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THE ECONOMICS OF CLIMATE FINANCE

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Resumen de la tesis

Esta tesis, titulada "La Economía de la Financiación para el Cambio Climático", consiste en un compendio de contribuciones, y está estructurada en cinco capítulos. Después del capítulo introductorio hay tres capítulos basados en las publicaciones resultantes del doctorado. Un capítulo final recoge las conclusiones generales.

El Capítulo 1 contiene los antecedentes, hipótesis y objetivos de la tesis, junto con un resumen de la metodología y los datos utilizados. En la sección de antecedentes (1.1) se detalla el contexto de la presente tesis, esto es, los retos de financiación que supone el cambio climático al conjunto de los países del mundo, y los compromisos actuales bajo la Convención Marco de las Naciones Unidas sobre el Cambio Climático (CMNUCC). Se presentan las cinco ramas de la literatura relevantes para esta tesis: 1) la literatura sobre financiación para el cambio climático, que emergió con la vocación de apoyar la toma de decisiones sobre este tema de vital importancia para coordinar la acción climática global; 2) la literatura sobre "economía verde", que aboga por la compatibilidad entre el buen funcionamiento de la economía y la protección del medio ambiente, y que aporta evidencias de las sinergias existentes entre estos dos objetivos; 3) la literatura sobre comercio internacional y cadenas de suministro globales, que estudia las redes de producción plurinacionales; 4) la literatura sobre ayuda ligada, una parte de la literatura sobre ayuda externa conectada con el comercio internacional; y 5) la literatura sobre el uso de requerimientos de contenido local, herramienta de desarrollo industrial también utilizada para el "desarrollo verde". Con una figura se ilustra la ubicación de esta tesis en la intersección de dichas ramas de la literatura, rellenando varias lagunas de conocimiento.

La siguiente sección (1.2) agrupa el conjunto de hipótesis que constituye el punto de partida de esta tesis, el objetivo general y las siete preguntas que guían el trabajo de investigación hacia dicho objetivo. Las tres primeras preguntas se abordan en el Capítulo 2, las siguientes dos en el Capítulo 3 y las dos últimas en el Capítulo 4. Esta sección también indica la utilidad de nuestros hallazgos para procesos de toma de decisiones.

La siguiente sección (1.3) comienza justificando la elección del enfoque de modelización utilizado: un modelo input-output de demanda dentro de un marco multiregional y global. Se explican las ventajas de este método en comparación con otra herramienta de evaluación de impacto (los modelos de equilibrio general computables). Luego se dan más detalles metodológicos y se especifican los requerimientos de datos para la aplicación del modelo. En concreto, se necesitan dos conjuntos de datos: la base de datos input-output y la información relativa a las acciones climáticas financiadas.

El Capítulo 2 se titula "Comercio internacional y la distribución de los beneficios de la financiación para el cambio climático". Éste se basa en una contribución publicada como documento de trabajo por el Centro Vasco para el Cambio Climático (BC3, por sus siglas en inglés), y que ha sido enviada a la revista científica *Climate and Development*. Dicho capítulo se estructura en seis secciones: introducción, métodos y materiales, resultados, discusión, observaciones finales y apéndice.

La introducción (sección 2.1) explica que en 2009 los países desarrollados se comprometieron bajo la CMNUCC a movilizar al menos 100 mil millones de dólares americanos para apoyar los esfuerzos de los países en desarrollo en materia de cambio climático. Desde entonces, varios investigadores han hecho el seguimiento de la evolución de los flujos de financiamiento para el cambio climático de Norte a Sur, detectando un persistente desequilibrio a favor de proyectos de mitigación en ciertos países asiáticos. En este contexto, el objetivo de esta contribución es aportar nuevos conocimientos sobre los impactos económicos de la financiación para el cambio climático a nivel global, contestando tres preguntas concretas: *¿cómo se distribuye geográficamente el impacto económico de la financiación para el cambio climático? ¿Cuánto permanece en la economía del país receptor y cuánto se desborda hacia otros países?* Y, *¿cuánto vuelve a los países donantes?*

La sección sobre métodos y materiales (2.2) explica cómo los desembolsos de financiación para el cambio climático se transforman en valor añadido que puede ser rastreado a través de sectores y países mediante un marco input-output multiregional global. Este enfoque metodológico permite observar el impacto económico de los desembolsos de financiación para el cambio climático que se produce más allá de las fronteras nacionales, lo que se conoce como los efectos derrame. A continuación, se explica cómo se hace el cálculo del valor añadido creado por cada país para satisfacer la demanda generada por el desembolso de financiación para el cambio climático. Tras advertir sobre las limitaciones de este método, se indican los datos utilizados para el análisis. En concreto, se utilizan los datos del año 2011 de la base de datos WIOD (World Input-Output Database) para cinco países receptores y cuatro grupos de países donantes. También se utilizan diversas fuentes de información para la caracterización de 26 tipos de acciones climáticas como shocks de demanda.

