Why do some economies benefit more from climate finance than others? A case study on North-to-South financial flows

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ABSTRACT:

International climate finance will continue increasing if the financial goal agreed in Copenhagen is to be reached. Apart from climate-related benefits, these monetary flows generate economic impacts via the purchase of goods and services. Due to international trade, impacts happen not only in recipient countries but also in other economies involved in the supply chain of these products. Countries differ in their ability to capture these economic benefits. We seek to clarify the factors underlying the differences between several recipient and donor countries by applying a structural decomposition analysis. We focus on specific climate actions, and quantify the contribution of four factors: value-added intensity, domestic multiplier, foreign multiplier and trade structure. Results point to the factors with the greatest potential to enhance the economic gains of climate finance in each country. This information is useful for the design of national strategies aimed at maximising synergies between climate action and development.

1. INTRODUCTION

For many countries the lack of financial resources is a barrier to the successful implementation of an appropriate mix of policies to mitigate climate change and its impacts. To enable a globally coordinated response to climate change, developed countries committed to jointly mobilize US dollar (USD) 100 billion per year by 2020 from a variety of sources to address developing countries' needs in terms of climate action at the 15th Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). The Copenhagen Accord contained this commitment, which is named Long-term Finance (UNFCCC, 2009). The decision 1/CP.21 accompanying the Paris Agreement urges developed countries to increase their level of financial support, with a concrete roadmap for achieving the commitment made in Copenhagen (UNFCCC, 2015). This decision upholds the USD 100 billion target from 2020 to 2025, and specifies that it will then review that collective target upwards.

Since the negotiation of the UNFCCC in 1992, the number of climate change funds that channel climate finance has increased rapidly. Today, there are around 100 international public funds, including the Global Environment Facility, the Adaptation Fund, the Climate Investment Funds and the Green Climate Fund (GCF), as well as a great number of private funds. The GCF, whose creation was agreed in the Cancun Agreements of the 16th COP in 2010, was conceived as the main channel for the Long-term Finance commitment (UNFCCC, 2010). As for December 2016, it had mobilized USD 10.3 billion and had started its support activities in developing countries (GCF, 2016). The Organization for Economic Co-operation and Development (OECD), in collaboration with the Climate Policy Initiative (a leading think tank on the subject), estimated that in the period 2013–2014 developed countries mobilized USD 57 billion per year on average for climate action in developing countries (71% from public sources) (OECD and CPI, 2015).

In the academic literature, the concept of climate finance is used to refer to climate-related financial flows within or between countries that are dedicated to both mitigation and adaptation (Glemarec, 2011; van Melle et al., 2011). The growing body of literature on climate finance has already explored different aspects and implications of this topic. Some researchers have focused on tracking the progress towards the quantitative goal of USD 100 billion per year, characterizing the landscape of climate finance (sources, channels, instruments, recipients and uses) and analysing climate funds (Amin, 2015; Buchner et al., 2011, 2013, 2014, 2015; Fridahl and Linnér, 2015; Schalatek et al., 2015). Others have provided quantitative estimates of the volume of financial resources required for financing the transition to a low-carbon resilient world (UNEP, 2014b, 2014a).

Using theoretical models of coalition formation, other authors have analysed the role of financial transfers between developed and developing countries as side payments to encourage participation in an international agreement for climate change (Barrett, 2009; Barrett and Stavins, 2003; Benchekroun et al., 2011; Marrouch and Ray Chaudhuri, 2011; de Zeeuw, 2015). Empirical models (e.g. Computable General Equilibrium or Integrated Assessment Models) have also been used to estimate the magnitude of North-to-South transfers that would enable such international climate agreements (Bowen et al., 2015; Tian and Whalley, 2010).

Another stream of the literature deals with the assessment of alternative options for the mobilization of climate finance. This group includes studies that, from formal and non-formal approaches, analyse welfare effects and fairness implications of different mobilization schemes (Buchholz and Peters, 2007; Buob and Stephan, 2013; Grasso, 2010; Heuson et al., 2012; Hof et al., 2011; Pickering et al., 2015; Pittel and Rübbelke, 2013; Rübbelke, 2011; Schenker and Stephan, 2014; Urpelainen, 2012a). Finally, other studies have dealt with climate finance effectiveness, studying the conditions required for climate finance to be effective (Bird and Brown, 2010; Chaum et al., 2011; Joffe et al., 2013; Michaelowa, 2012; Urpelainen, 2012b; Vandeweerd et al., 2012).

The present paper seeks to contribute to this body of literature by studying the factors that determine the size and spatial distribution of the economic benefits of climate finance. Even though it is not its purpose (climate finance aims at enabling climate action in recipient countries), climate finance generates an economic impact inasmuch as disbursements are used in the implementation of mitigation and adaptation actions. As in developed countries the fight against climate change has been seen as an opportunity for the development of a green economy able to generate economic growth and employment (see, for example, Mundaca et al., 2016), likewise the disbursements of climate finance can contribute to the economic progress of developing countries (as described in Román et al., 2016).

In this paper, we focus on North-to-South financial flows enabling the implementation of mitigation and/or adaptation actions (including measures, projects or programmes) in the recipient country. Our analysis is centred on the effects of disbursements of climate finance, independently of the channel (bilateral or multilateral) and the source (public or private).

Value-added creation, which reflects the remuneration of primary production factors (i.e. labour and capital), was used in this study as a measure of the economic benefits of a particular intervention. In our case, the intervention studied consists of climate finance disbursements generating new demand for goods and services. In order to respond to this new demand, industries involved in the production of these goods and services pay employees and capital owners, creating value-added. The entire amount of financial resources transferred to the recipient country is finally transformed into value-added in different countries of the world to remunerate the production factors involved. The proportion of the value-added created that is domestically retained is referred to as the local economic impact of climate finance. The remainder constitutes the spillover effect resulting from international trade. [1]

The geographic distribution of value-added creation differs depending on where climate finance is disbursed. In a previous paper (ibid), we quantified the domestic impact and spillovers of different types of climate actions for different countries. The present paper supplements this previous research by explaining the observed differences between countries' ability to capture economic impacts. In order to do this, we apply the Structural Decomposition Analysis (SDA), a technique that is based on Input−Output tables.. This methodology has extensively been used in climate change literature to quantify the contribution of different factors to the growth in greenhouse gas emissions, and to assess the outsourcing of emissions phenomenon and carbon footprints (as Lenzen, 2016 explains). But to the best of our knowledge, it has not been applied to explain the contribution of climate finance to countries' economies.

With this work we seek to bring to light the relative importance of the factors that determine the scale of the value-added created for both donors and recipients of climate finance disbursements. Our specific research questions are the following: (1) What factors determine the magnitude of the economic impact of climate finance? (2) What is the contribution of each factor to the differences between countries' ability to capture economic impacts? (3) Which industries offer the highest potential for increasing the economic impact of climate finance in each country?

The rest of the paper is structured as follows: Section 2 describes the methodology; Section 3 contains the results at both aggregated and sectoral levels; Section 4 discusses the main outcomes and contains some conclusions.

2. MATERIALS AND METHODS

To quantify the contribution of each factor in explaining the differences between countries in the scale of value-added impact, we apply a SDA within a Global Multi−Regional Input−Output (GMRIO) framework. This technique is normally used to decompose changes in a variable over time. For example, Xu and Dietzenbacher (2014) and Arto and Dietzenbacher (2014) used this method to identify the factors driving the change in greenhouse gas emissions by comparing different years. Like Alcántara and Duarte (2004) de Nooij et al. (2003) and Hasegawa (2006) we perform a spatial SDA, which consists on comparing different locations with data for the same year.

