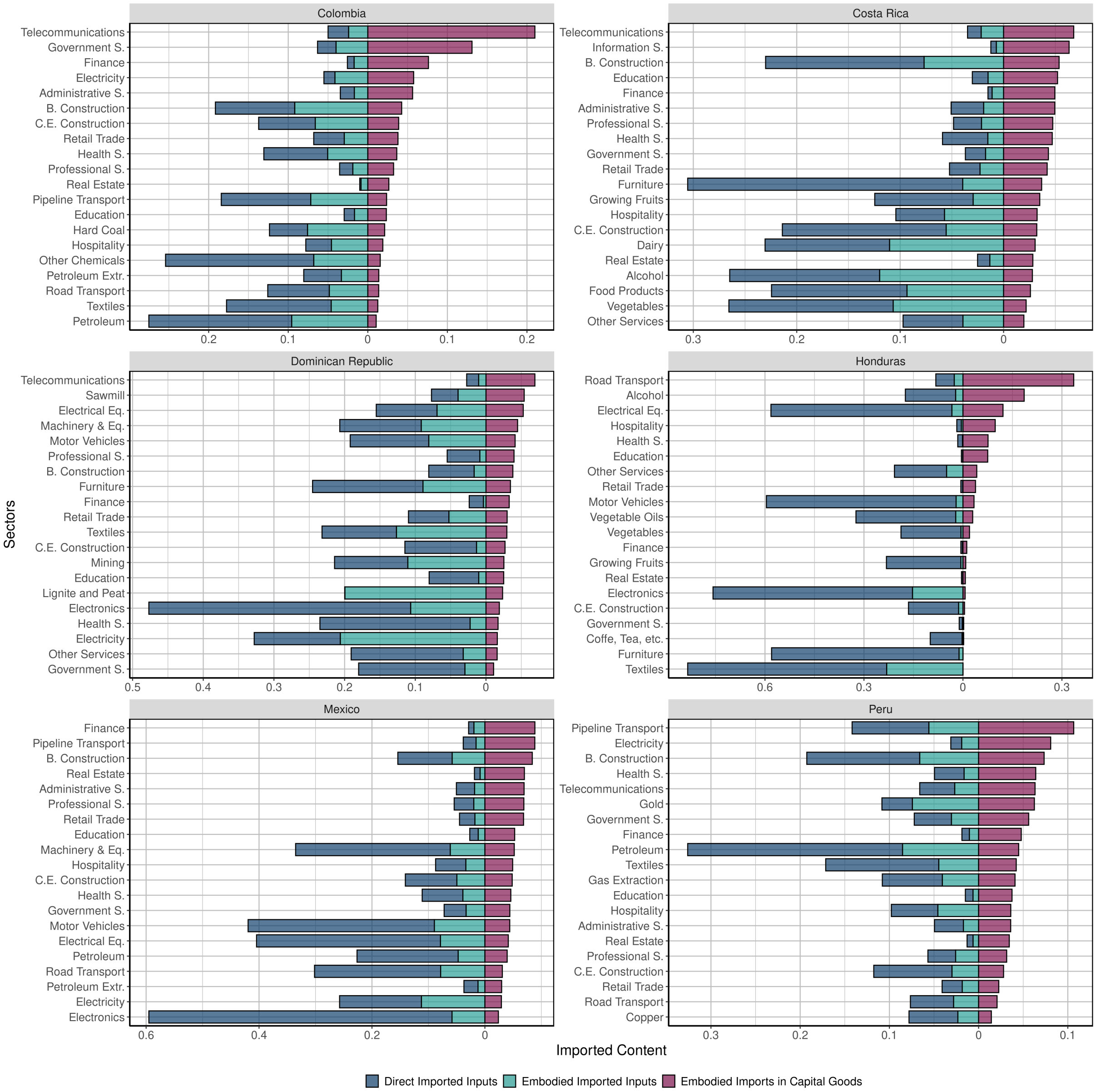
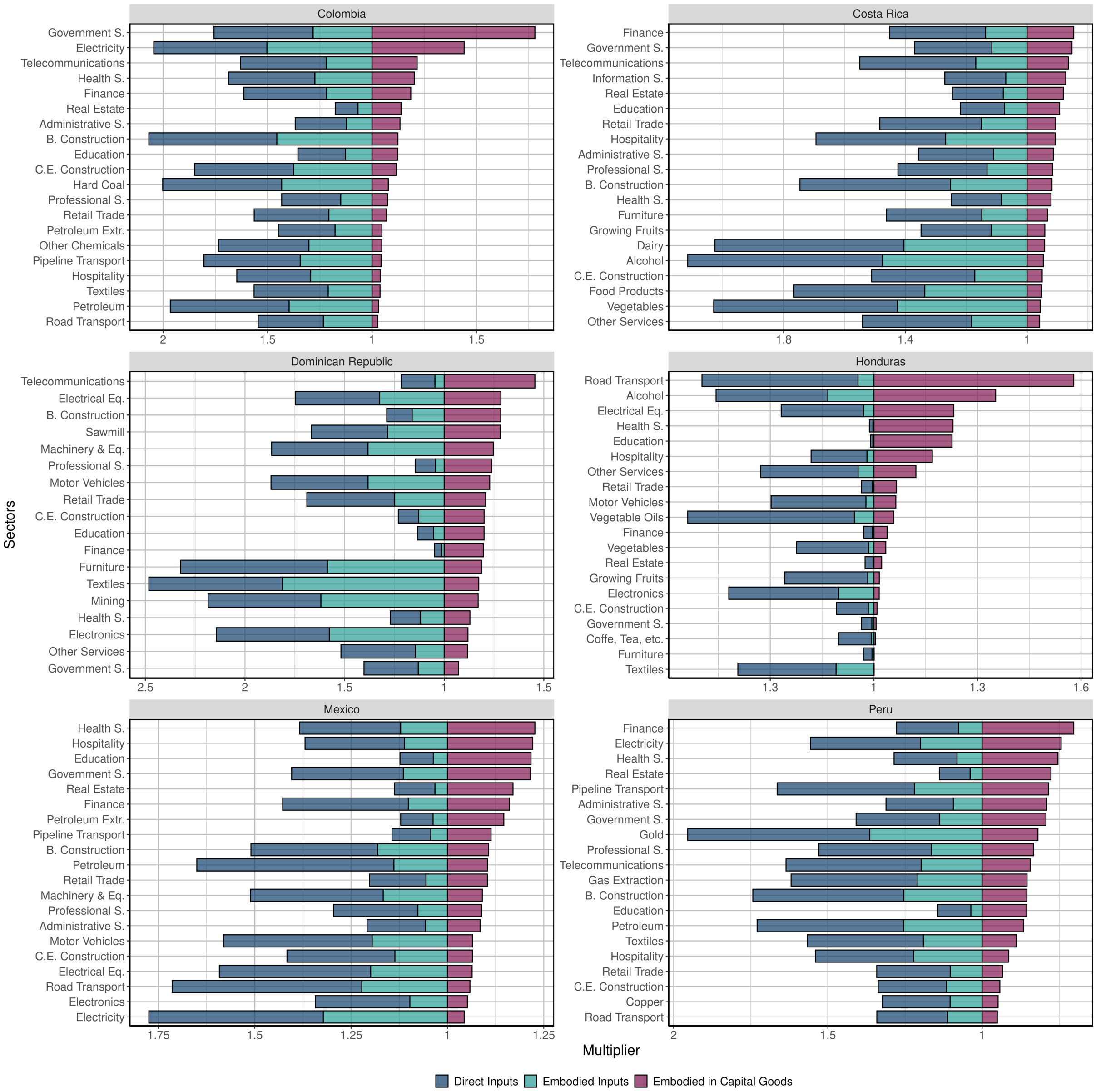


Figure 2: Sectoral Output Multipliers



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