La sección de resultados (2.3) está subdividida en tres subsecciones (una para cada pregunta de investigación). En ella se muestra, en primer lugar, el impacto local de los desembolsos de financiación para el cambio climático en país receptor, así como los efectos derrame sobre cada grupo de donantes. En segundo lugar, se distingue el impacto local y los efectos derrame en función del tipo de intervención climática. Por último se indican los efectos derrame para cada donante según tipo de intervención y país receptor. Dichos resultados ponen de relieve cómo la distribución del impacto económico varía dependiendo de a qué se destina el financiamiento.

En la discusión (2.4) se destaca la consistencia entre el interés económico de los donantes (en cuanto a los efectos derrame estimados) y el sesgo observado en la financiación hacia proyectos de mitigación. Asimismo, el interés económico de los países receptores (en cuanto al impacto local estimado) resulta coherente con su demanda de más financiación para adaptación. Si bien no se demuestra ninguna relación de causalidad, los resultados sugieren que el impacto económico puede ser un factor a considerar en las decisiones sobre desembolso de financiación para el cambio climático.

Tras mencionar varias ideas de investigación futuras inspiradas en estos hallazgos, la sección 2.5 incluye algunas conclusiones, como que la posición de una economía en los mercados internacionales determina en qué medida ésta se beneficia del impacto económico derivado de la financiación para el cambio climático, y que los países receptores tienen margen de mejora para retener mayores proporciones del impacto.

Una de las líneas de investigación abiertas por el Capítulo 2 se aborda en el Capítulo 3: la tarea de desentrañar la contribución de los diferentes factores que explican las diferencias observadas entre los países en su capacidad de retener o capturar el impacto de los desembolsos de financiación para el cambio climático. Éste capítulo, titulado "Análisis de descomposición espacial de los beneficios económicos de la financiación para el cambio climático", se basa en una contribución publicada como documento de trabajo por el BC3 y presentada a la revista científica *Economic Systems Research* (actualmente se encuentra en la segunda ronda de revisión). Consta de cinco secciones: la introducción, la metodología, los resultados, debate y conclusiones, y el apéndice.

La introducción (sección 3.1) revisa brevemente la literatura sobre la financiación para el cambio climático y ubica esta contribución como una continuación del Capítulo 2. También aquí se indican las preguntas de investigación específicas de este capítulo: *¿cuál es la contribución de cada factor a las diferencias observadas entre los países?* Y, *¿qué industrias ofrecen el mayor potencial para aumentar el impacto económico de la financiación para el cambio climático?* También se introducen la técnica utilizada para responder a estas preguntas: el análisis de descomposición estructural (SDA, por sus siglas en inglés), y sus aplicaciones anteriores a otros temas relacionados con el cambio climático.

En la sección sobre materiales y métodos (3.2) se detalla cómo se utiliza el SDA para explicar las diferencias entre países definiendo un país de referencia con el que comparar el resto. Proponemos una descomposición en cuatro factores (intensidad de valor añadido, multiplicador doméstico, multiplicador extranjero y estructura de comercio) y detallamos los cálculos requeridos para llevarla a cabo. Los materiales son, en este caso, las tablas input-output multiregionales para el año 2011 de la base de datos WIOD de cinco países receptores y cuatro países donantes, y datos sobre los gastos asociados a seis tipos de intervenciones climáticas, extraídos de diferentes fuentes secundarias de información. Se detallan dichas fuentes y las correspondencias utilizadas en la preparación de los datos para su uso en el modelo.

La sección de resultados (3.3) se divide en dos subsecciones, una para los resultados a nivel país y otra para los resultados a nivel sectorial. Esta sección indica cuáles son los países de referencia, a qué distancia de éstos se encuentra cada país y la contribución de cada factor a dicha distancia. Los resultados por sectores sirven para identificar las principales industrias que dan lugar a los resultados agregados, que resultan ser diferentes en el caso de los países receptores y donantes.