[1] Note that the economic effects referred to in this paper are those generated by the use of climate finance. Other authors have studied the economic consequences of the mobilization of financial resources (Basu et al., 2011; IMF, 2011; Jones et al., 2013; Parker et al., 2010).

The main data source for our analysis is the World Input−Output Database (WIOD) for the year 2011 (Timmer et al., 2012).[2] As regards climate finance recipient countries, we consider the five developing countries for which data are available in the WIOD: India, Brazil, China, Indonesia and Mexico. This set of recipient countries represents around 60% of the emissions as well as GDP of developing countries in 2011, according to the World Bank Indicators. As regards climate finance donor countries, we consider the four main contributors to bilateral and multilateral climate funds for which data are available in the WIOD: Germany, the United Kingdom (UK), Japan and the United States of America (USA). This set of countries represents 62% of the total contributions to climate funds pledged as for October 2016, according to the Climate Funds Update (2016).[3] The information in these tables (transactions between industries, purchases of end products, remuneration of labour and capital and total output of each industry in each country in monetary terms), enables us to trace value-added creation associated with a specific demand shock back to the country where it is created.

Our exercise is based on the assumption that climate finance, once disbursed in a recipient country, results in the expenditures required for a certain intervention with mitigation and/or adaptation purposes. We denote such intervention as "climate action", and introduce it in the Input-Output model as an exogenous demand shock. In order to account for different types of mitigation and adaptation options, we define six categories of climate actions. For each of them we define a demand shock of the same magnitude but with a different composition of products (or cost structure), depending on the requirements of the specific type of intervention. The cost structure of one climate action consists of a specific distribution of the budget between the different industries in the economy. Figure 1 illustrates the cost structures of climate actions considered in this paper. For example, while 100% of the expenditures in building insulation consist of construction services, when climate finance is spent in wind power generation, expenditures are shared out between several sectors: 49% for machinery, 19% for metals and other minerals, 13% for other business activities, 3% for construction and 16% for other industries.

[FIGURE 1]

The types of climate action studied include the most widely used renewable energy technologies worldwide: onshore wind, solar thermal and hydropower. Data used in previous studies (Lehr et al., 2008, 2012), reflecting the cost structures of projects in Germany in 2011, are used to define the cost structures of these types of climate action. Another mitigation action studied is energy efficiency measures in buildings (i.e. building insulation). Data for defining the cost structure of building insulation are taken from Markaki et al. (2013). Finally, different adaptation actions are also considered. For the sake of tractability of results, adaptation options are grouped into hard and soft adaptation. Table B.1 in the Supplementary Material contains all the adaptation measures considered and the sources of information used, which are specific Priority Project Profile documents from National Adaptation Programmes of Action (UNFCCC,

[2] For a detailed description of the WIOD project, the WIOT (World Input-Output Tables) and main weaknesses see also Dietzenbacher at al. (2013) and Timmer et al. (2015).
[3] Another relevant contributor to climate finance is Norway, but it is not included in the WIOD.

2014). [4] The cost structure for hard and soft adaptation is the average cost structure of the selected projects. Since some sources of information report budget allocations in terms of commodities, the correspondence reported in Table B.2 of the Supplementary Material is used to express cost structures in terms of industries. We use the same classification as the WIOD (CPA-NACE) in order to connect this information with the GMRIO framework. [5]

The production induced by demand shocks initiates a sequence of requirements of intermediate goods and services, and value-added generation across different industries and countries. All these relations can be captured by a GMRIO model as described next.

Let be $\mathbf{v}^r = \left(\hat{\mathbf{x}}^r\right)^{-1}\mathbf{w}^r$ the vector of value-added coefficients, where $\mathbf{x}^r$ is the column vector of gross outputs in country r, $\left(\hat{\mathbf{x}}^r\right)^{-1}$ is the inverse of the diagonal matrix of this vector and $\mathbf{w}^r$ is a column vector of value-added in country r with elements w_i^r indicating the value-added created in each sector i of that country; $\mathbf{Z}^{rs}$ is the matrix of intermediate inputs from country r to country s, with elements z_{ij}^{rs} indicating the sales of sector i in country r to sector j in country s; $\mathbf{A}^{rs} = \mathbf{Z}^{rs}\left(\hat{\mathbf{x}}^s\right)^{-1}$ is the matrix of input coefficients; $\mathbf{L} \equiv \left(\mathbf{I}\text{-}\mathbf{A}\right)^{-1}$ is the Leontief inverse matrix, where $\mathbf{I}$ is an identity matrix of the appropriate dimension; $\mathbf{f}^{st}$ is the column vector with final demand, with elements f_j^{st} indicating the final demand in country t for products of sector j produced by country s. We can calculate the fraction of the total final demand in country t for commodities of sector j imported from country s (when $s \neq t$) or domestically produced (when $s = t$) as $t_j^{st} = \frac{f_j^{st}}{\sum_s f_j^{st}}$. The column vector $\mathbf{t}^{st}$ indicates the trade structure of country t.

Finally, we define $\mathbf{e}^a$ as the column vector of the demand shock, with elements e_j^a indicating the proportion of the total expenditure on a specific climate action a spent in sector j.

With these elements we can calculate the value-added created in country r as a consequence of the implementation of climate action a in the recipient country t as

<equation 1>

where $\otimes$ denotes the Hadamard product (i.e. the element by element multiplication). This expression shows the value-added of country r as the product of a series of factors.

Once the local value-added derived from climate finance in each country is calculated, the country with greatest impact is identified as the benchmark against which other countries are compared. Within the

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[4] The choice of adaptation actions is based on categorizations of previous studies (Blazejczak et al., 2014; Buchner et al., 2013; OECD/IEA, 2014; Prowse and Snilstveit, 2010; REN21, 2014).

[5] CPA is the statistical classification of products by activity, and each CPA product is related to activities defined by the statistical classification of economic activities in the European Community, abbreviated as NACE.

recipient countries group, the benchmark is the country that is able to retain the largest part of the total value-added created. Donor countries are compared to the country able to attract the largest proportion of spillover effects.

Thus, the difference in the value-added created by the implementation of climate action a in country t between two countries: B (the benchmark) and C (each of the rest of countries in the group) is given by the following expression:

<equation 2>

The difference in the value-added captured by recipient and donor countries is given by the following expressions respectively:

<equation 3>

<equation 4>

Next, we illustrate the functioning of the SDA with the case of two factors (as explained by Arto and Dietzenbacher, 2014). Let be a_x the value of a variable a in country x. Let us assume that a is defined as the product of two exogenous parameters: $a_x = b_x c_x$. The difference in a between country A and country B is

<equation 5>

Following Dietzenbacher and Los (1998), this difference can be decomposed in two different ways:

<equation 6>

<equation 7>

Dietzenbacher and Los (1998), also discuss that Δa can be expressed as the average of these two decompositions.

<equation 8>

Equation 8 expresses the difference in a as the sum of the contribution of each factor (b and c) to the difference in a .

We can operate in Equations 3 and 4 in order to decompose the differences in the value-added as the sum of a series of factors. [6]

For instance, for the case of recipients, and following Dietzenbacher and Los (1998), expression 3 can be decomposed as the average of the two polar decompositions, $\Delta \mathrm{w}^a = \frac{1}{2}\left(\Delta w_1^a + \Delta w_2^a\right)$, where

[6] For the sake of simplicity we just show the differences in recipient countries; the procedure to compare donor countries is very similar (see Appendix A in the Supplementary Material).

<equation 9>

<equation 10>

And

<equation 11>

<equation 12>

<equation 13>

Thus, the average of the polar decomposition is

<equation 14>.

The second and third terms of Equation 14 can be further decomposed. The resulting expression is <equation 15>.

Expression 15 decomposes the difference in the value-added generated in donor countries as the sum of series factors, which can be aggregated into four:

<equation 16>

<equation 17>

<equation 18>

<equation 19>

- VAiE is the value-added intensity effect, which reflects differences in value-added per unit of domestic output. A positive (negative) VAiE means that the benchmark country (B) produces more (less) value-added per unit of output than the studied country (C). High value-added intensities are typical in countries specialised in the production of high technology commodities that require high-skilled labour.
- DME is the domestic multiplier effect, which reflects differences in domestic production per unit of domestic demand. A positive (negative) DME means that the amount of production generated in B per unit of demand of goods/services produced in B is bigger (smaller) than the amount of production generated in C per unit of demand of goods/services produced in C. High domestic multipliers are typical of highly integrated economies, characterised by the presence of industrial clusters for different commodities that are relatively independent of foreign production.
- FME is the foreign multiplier effect, which reflects differences in domestic production per unit of demand of foreign products. A positive (negative) FME means that the amount of production generated in B per unit of goods/services produced in other countries is bigger (smaller) than the amount of production generated in C per unit of goods/services produced in other countries. High foreign multiplier effects are typical of countries that participate in global supply chains for many products and services.
- TSE is the trade structure effect, which reflects differences in the demand of domestic products generated by a climate action. We assume that the demand shock generated by each type of climate

action is similar for all recipient countries in terms of level and composition of commodities. But we take into account that the origin of the commodities varies depending on the recipient country. A positive (negative) TSE means that the demand of goods/services produced in B generated by the implementation of a particular climate action is larger (smaller) than the demand of goods/services produced in C generated by the implementation of the same action in C. In the case of recipient countries, this is the effect of the degree of dependency on final goods and services produced abroad, something that is related to the size of the country. In the case of donors, this is the effect of the penetration of their final products on the recipient countries' markets.

3. RESULTS

This section includes general considerations that apply to all the results. Results are then grouped into two subsections according to their level of detail. Aggregated results for each economy are presented first, followed by results at industry level. Results for climate finance recipient countries distinguish between the types of climate action implemented. In the case of donor countries the focus is exclusively on renewable energy technologies, since these are the climate actions that yield the largest spillover effects (Román et al., 2016). However, since the volume of spillovers varies widely depending on the country receiving climate finance, results distinguish between the destinations of climate finance. [7]

Results reflect the comparison between the benchmark country and each of the other countries in the group. Amongst recipient countries, the benchmark varies depending on the climate action implemented. Amongst countries benefiting from spillovers, the benchmark varies depending on the country receiving climate finance. Table 1 shows the proportion of the impact retained by each recipient country, the proportion attracted by each donor country and the benchmark country in each case. [8]

For example, we see that out of every USD 100 spent in wind energy in India, USD 72 stay within the country (in the form of wages or benefits of Indian companies). The rest goes to other countries participating in the production of final goods/services or intermediate inputs required for the wind power project. However, the same expenditure in Mexico would leave in the country only USD 44. The decomposition explains what drives the difference of USD 28 between India and Mexico. In the case of donors, we see that out of every USD 100 spent in mitigation projects in Mexico, USD 20 end up in the USA as wages or companies' profits, due to their participation in the production of the inputs of the project. Japan, however, only receives three dollars. The decomposition shows the contribution of each of the four factors considered to this USD 17 difference.

[7] The SDA of spillovers depends on which country is the donor, which one is the recipient and what type of climate action is implemented. This three-fold dependency complicates the presentation and interpretation of results. We therefore concentrate on renewable energy technologies, because they are the actions that yield the largest spillovers for donors, and present average results for wind, hydropower and solar.

[8] Note that China is the benchmark country against which donor countries are compared in the case of climate finance disbursed in Brazil, Indonesia and India because in those cases China is the country that benefits from the largest spillovers.

Since benchmark countries are determined based on the economic impact at country level, aggregated results show always positive differences between the benchmark and other countries. This is not necessarily the case for results at industry level, where both positive and negative differences might appear. At both levels, the sign of the different effects (i.e. VAiE, DME, FME and TSE) can be either positive or negative, depending on whether they contribute positively to the dominant effect or counteract it. In other words, positive effects help explaining why benchmarks are benchmarks, and negative effects explain why differences between benchmarks and other countries are not even larger.

[TABLE 1]

3.1. Aggregated Results

In this section, the results for each climate finance recipient country are shown first, followed by results for each donor country. Figures 2 and 3 illustrate the results for recipient and donor countries. To explain the content of Figure 2 we continue with the previous example: the USD 28 of difference between the domestic impact in India and Mexico is because the trade structure generates USD 19 more in India (Figure 2(b)) than in Mexico (Figure 2(e)), the domestic multiplier generates USD 12 more in India than in Mexico and the value-added intensity generates three dollars more in Mexico than in India

Brazil (Figure 2(a)) is the benchmark for all types of climate action except wind power and hydropower, for which the largest local economic benefits happen in India. However, Brazil is very close to the benchmark even there, with a local impact that is only one percentage point (pp) lower in the case of hydropower and two percentage points lower in the case of wind power. In both cases, the effects that contribute positively to the difference are the domestic multiplier and the trade structure effects. Counteracting these two factors is the effect of the value-added intensity.

India (Figure 2(b)) is the benchmark for wind power and hydropower but is surpassed by Brazil in the rest of climate actions, with a difference of two percentage points for soft adaptation, three percentage points for solar and hard adaptation and eight percentage points for building insulation. In most cases (with the exception of soft adaptation), the effect of value-added intensity contributes to the difference while the effect of the domestic multiplier acts in the opposite direction.

China (Figure 2(c)) is between one and nine percentage points from the benchmark countries, depending on the climate action. The largest differences are for building insulation and soft adaptation (nine and eight percentage points, respectively). But we see as a common pattern for all climate actions that differences with the benchmark are the result of two contrary and sizeable forces: a positive value-added intensity effect (that surpasses 20 pp) and a negative domestic multiplier effect (almost of the same magnitude).

Indonesia (Figure 2(d)) is farther from the benchmarks (between 10 and 23 pp), with the largest differences being found in renewable energy technologies (13-23 pp). In these cases, three factors contribute positively to the difference: mainly the effect of the trade structure, but also those of the domestic multiplier and the value-added intensity. The difference for building insulation (10 pp) results from the effect of the value-added intensity, which is partially offset by the domestic multiplier effect. In the case of adaptation actions, the dominant effects are the value-added intensity and the trade structure effects.