En la discusión (sección 3.4), cada país se analiza por separado, haciendo hincapié en sus principales fortalezas y debilidades, y se explican los resultados a la luz de indicadores extraídos de las tablas input-output. Esta sección concluye dando recomendaciones a los distintos países sobre cómo acercarse al país de referencia y aumentar así su cuota del impacto económico de la financiación para el cambio climático.

El Capítulo 4 se titula "Efecto derrame de la financiación para el cambio climático: ayuda ligada y requisitos de contenido local", y está estructurado en siete secciones: la introducción, un resumen sobre la ayuda ligada y los requisitos de contenido local (LCR, por sus siglas en inglés), la sección de métodos y datos, los resultados, la discusión, las conclusiones y un apéndice.

La introducción (4.1) sitúa esta contribución como una extensión del Capítulo 2 y define el alcance y el objetivo de este capítulo, que responde a las siguientes preguntas: *¿cuál es el efecto de la ayuda ligada y los LCR en el efecto derrame sobre los países donantes?* Y, *¿qué localizaciones e industrias son más sensibles a los efectos de estas condiciones?* A continuación, se incluye una sección (4.2) que explica los antecedentes de las dos prácticas objeto de este estudio, resumiendo las evidencias de su uso en los países objeto de análisis. Para los países desarrollados considerados se indican las evidencias del uso de la ayuda ligada en sus contribuciones a la financiación para el cambio climático. De los países en desarrollo considerados se recoge el uso de LCR para la promoción de "tecnologías verdes".

La sección de métodos y datos (4.3) introduce el marco metodológico utilizado (el modelo input-output multiregional global) y hace referencia a algunas de sus aplicaciones previas a cuestiones similares. Esta sección incluye detalles sobre los datos utilizados para nuestra aplicación concreta, cuyo alcance se limita a un conjunto de países, el año 2011 y 26 tipos de medidas climáticas. A continuación, se explica el diseño de los escenarios cuyo análisis permite esclarecer el efecto de las condiciones impuestas sobre el origen de los bienes cuando la ayuda es ligada y cuando hay requerimientos de contenido local. También se explica cómo se realiza la agrupación de las 26 acciones climáticas consideradas en cinco grupos para facilitar el análisis y la comunicación de los resultados. Seguidamente se incluye una descripción de las características distintivas de cada grupo obtenido y la sección termina con las limitaciones de la metodología utilizada.

La sección de resultados (4.4) se divide en resultados a nivel país y a nivel sector. La primera parte demuestra cómo el efecto derrame aumenta cuando la ayuda es ligada, y cómo disminuye cuando hay requerimientos de contenido local. Además se muestra que el efecto de la ayuda ligada es mucho más importante que el de los requerimientos de contenido local. El impacto de estas disposiciones sobre el efecto derrame depende del país receptor de los fondos, del tipo de acción implementada y del país donante. Los resultados por sector indican las tres industrias donde el efecto derrame es más grande en cada escenario, analizando cada país por separado.

En la discusión (sección 4.5), los resultados se explican a la luz de la información recogida por las tablas input-output multiregionales. La sección de conclusiones (4.6) incluye algunas implicaciones de los hallazgos obtenidos para las discusiones sobre la asignación de la financiación para el cambio climático, y sobre los canales de la misma, así como para el desarrollo de industrias verdes competitivas.

El Capítulo 5 se divide en cinco secciones: una introducción, un resumen de los hallazgos, una sección sobre las implicaciones para las políticas, algunas observaciones finales y las futuras líneas de investigación. La introducción (sección 5.1) habla sobre la relevancia del estudio de los impactos económicos de la financiación para el cambio climático en un momento en que se espera que dichos flujos financieros vayan en aumento.

A continuación (sección 5.2) se resumen los resultados de esta tesis. Éstos se pueden recoger en tres frases: 1) el comercio internacional redistribuye una parte del impacto económico de la financiación para el cambio climático fuera de los países receptores; 2) la relevancia de cada uno de los factores que determinan el tamaño del impacto económico de la financiación para el cambio climático varía con el país; 3) las disposiciones sobre el uso de los fondos transferidos modifican la magnitud de la parte del impacto capturada por los países donantes.

En la siguiente sección (5.3) se recogen las principales implicaciones para las políticas derivadas de la tesis, distinguiendo por un lado las que afectan a los países donantes, y por otro aquellas de interés para los países receptores. A modo de conclusiones incluimos en la sección 5.4 tres observaciones derivadas de nuestra investigación. En primer lugar, la importancia de adoptar una escala global de análisis al evaluar los impactos económicos de la financiación para el cambio climático. En segundo lugar, la utilidad de evaluaciones de impacto económico como la nuestra de cara a la identificación de sinergias entre economía y acción climática. Y en tercer lugar, el potencial de los modelos input-output multiregionales globales para sacar a la luz aspectos relevantes para la acción global contra el cambio climático.

Esta tesis finaliza señalando en la sección 5.5 tres direcciones para futuros trabajos de investigación: 1) la ampliación del alcance geográfico del análisis mediante otras bases de datos que contengan más países; 2) completar el ejercicio con el cálculo de las emisiones netas derivadas de cada tipo de medida climática; y 3) la desagregación del impacto de valor añadido en sus dos componentes: rentas de la mano de obra y rentas del capital.

Abbreviations and acronyms

- COP: Conference of Parties
- CPA: Statistical classification of products by activity
- CSP: Concentrated solar power
- DAC: Development Assistance Committee
- DME: Domestic multiplier effect
- EA: East Asia
- EGW: Electricity, Gas and Water Supply
- EU: European Union
- FME: Foreign multiplier effect
- FSF: Fast Start Finance
- GCF: Green Climate Fund
- GDP: Gross domestic product
- GHG: Greenhouse gas
- GMRIO: Global Multiregional Input-Output
- GVC: Global value chains
- IO: Input-Output
- IPCC: Intergovernmental Panel on Climate Change
- LCR: Local Content Requirements
- M&A: Mitigation and adaptation
- n.e.c.: Not elsewhere classified
- NACE: *Nomenclature statistique des activités économiques dans la Communauté européenne*
- NAPA: National Adaptation Programmes of Action
- NAPs: National Adaptation Plans
- NDCs: Nationally Determined Contributions
- OBA: Other Business Activities
- ODC: Other developed countries
- OECD: Organization for Economic Co-operation and Development
- pp: Percentage points
- ROW: Rest of the world

- SDA: Structural Decomposition Analysis
- SUT: Supply and Use Tables
- TSE: Trade structure effect
- UK: United Kingdom
- UNFCCC: United Nations Framework Convention on Climate Change
- USA: United States of America
- USD: United States dollar
- VAiE: Value-added intensity effect
- WIOD: World Input-Output Database
- WIOT: World Input-Output Tables
- WTO: World Trade Organization

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1. Introduction

1.1.Background

Climate change is one of the main threats to humankind. Societies can respond to climate change by decreasing the rate and magnitude of the change through the reduction of greenhouse gas (GHG) emissions (i.e. mitigation) and by adapting to their impacts (IPCC, 2007). Mitigation of climate change requires important transformations in many different dimensions of society (energy, transportation, agriculture, forestry, etc.) and will require a significant volume of financial resources. For instance, the International Energy Agency estimates that from 2015 to 2040 the world would need to invest, on average, around 1.7 trillion United States Dollar (USD) per year in energy-supply infrastructure to limit the average temperature rise above pre-industrial levels to no more than 2 degrees Celsius with a probability of 50% (OECD/IEA, 2015). Besides, efforts in adaptation to climate change will be required, since mitigation will not prevent climate change from happening in the next few decades. According to the Intergovernmental Panel on Climate Change (IPCC, 2001a), adaptation to climate change is any adjustment in ecological, social, or economic systems responding to actual or expected climate changes. There is a wide range of technological, behavioural and institutional options to adapt to climate change, many of which will entail substantial costs. Only in developing countries, the costs of adaptation could reach several hundreds of USD billion per year, according to the United Nations Environment Program (UNEP, 2014a). Thus, climate change poses enormous financial challenges to the international community, especially to less developed countries, which do not have easy access to the required financial resources and where the impacts of climate change are expected to be stronger.

In this context, there is a growing interest in the concept of climate finance. 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). According to the Standing Committee of Finance of the United Nations Framework Convention on Climate Change (UNFCCC), climate finance *"aims at reducing emissions, and enhancing sinks of greenhouse gases and aims at reducing vulnerability of, and maintaining and* *increasing the resilience of, human and ecological systems to negative climate change impacts"* (UNFCCC, 2014a) [1].