[FIGURE 2]

Mexico (Figure 2(e)) is the farthest from benchmark countries: between 9-30 pp. Again, the largest differences are for renewable energy technologies (21-30 pp), and the lowest for building insulation (9 pp). This time the dominant effect in most cases is the trade structure, with the domestic multiplier as the other factor that contributes to the difference. In most cases, the value-added intensity also counteracts these former effects. The case of building insulation is different, with the trade structure having no influence, and both the domestic multiplier and the value-added intensity contributing positively to the difference. Note that the effect of the foreign multiplier does not appear as a relevant factor in explaining the differences in the domestic economic impact of climate finance between recipient countries.

To explain the results contained in Figure 3, we continue with the previous example: the USD 17 of difference between spillovers captured by the USA and Japan from a mitigation project in Mexico are because the Mexican trade structure generates USD 12 more for the USA (Figure 3(d)) than for Japan (Figure 3(c)), the foreign multiplier creates four dollars more in the USA than in Japan, the higher value-added intensity of American production produces two dollars of difference, and the domestic multiplier generates one dollar more in Japan than in the USA.

Spillovers attracted by Germany (Figure 3(a)) are only one percentage point lower than those attracted by the benchmark country (Japan) when the recipient country is China. The difference rises to 17 pp when the recipient country is Mexico (the benchmark country is the USA in this case). In general, the dominant factor is the trade structure. Two other factors that also contribute positively to the difference are the domestic and foreign multipliers. Finally, the only factor that counteracts those effects is the value-added intensity, showing that this is generally larger in the German production than in benchmark countries (with the exception of the USA). The same happens with the UK (Figure 3(b)), whose results are very similar. Differences are slightly larger in the case of the UK (between 3 pp and 19 pp), but the signs and relative magnitude of the different factors are the same than for Germany.

Japan (Figure 3(c)) is the benchmark country when China receives funding for deploying renewable energy technologies. In other cases, spillovers captured by Japan are between 3 pp and 17 pp lower than those captured by the benchmark country: the average is four percentage points when then benchmark country is China and 17 pp when it is the USA. Again, the dominant factor is the trade structure. The foreign multiplier also contributes positively to the difference. The signs of the other two factors differ depending on the benchmark country: when it is China, the effect of the domestic multiplier increases the difference and the value-added intensity effect decreases it; when it is the USA, the opposite occurs.

The USA (Figure 3(d)) is the benchmark when Mexico is the recipient country. In other cases differences with the benchmark countries do not exceed five percentage points. The most relevant factors are the trade structure and value-added intensity. This latter counteracting the rest of the effects, something which indicates that value-added per unit of output is greater in the USA than in benchmark countries.

[FIGURE 3]

3.2. Sectoral Results

A small group of sectors concentrates the main effects in the countries analysed: “Mining and Quarrying”, “Basic Metals and Fabricated Metal”, “Machinery n.e.c.”, “Electrical and Optical Equipment”, “Electricity, Gas and Water Supply”, “Construction”, “Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles”, “Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods”, “Inland Transport”, “Financial Intermediation” and “Other Business Activities” .[9] Figure B.1 in the Supplementary Material illustrates the results for recipients and donor countries.

In Brazil (Figure B.1(a)), the largest positive differences with the benchmark (India) appear in trade sectors (due to the effect of value-added intensity, the domestic multiplier and the trade structure) and the transport sector (especially due to the domestic multiplier). The sectors with the largest negative differences (around -2 pp) are metals and electricity, gas and water supply (in wind and hydropower, respectively), especially due to the negative effect of the value-added intensity.

When comparing India (Figure B.1(b)) to the benchmark (Brazil), the most relevant difference at aggregated level is found in building insulation projects. This result can be explained by the large difference (16 pp) in the construction sector, associated with the value-added intensity. This effect in the construction sector may also explain the differences in solar and hard adaptation. Negative differences appear in metals, retail trade and transport for building insulation projects. These negative differences are generally driven by the domestic multiplier.

Sectoral results for China (Figure B.1(c)) show that the differences observed in building insulation projects are associated with the construction sector (34 pp). The differences in soft adaptation are due to the other business activities sector (13 pp), and those observed in hard adaptation are due to both the construction and other business activities sectors (around 8 pp each). These differences are a consequence of a positive effect of the value-added intensity. Also noteworthy is the positive domestic multiplier effect in the retail trade sector regardless of the type of action. This effect is negative at the aggregated level due to sectors such as metals and equipment.

In Indonesia (Figure B.1(d)), metals and machinery sectors contribute to the large difference in renewable energy projects, especially due to the effect of the domestic multiplier in the former and the effect of the trade structure in the latter. The difference observed in building insulation projects might be explained in part by the value-added intensity in the construction sector. This effect in this sector might also influence the aggregated results in solar and hard adaptation projects. The value-added intensity in other business activities and the trade structure in machinery influence the differences in adaptation projects. This latter effect in the machinery sector contributes to the positive difference in all types of action except for building insulation. Notable negative differences are observed in the mining sector (up to 9 pp)

[9] N.e.c. is the abbreviation of “not elsewhere classified”.

regardless of the type of action, as a consequence of the effects of the domestic multiplier and the value-added intensity.

According to the sectoral results, the trade structure in the machinery sector contributes to the differences observed for renewable energy projects in Mexico (Figure B.1(e)). Actually, this effect in this sector contributes to the difference in all types of project except for building insulation. Other sectors, such as metals, equipment and financial intermediation, also contribute to the difference in renewable energy actions due to the trade structure and the domestic multiplier. In this type of action, the role of the value-added intensity is negative with the exception of the equipment sector. In adaptation actions, the most influential effect is the trade structure in machinery. Regarding negative differences, the other business activities sector stands out, especially due to the value-added intensity in adaptation projects.

Three sectors concentrate the most significant effects in explaining differences between donor countries: "Basic Metals and Fabricated Metal", "Machinery n.e.c" and "Electrical and Optical Equipment". In the case of Germany (Figure B.1(f)), the trade structure of these three sectors is especially influential, particularly when the benchmark countries are China and the USA. The UK (Figure B.1(g)) and Japan (Figure B.1(h)) present very similar results regarding the relative importance of sectors and the signs of effects. The case of the USA (Figure B.1(i)) is also similar, but with some noteworthy features such as the negative effect of the value-added intensity on the equipment and machinery sector, especially when the benchmark country is China.

4. DISCUSSION

One of the reasons why Brazil, out of all the recipient countries considered in the analysis, is the one where climate finance produces the largest domestic impact in most cases (i.e. for solar energy, building insulation and adaptation projects) is the value-added intensity. According to the sectoral results, this effect makes the impact of mitigation actions especially larger in the Brazilian metals, electricity, gas and water supply, and construction sectors. Table 2, which shows value-added coefficients by country and sector, confirms that these sectors are relatively more intensive in primary inputs in Brazil than in the other recipient countries, which might be due to a higher level of sophistication in the production and the use of high technology and skilled labour. An alternative (or complementary) explanation for higher value-added per unit of output is a higher degree of protectionism in the economy. In fact, Brazil ranks at the bottom of the ICC open markets index for the year of study (ICC, 2011), behind the other recipient countries. [10] Thus, the high values of value-added per unit of output might also be due to a lack of competition with foreign producers, who find barriers to entry into Brazilian markets. The high value-added coefficient in the Brazilian electricity, gas and water supply sector may be associated with the large share of hydropower in the Brazilian energy mix, an energy source with low requirements for intermediate inputs.

[TABLE 2]

[10] The position of recipient countries in ascending order is: Indonesia (54), China (57), Mexico (58), India (66), and Brazil (68).

When climate finance is spent on wind or hydropower projects, India is the recipient country with the largest domestic impact. According to our results, this is mainly due to the fact that India imports less final products than other recipient countries for undertaking such projects. According to the sectoral results, this effect means that the impact of these projects in the machinery industry is larger in India than in other recipient countries. Table 3, which shows the share of domestic production per industry in the final demand of recipient countries, confirms that India is, on average, the recipient country with the largest share of domestic production in its final demand. India has also a high level of self-sufficiency in machinery, equipment and transport equipment, the main components of this type of projects. Moreover, demand for Indian products triggers greater domestic production (especially in the metals and transport sectors) than in other countries. Both effects reflect the high level of self-sufficiency and integration of the Indian economy, a relatively well developed, independent industrial base and the existence of intraregional communication and transport networks.

China is the other side of the coin compared to Brazil: a lower weight of labour and capital in the total production costs of Chinese industries is the main reason why China is not able to retain a larger proportion of the impact of climate finance. According to sectoral results, the value-added intensity makes the impact of climate actions in the Chinese metals, construction and other business activities sectors lower than in the benchmark cases. Table 3 confirms that China is the recipient country with the smallest value-added coefficients in almost all industries, including these three.

Indonesia and Mexico are even farther away from the benchmarks than China, as a result of a combination of factors. First, both countries import a large part of their final demand. Sectoral results show relevant differences in the impact of renewable energy and adaptation projects in the metals and machinery sectors due to this effect. Table 3 confirms that these two countries are (on average and also in these two sectors) the recipient countries which depend most on others countries' end products. Another factor that contributes to the lower impact of renewable energy projects is the fact that domestic demand generates less domestic production in the metals industry (i.e. metals required for domestic production are also more frequently imported).

The salient feature of Indonesia is the domestic multiplier effect of the mining sector, which reduces the difference with the benchmark in the cases of renewable energy and energy efficiency projects. This reflects the fact that Indonesia is relatively self-sufficient in this sector. According to PwC (2014), the mining sector was very important in the Indonesian economy in 2011, accounting for 19.5% of the GDP. In Mexico, the salient feature is value-added per unit of output, especially in the metals and other business activities sectors (see Table 2). This factor reduces the difference with the benchmark for renewable energy and adaptation projects.

Major differences in the distribution of spillovers of renewable energy projects appear when other donors are compared with the USA, the benchmark country when climate finance is disbursed in Mexico. According to our results, the main driver of these large differences is trade in both final and intermediate commodities. As Table 3 shows, Mexico is relatively dependent on others countries' production to meet its final demand, something that, together with the geographic proximity and accessibility of the American market, explains the significance of trade in end products (i.e. the effect of the trade structure). The relevance of trade in intermediate inputs (i.e. the effect of the foreign multiplier) is due to two facts: first, regional trade facilitated by proximity and trade treaties (i.e. North American Free Trade Agreement) also benefits the USA indirectly (i.e. via Mexican imports of Canadian products that require American intermediate inputs); and second, American industries are well positioned in global markets, which enables them to participate in global supply chains and capture a share of the economic benefits generated from consumption in many parts of the world.[11] According to the World Bank, in 2011 the USA was the top market for world exports and the second exporting country (World Bank, 2011). Results also show that the USA is the donor that creates most value-added per unit of output, followed by Germany and the UK. Japan is in the last place in this aspect. Note that this ranking is in line with the average value-added coefficients contained in Table 2.

[TABLE 3]

The fact that the largest spillover effects when the recipient is China take place in Japan also reflects the effect of proximity in trade. However, the fact that China attracts spillovers between three and eight percentage points larger than any donor country when finance is disbursed in Brazil, Indonesia and India cannot be explained by geographic proximity. However, the prominent position of China in global trade - in 2011 it was the world's number one exporter and number two importer, according to the World Bank (2011) - might provide an explanation for this result.

5. **CONCLUDING REMARKS**

The main aim of this paper is disentangling the underlying factors explaining the different abilities of countries for deriving economic benefits from climate finance. Regarding developing countries, our results show that in those countries where the industries involved in mitigation and adaptation projects are well developed and connected, and offer competitive products and services with a high content of value-added, climate actions deliver larger economic benefits to the local population. This finding indicates that active policies to facilitate the local development of such industries would deliver climate and development benefits at the same time.

Some researchers have suggested that there is a need to align climate finance and development finance, and that the effectiveness of climate finance depends on the capability of developing countries to manage the available sources of finance in favour of their national development strategies and needs (Haites, 2014; IPCC, 2014). Theoretical and empirical studies have suggested that climate action and development strategies might be complementary provided that climate change is considered in the design of development policies (Andreoni and Miola, 2014; Chambwera et al., 2014; Fankhauser and McDermott, 2014; Halsnæs and Verhagen, 2007). Here, we support this idea and identify three areas of action where governments of developing countries can focus in order to exploit this complementarity: 1) the value-added content (skilled

[11] In the comparison of recipient countries, the foreign multiplier represents a feedback effect: the recipient country imports final goods and services that require intermediate inputs from the recipient country. According to our results, and in line with previous empirical evidence, feedback effects are negligible (Meng and Chao, 2007).

labour and high technology) of production; 2) the integration of the economy; and 3) the degree of self-sufficiency in climate-related industries.

In the case of donor countries, the first two recommendations also apply. Moreover, our analysis shows that trade interconnections with recipient countries increase the ability of countries to capture spillovers. Based on these findings, donors could be tempted to focus climate aid on their specific commercial area. An alternative strategy would be to increase participation in global supply chains of high-quality products and services related to the fight against climate change. This would enable them to profit from global climate action regardless of where it takes place, and from climate finance flows regardless of who mobilises them. Thus, our findings suggest that countries which seek to benefit from spillovers of climate action could promote globally competitive industries in the sectors involved in climate action.

Summarizing, this exercise provides an evidence of the compatibility of climate action with economic gains. Our results suggest that both donors and recipient countries should strategically direct their development towards climate-related industries with high value-added content if they want to enjoy from larger shares of the economic benefits associated to the increasing amounts of climate finance. This is a very relevant message, since the search for short-term economic co-benefits of climate action could promote the (currently still lacking) coordination of countries for the development of solutions for this global environmental problem.

Our paper also shows that the study of the economic impact of climate finance provides useful insights for the consecution of one of the objectives of the Paris Agreement regarding climate finance: the design of country-driven strategies, having into account the priorities and needs of developing countries e. Given that development is one of the priorities of these countries, information on the potential economic co-benefits of alternative climate-related measures (and guidance about how to improve that potential) facilitates the design of such country-driven strategies.

With enhanced country ownership of climate-related plans, effectiveness of climate finance would also improve, as recognized by the IPCC (2014). Developed countries have recently stressed that it is more efficient and effective to integrate climate action in programmes that generate wider development results (UK Government and Australian Government, 2016). For that reason, they have committed to support developing countries in the preparation of National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs) consistent with their national development plans. [12] Our findings might be used in the design of such plans, with the objective of aligning them with development objectives, enhancing at the same time the effectiveness of climate finance in terms of mitigation and adaptation outcomes.