Since 2009 climate finance is of paramount importance for global climate action. At the 15th Conference of Parties (COP) to the UNFCCC, developed countries committed to jointly mobilize USD 100 billion per year in climate finance by 2020 from a variety of sources (public, private, bilateral and multilateral, and alternative ones) to address developing countries' needs in terms of climate action. The Copenhagen Accord (UNFCCC, 2009) contained this commitment, which is named Long-term Finance, together with the promise by developed countries to provide USD 30 billion from 2010 to 2012 as Fast Start Finance (FSF) to support immediate action on the ground (IPCC, 2014). At the 21st COP in Paris, the Long-term Finance commitment was reaffirmed. 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 this collective target will then be reviewed upwards.

Climate finance flows through multilateral channels – both within and outside of UNFCCC financing mechanisms –, but also increasingly through bilateral channels. Since the negotiation of the UNFCCC in 1992, the number of climate change funds 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 (UNFCCC, 2010), was conceived as the main channel for the Long-term Finance commitment. 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 2013–2014 developed countries mobilized USD 57 billion per year on

[1] The Standing Committee of Finance is the body in charge of assisting the COP in the tasks of

average for climate action in developing countries (71% from public sources) (OECD and CPI, 2015). The Standing Committee on Finance estimates, on its last report, that 70% of these funds went to mitigation projects, whereas only 25% went to adaptation purposes (the remaining share is classified as cross-cutting issues). This report also remarks that most of these financial resources are directed to Asia, especially to countries with attractive investment environments, and to mitigation measures. Latin American and African countries receive a smaller share of the funds, mainly for adaptation (UNFCCC, 2016).

These findings confirm a pervasive thematic and geographic unbalance in the climate finance distribution. Previous studies had already found that both public and private finance were predominantly focused on mitigation, with disbursements concentrated in a small number of emerging economies (China, India, South Africa and Brazil), while adaptation finance (coming almost exclusively from public sources) represented a small share of the total climate finance (Buchner et al., 2015). Thus, low-income countries in the Middle East and Africa, where adaptation needs are concentrated and mitigation potential is low, have problems to access climate finance (Boyle et al., 2014). The Standing Committee on Finance also recognizes that many developing countries lack the technical capacity to deal with the bureaucratic burdens associated with the proliferation of diverse funding channels (UNFCCC, 2016, 2014a).

For that reason, the Board of the GCF decided to aspire to a balance of 50:50 between mitigation and adaptation. As for October 2016, out of the USD 424.4 millions of disbursements approved by the GCF, more than 50% (USD 219.9 millions) were allocated to adaptation (UK Government and Australian Government, 2016). Also responding to these concerns, the Paris Agreement included the objective of scaling up financial resources for adaptation, reaching balance in the thematic allocation of funds, and designing country-driven strategies having into account the priorities and needs of developing countries. In a roadmap presented right before the 22nd COP in Marrakech 2016 (ibid), developed countries recognize that adaptation is a priority for many developing countries and urged donors to enhance accessibility to funds (Román et al. 2016).

measurement, reporting and verification of the support provided to developing countries.

The mention of country-driven strategies in the Paris Agreement might be motivated by concerns about the effectiveness of climate finance. According to the IPCC, the effectiveness of climate finance would increase if developing countries had the capacity to cope with the diversity of channels, and to manage the available sources of finance in favour of their national development strategies and needs (IPCC, 2014). Country ownership which, as defined by the World Bank, means that *"there is sufficient political support within a country to implement its developmental strategy, including the projects, programs, and policies for which external partners provide assistance"*, was already recognized to be a condition for aid effectiveness in the 2005 Paris Declaration on Aid Effectiveness and the Accra High-Level Forum of Aid Effectiveness (Gomez-Echeverri, 2013).

So, it seems that with the Paris Agreement and the last progresses made under the UNFCCC, donors are trying to address some of the challenges related to climate finance, including unbalance, accessibility and effectiveness (Román et al., 2017). This would not be possible without the insights provided by the prolific scientific literature on climate finance spurred by the Copenhagen Accord.

Many aspects of climate finance have already been explored in the literature. 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., 2015, 2014, 2013, 2011; 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, 2014a, 2014b).

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; de Zeeuw, 2015; Marrouch and Ray Chaudhuri, 2011). 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 agreement (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., 2015a; Pittel and Rübbelke, 2013; Rübbelke, 2011; Schenker and Stephan, 2014; Urpelainen, 2012a). Finally, other studies have dealt with the aforementioned issue of 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).