We conclude that GMRIO models have great potential to contribute to discussions on the global climate regime. So far they have provided interesting insights on the topic of responsibility with evidences of carbon footprint and leakage. With this paper we explore a different avenue of research that focuses on the opportunities of the required transition towards decarbonized and resilient societies. In future studies,

[12] Each developing country can request up to USD 3 million to the GCF for the formulation of NAPs.

GMRIO could be used to complement this assessment of value-added benefits with the estimation of the mitigation potential of financed climate actions.

Finally, a remark is required on the main limitation of this exercise, which lies on the assumptions required to determine the demands of different categories of actions for the sectors of the economy. Profiles for expenditure on mitigation actions are taken from the existing literature, and the characterisation of adaptation actions is the result of an ad-hoc selection process from the NAPAs available on the UNFCCC website. The subsequent grouping into two main categories of adaptation (soft and hard) via the calculation of the corresponding averages means neglecting some degree of variation. In particular, the largest standard deviations are associated with expenses in the construction and machinery sectors (34% and 18% for construction in hard and soft adaptation, respectively; 27% and 17% for machinery in hard and soft adaptation, respectively). Bearing in mind that adaptation actions are as varied as countries' adaptation needs, the results of this study provide an estimate of the impact of the "typical" or "average" soft and hard adaptation actions.

The cost structures used in this exercise may differ from the real ones, depending on where and when each climate action takes place. This happens because many factors affecting the cost structures, such as the price of raw materials, the labour costs and the maturity of technologies vary over time and space. [13] Nevertheless, and given that the ultimate objective of the present study is to provide general policy advice, extrapolating the cost structures of projects in certain countries may constitute a first step. For specific case studies, detailed data at project level should be used in future applications of this methodology.

We are also aware of the remarkable differences between the countries considered. The comparison we propose, based on the national accounts and international trade statistics brings to light their differences in terms of size, trade liberalization, economic integration, productive specialization, competitiveness, etc. Results reflect the consequences of these differences and serve to identify where the largest improvement potentials lie. Future studies could elaborate further on the concrete strategies that each country could pursue taking into account limiting factors such as institutional or cultural conditions, natural resources availability or geographical location.

[13] Note that the local content is site specific in our exercise. Trade structures representing the origin of the products purchased by each recipient country are obtained from the WIOD, which is based on official trade statistics.

Equations

$$\mathrm{w}^{rta} = \sum_{s} \mathbf{v}^{r}\,'\mathbf{L}^{rs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} \qquad [1]$$

$$\Delta \mathrm{w}^{ta} = \sum_{s} \mathbf{v}^{B}\,'\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} - \sum_{s} \mathbf{v}^{C}\,'\mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} \qquad [2]$$

$$\Delta \mathrm{w}^{a} = \sum_{s} \mathbf{v}^{B}\,'\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^{a} - \sum_{s} \mathbf{v}^{C}\,'\mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^{a} \qquad [3]$$

$$\Delta \mathrm{w}^{ta} = \sum_{s} \mathbf{v}^{B}\,'\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} - \sum_{s} \mathbf{v}^{C}\,'\mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} \qquad t \neq B, C \qquad [4]$$

$$\Delta a = a_A - a_B \qquad [5]$$

$$\Delta a = \left(b_A - b_B\right)c_A + b_B\left(c_A - c_B\right) = \Delta b c_A + b_B \Delta c \qquad [6]$$

$$\Delta a = \left(b_A - b_B\right)c_B + b_A\left(c_A - c_B\right) = \Delta b c_B + b_A \Delta c \qquad [7]$$

$$\Delta a = \tfrac{1}{2}\Delta b\left(c_A + c_B\right) + \tfrac{1}{2}\left(b_A + b_B\right)\Delta c \qquad [8]$$

$$\Delta w_1^{a} = \sum_{s} (\Delta \mathbf{v}')\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{C}{}'(\Delta \mathbf{L}^{\bullet s})\mathbf{t}^{sB} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{C}{}'\mathbf{L}^{Cs}(\Delta \mathbf{t}^{s\bullet}) \otimes \mathbf{e}^{a} \qquad [9]$$

$$\Delta w_2^{a} = \sum_{s} (\Delta \mathbf{v}')\mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{B}{}'(\Delta \mathbf{L}^{\bullet s})\mathbf{t}^{sC} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{B}\,'\mathbf{L}^{Bs}(\Delta \mathbf{t}^{s\bullet}) \otimes \mathbf{e}^{a} \qquad [10]$$

$$\left(\Delta \mathbf{v}'\right) = \left(\mathbf{v}^{B}\,' - \mathbf{v}^{C}\,'\right) \qquad [11]$$

$$(\Delta \mathbf{L}^{\bullet s}) = (\mathbf{L}^{BB} - \mathbf{L}^{CC}) + (\mathbf{L}^{BC} - \mathbf{L}^{CB}) + \sum_{\mathrm{s \neq B, s \neq C}} (\mathbf{L}^{Bs} - \mathbf{L}^{Cs}) \qquad [12]$$

$$\Delta \mathbf{t}^{s\bullet} = \left(\mathbf{t}^{BB} - \mathbf{t}^{CC}\right) + \left(\mathbf{t}^{CB} - \mathbf{t}^{BC}\right) + \sum_{\mathrm{s \neq B, s \neq C}} (\mathbf{t}^{sB} - \mathbf{t}^{sC}) \qquad [13]$$

$$\Delta w^{a} = \frac{1}{2}\sum_{s} \Delta \mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^{a} + \mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^{a}\right) + \frac{1}{2}\sum_{s} \mathbf{v}^{C}\,'\Delta \mathbf{L}^{\bullet s}\mathbf{t}^{sB} \otimes \mathbf{e}^{a}$$
$$+ \frac{1}{2}\sum_{s} \mathbf{v}^{B}\,'\Delta \mathbf{L}^{\bullet s}\mathbf{t}^{sC} \otimes \mathbf{e}^{a} + \frac{1}{2}\sum_{s}\left(\mathbf{v}^{C}\,'\mathbf{L}^{Cs} + \mathbf{v}^{B}\,'\mathbf{L}^{Bs}\right)\Delta \mathbf{t}^{s\bullet} \otimes \mathbf{e}^{a} \qquad [14]$$

$$\Delta w^a = \frac{1}{2}\sum_s \Delta\mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{sB}\otimes\mathbf{e}^a + \mathbf{L}^{Cs}\mathbf{t}^{sC}\otimes\mathbf{e}^a\right)$$
$$+\frac{1}{2}\mathbf{v}^{B}{}'\left(\mathbf{L}^{BB}-\mathbf{L}^{CC}\right)\mathbf{t}^{CC}\otimes\mathbf{e}^a + \frac{1}{2}\mathbf{v}^{C}{}'\left(\mathbf{L}^{BB}-\mathbf{L}^{CC}\right)\mathbf{t}^{BB}\otimes\mathbf{e}^a$$
$$+\frac{1}{2}\mathbf{v}^{B}{}'\left(\mathbf{L}^{BC}-\mathbf{L}^{CB}\right)\mathbf{t}^{CC}\otimes\mathbf{e}^a + \frac{1}{2}\mathbf{v}^{C}{}'\left(\mathbf{L}^{BC}-\mathbf{L}^{CB}\right)\mathbf{t}^{BB}\otimes\mathbf{e}^a \quad [15]$$
$$+\frac{1}{2}\sum_{s\neq B,C}\mathbf{v}^{B}{}'\left(\mathbf{L}^{Bs}-\mathbf{L}^{Cs}\right)\mathbf{t}^{sC}\otimes\mathbf{e}^a + \frac{1}{2}\sum_{s\neq B,C}\mathbf{v}^{C}{}'\left(\mathbf{L}^{Bs}-\mathbf{L}^{Cs}\right)\mathbf{t}^{sB}\otimes\mathbf{e}^a$$
$$+\frac{1}{2}\sum_s\left(\mathbf{v}^{C}{}'\mathbf{L}^{Cs}+\mathbf{v}^{B}{}'\mathbf{L}^{Bs}\right)\Delta\mathbf{t}^{s\square}\otimes\mathbf{e}^a$$

$$\text{VAiE} \equiv \frac{1}{2}\sum_s \Delta\mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{sB}\otimes\mathbf{e}^a + \mathbf{L}^{Cs}\mathbf{t}^{sC}\otimes\mathbf{e}^a\right) \quad [16]$$

$$\text{DME} \equiv \frac{1}{2}\mathbf{v}^{B}{}'\left(\mathbf{L}^{BB}-\mathbf{L}^{CC}\right)\mathbf{t}^{CC}\otimes\mathbf{e}^a + \frac{1}{2}\mathbf{v}^{C}{}'\left(\mathbf{L}^{BB}-\mathbf{L}^{CC}\right)\mathbf{t}^{BB}\otimes\mathbf{e}^a \quad [17]$$

$$\text{FME} \equiv \frac{1}{2}\mathbf{v}^{B}{}'\left(\mathbf{L}^{BC}-\mathbf{L}^{CB}\right)\mathbf{t}^{CC}\otimes\mathbf{e}^a + \frac{1}{2}\mathbf{v}^{C}{}'\left(\mathbf{L}^{BC}-\mathbf{L}^{CB}\right)\mathbf{t}^{BB}\otimes\mathbf{e}^a$$
$$+\frac{1}{2}\sum_{s\neq B,C}\mathbf{v}^{B}{}'\left(\mathbf{L}^{Bs}-\mathbf{L}^{Cs}\right)\mathbf{t}^{sC}\otimes\mathbf{e}^a + \frac{1}{2}\sum_{s\neq B,C}\mathbf{v}^{C}{}'\left(\mathbf{L}^{Bs}-\mathbf{L}^{Cs}\right)\mathbf{t}^{sB}\otimes\mathbf{e}^a \quad [18]$$

$$\text{TSE} \equiv \frac{1}{2}\sum_s\left(\mathbf{v}^{C}{}'\mathbf{L}^{Cs}+\mathbf{v}^{B}{}'\mathbf{L}^{Bs}\right)\Delta\mathbf{t}^{s\square}\otimes\mathbf{e}^a \quad [19]$$

References

Alcántara, V., and Duarte, R. (2004). Comparison of energy intensities in European Union countries. Results of a structural decomposition analysis. Energy Policy *32*, 177–189.

Amin, A.-L. (2015). What next for the Green Climate Fund?

Andreoni, V., and Miola, A. (2014). Climate Vulnerability of the Supply-Chain: Literature and Methodological review (Luxemburg. doi:10.2788/38860: European Union, Publications Office).

Arto, I., and Dietzenbacher, E. (2014). Drivers of the growth in global greenhouse gas emissions. Environ. Sci. Technol. *48*, 5388–5394.

Barrett, S. (2009). Negotiating the Next Climate Change Treaty (Clutha House,10 Storey's Gate, London SW1P 3AY: Policy Exchange).

Barrett, S., and Stavins, R. (2003). Increasing participation and compliance in international climate change agreements. Int. Environ. Agreem. *3*, 349–376.

Basu, P., Finneran, L., Bishop, V., and Sundararaman, T. (2011). The Scope for MDB Leverage and Innovation in Climate Finance. Background paper for Mobilizing Climate Finance, prepared at the request of G20 Finance Ministers.

Benchekroun, H., Marrouch, W., and Ray Chaudhuri, A. (2011). Adaptation effectiveness and free-riding incentives in international environmental agreements. CentER *2011–120*.

Bird, N., and Brown, J. (2010). International Climate Finance: Principles for European Support to Developing Countries (EDC2020).

Blazejczak, J., Braun, F.G., Edler, D., and Schill, W.-P. (2014). Economic effects of renewable energy expansion: A model-based analysis for Germany. Renew. Sustain. Energy Rev. *40*, 1070–1080.

Bowen, A., Campiglio, E., and Herreras, S. (2015). The "Optimal and Equitable" Climate Finance Gap (Centre for Climate Change Economics and Policy, Working Paper No. 209).

Buchholz, W., and Peters, W. (2007). Justifying the Lindahl solution as an outcome of fair cooperation. Public Choice *133*, 157–169.

Buchner, B., Falconer, A., Hervé-Mignucci, M., Trabacchi, C., and Brinkman, M. (2011). The Landscape of Climate Finance (Climate Policy Initiative).

Buchner, B., Herve-Mignucci, M., Trabacchi, C., Wilkinson, J., Stadelmann, M., Boyd, R., Mazza, F., Falconer, A., and Micale, V. (2013). Global Landscape of Climate Finance 2013 (Climate Policy Initiative).

Buchner, B., Stadelmann, M., Wilkinson, J., Mazza, F., Rosenberg, A., and Abramskiehn, D. (2014). The Global Landscape of Climate Finance 2014 (Climate Policy Initiative).

Buchner, B., Trabacchi, C., Mazza, F., Abramskiehn, D., and Wang, D. (2015). Global Landscape of Climate Finance 2015 (Climate Policy Initiative).

Buob, S., and Stephan, G. (2013). On the incentive compatibility of funding adaptation. Clim. Change Econ. *4*.

Chambwera, M., Heal, G., Dubeux, C., Hallegatte, S., Leclerc, L., Markandya, A., McCarl, B.A., Mechler, R., and Neumann, J.E. (2014). Economics of adaptation. In Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press), pp. 945–977.

Chaum, M., Faris, C., Wagner, G., Buchner, B., Falconer, A., Trabacchi, C., Brown, J., and Sierra, K. (2011). Improving the effectiveness of climate finance: key lessons (Overseas Development Institute. Climate Policy Initiative. Environmental Defense Fund. Brookings).

Climate Funds Update (2016). The data. http://www.climatefundsupdate.org/data.

De Nooij, M., van der Kruk, R., and van Soest, D.P. (2003). International comparisons of domestic energy consumption. Energy Econ. *25*, 359–373.

Dietzenbacher, E., and Los, B. (1998). Structural decomposition techniques: sense and sensitivity. Econ. Syst. Res. *10*, 307–324.

Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M., and De Vries, G. (2013). The construction of world input–output tables in the WIOD project. Econ. Syst. Res. *25*, 71–98.

Fankhauser, S., and McDermott, T.K. (2014). Understanding the adaptation deficit: why are poor countries more vulnerable to climate events than rich countries? Glob. Environ. Change *27*, 9–18.

Fridahl, M., and Linnér, B.-O. (2015). Perspectives on the Green Climate Fund: possible compromises on capitalization and balanced allocation. Clim. Dev. *8*, 105–109.

GCF (2016). Pledge Tracker - Green Climate Fund.

Grasso, M. (2010). An ethical approach to climate adaptation finance. Glob. Environ. Change *20*, 74–81.

Haites, E. (2014). Aligning Climate Finance and Development Finance for Asia and the Pacific: Potential and Prospects (Asian Development Bank).

Halsnæs, K., and Verhagen, J. (2007). Development based climate change adaptation and mitigation—conceptual issues and lessons learned in studies in developing countries. Mitig. Adapt. Strateg. Glob. Change *12*, 665–684.

Hasegawa, R. (2006). Regional comparisons and decomposition analyses of CO2 emissions in Japan. Env. Sci *19*, 277–289.

Heuson, C., Peters, W., Schwarze, R., and Topp, A.-K. (2012). Which mode of funding developing countries' climate policies under the post-Kyoto framework? (Helmholtz-Zentrum für Umweltforschung GmgH - UFZ).

Hof, A.F., den Elzen, M.G.J., and Mendoza Beltran, A. (2011). Predictability, equitability and adequacy of post-2012 international climate financing proposals. Environ. Sci. Policy *14*, 615–627.

ICC (2011). ICC Open Markets Index 2011 (International Chamber of Commerce Research Foundation).

IMF (2011). Promising Domestic Fiscal Instruments for Climate Finance. Background Paper for the Report to the G20 on―Mobilizing Sources of Climate Finance (International Monetary Fund).

IPCC (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press).

Joffe, P., Waskow, D., DeAngelis, K., Bevins, W., and Dagnet, Y. (2013). Equity lessons from multilateral regimes for the new climate agreement (World Resources Institute).

Jones, B., Keen, M., and Strand, J. (2013). Fiscal implications of climate change. Int. Tax Public Finance *20*, 29–70.

Lehr, U., Nitsch, J., Kratzat, M., Lutz, C., and Edler, D. (2008). Renewable energy and employment in Germany. Energy Policy *36*, 108–117.

Lehr, U., Lutz, C., and Edler, D. (2012). Green jobs? Economic impacts of renewable energy in Germany. Energy Policy *47*, 358–364.

Lenzen, M. (2016). Structural analyses of energy use and carbon emissions–an overview. Econ. Syst. Res. *28*, 119–132.

Markaki, M., Belegri-Roboli, A., Michaelides, P., Mirasgedis, S., and Lalas, D.P. (2013). The impact of clean energy investments on the Greek economy: An input-output analysis (2010-2020). Energy Policy *57*, 263–275.

Marrouch, W., and Ray Chaudhuri, A. (2011). International environmental agreements in the presence of adaptation. Int. Environ. Agreem. Presence Adapt. April 27 2011 FEEM Work. Pap.

Meng, B., and Chao, Q. (2007). Application of the Input-Output Decomposition Technique to China’s Regional Economies (Institute of Developing Economies, JETRO).

Michaelowa, A. (2012). Carbon Markets or Climate Finance. Low Carbon and Adaptation Investment Choices for the Developing World (London: Routledge).

Mundaca, L., Neij, L., Markandya, A., Hennicke, P., and Yan, J. (2016). Towards a Green Energy Economy? Assessing policy choices, strategies and transitional pathways. Appl. Energy *179*, 1283–1292.

OECD, and CPI (2015). Climate Finance in 2013-14 and the USD 100 billion goal. A report by the Organization for Economic Co-operation and Development (OECD) in collaboration with Climate Policy Initiative (CPI).

OECD/IEA (2014). Tracking Clean Energy Progress 2014 (IEA, International Energy Agency).

Parker, C., Brown, J., Pickering, J., Roynestad, E., Mardas, N., and Mitchell, A. (2010). The little climate finance book: A guide to financing options for forests and climate change (Global Canopy Foundation).

Pickering, J., Jotzo, F., and Wood, P.J. (2015). Splitting the difference: can limited coordination achieve a fair distribution of the global climate financing effort? (Centre for Climate Economic & Policy, Crawford School of Public Policy).

Pittel, K., and Rübbelke, D. (2013). International climate finance and its influence on fairness and policy. World Econ. *36*, 419–436.

Prowse, M., and Snilstveit, B. (2010). Impact evaluation and interventions to address climate change: a scoping study. J. Dev. Eff. *2*, 228–262.

PwC (2014). Challenging times ahead for the Indonesian mining sector.

REN21 (2014). Renewables 2014. Global status report (Paris: REN21 Secretariat: Renewable Energy Policy Network for the 21sr Century).

Román, M.V., Arto, I., and Ansuategi, A. (2016). The geographic distribution of the economic impact of climate finance (Bilbao, Spain: Basque Centre for Climate Change (BC3)).

Rübbelke, D.T.G. (2011). International support of climate change policies in developing countries: Strategic, moral and fairness aspects. Ecol. Econ. *70*, 1470–1480.

Schalatek, L., Nakhooda, S., and Watson, C. (2015). The Green Climate Fund (Heinrich Böll Stiftung, ODI).

Schenker, O., and Stephan, G. (2014). Give and take: How the funding of adaptation to climate change can improve the donor's terms-of-trade. Ecol. Econ. *106*, 44–55.

Tian, H., and Whalley, J. (2010). Trade sanctions, financial transfers and BRIC participation in global climate change negotiations. J. Policy Model. *32*, 47–63.

Timmer, M., Erumban, A.A., Gouma, R., Los, B., Temurshoev, U., de Vries, G.J., Arto, I., Genty, V.A.A., Neuwahl, F., Francois, J., et al. (2012). The world input-output database (WIOD): contents, sources and methods (Institute for International and Development Economics).

Timmer, M.P., Dietzenbacher, E., Los, B., Stehrer, R., and Vries, G.J. (2015). An illustrated user guide to the world input–output database: the case of global automotive production. Rev. Int. Econ. *23*, 575–605.

UK Government, and Australian Government (2016). Roadmap to US$100 Billion (UK Department for Business, Energy and Industrial Strategy, Australian Department of Foreign Affairs and Trade/).

UNEP (2014b). The Adaptation Gap Report 2014 (Nairobi, Kenya: United Nations Environment Programme (UNEP)).

UNEP (2014a). The Emissions Gap Report 2014. A UNEP Synthesis Report (Nairobi: United Nations Environment Programme (UNEP)).

UNFCCC (2009). FCCC/CP/2009/L.7. Copenhagen Accord.

UNFCCC (2010). UNFCCC Decision 1/CP.16. The Cancun Agreements.

UNFCCC (2014). NAPAs received by the secretariat.

UNFCCC (2015). Adoption of the Paris Agreement. Proposal by the President. Draft decision -/CP.21. FCCC/CP/2015/L.9.

Urpelainen, J. (2012a). Strategic problems in North–South climate finance: creating joint gains for donors and recipients. Environ. Sci. Policy *21*, 14–23.

Urpelainen, J. (2012b). The strategic design of technology funds for climate cooperation: generating joint gains. Environ. Sci. Policy *15*, 92–105.

Vandeweerd, V., Glemarec, Y., and Billett, S. (2012). Climate Finance Readiness. A framework for what it means to be ready to use climate finance effectively (United Nations Development Programme).

World Bank (2011). Trade | Data, http://data.worldbank.org/topic/trade.

Xu, Y., and Dietzenbacher, E. (2014). A structural decomposition analysis of the emissions embodied in trade. Ecol. Econ. *101*, 10–20.

de Zeeuw, A. (2015). International Environmental Agreements. Annu. Rev. Resour. Econ. *7*, 151–168.