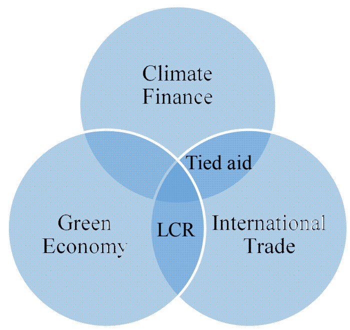
However, the economic impacts of climate finance disbursements have not been studied yet. On the contrary, there exists an extensive literature supporting the idea of a "green economy" where synergies between economic and climate objectives are exploited. For example, many studies have provided estimates of the "green jobs" creation associated with the transition to a low-carbon economy through the deployment of renewable energy sources. We are specially aware of studies made for Europe (Cameron and van der Zwaan, 2015; Lehr et al., 2012, 2008; Markaki et al., 2013; Markandya et al., 2016; Moreno and López, 2008; Oliveira et al., 2013; Ortega et al., 2015; O'Sullivan et al., 2014; Ragwitz et al., 2009), but we can also mention some assessments of the potential employment impacts of renewable energy sources for the United States of America (USA) (Wei et al., 2010), China (Cai et al., 2014), Middle East (Van der Zwaan et al., 2013) and Morocco (Ciorba et al., 2004). This stream of the literature suggests that some mitigation policies, such as the promotion of low-carbon technologies in the energy sector, would come with an economic benefit in the form of additional jobs. Similarly, it could be argued that climate finance, in addition to enabling mitigation and adaptation, can also contribute to the achievement of economic goals.

On the other hand, most of the studies on the green economy, have focused on the domestic impacts in a specific country or region, ignoring the trans-boundary effects due to international trade flows (an exception would be Markandya et al. 2016). This is especially relevant in the current globalized world, where value chains are increasingly fragmented across countries, with each country playing a specialized role in particular stages in the production chain (Timmer et al., 2014). The literature on global value chains (GVC) has illustrated the current fragmentation of production processes with particular case studies (Ali-Yrkkö et al., 2011; Ando and Kimura, 2005; Dedrick et al., 2009; Fukao et al., 2003; Hanson et al., 2005; Marin, 2010) and with more systematic approaches assessing the degree of vertical specialization and tracing value-added along the supply chain (Daudin et al., 2011; Hummels et al., 2001; Johnson and Noguera, 2012; Koopman et al., 2014, 2012, 2010; Los et al., 2015; Nagengast and Stehrer, 2016; Timmer et al., 2014; Trefler and Zhu, 2010).

These authors have contributed to the debate about the distribution of the benefits of globalization, by studying the consequences of this process of unbundling on the geographic location of production, on employment and on income distribution (within and between countries). In the climate change literature, the role of international trade and GVC has been introduced in the discussion about countries' responsibility for current concentrations of atmospheric GHGs. (Barrett et al., 2013; Davis et al., 2011; Davis and Caldeira, 2010; Peters, 2008; Peters et al., 2012, 2011). However, the influence of international trade on the distribution of the economic benefits produced by climate finance has not been studied yet.

Accordingly, in this thesis we will explore the links between climate finance and green economy from the perspective of GVC. There are two additional branches of the literature that are related to this doctoral thesis. Both refer to practices by national governments aimed at stimulating the development of domestic industries and enhancing their competitiveness at global level. The first one is known as "tying aid" and consists in using development aid as an instrument to promote exports of donors. The second one consists in imposing Local (or National) Content Requirements (LCR) to development projects in order to protect and boost the industries of recipient countries. **Figure 1** illustrates the literature streams relevant for this thesis.

Figure 1. Literature streams relevant for this thesis



Source: Own work

In the 90s, approximately 50% of foreign aid was "tied", meaning that donors imposed beneficiaries of aid the explicit obligation of spending the received funds in products and services fabricated in the donor country. This practice has been officially criticized in numerous occasions (in 1991 by the Helsinki Package of discipline for tied aid, in 2001 by an OECD Development Assistance Committee recommendation and in 2005 with the Paris Declaration for Aid Effectiveness). Several studies have analysed the underlying causes of this practice, assessed the benefits of untying aid and documented the evolution of this practice (Brakman and van Marrewijk, 1995; Clay et al., 2009; Martínez-Zarzoso et al., 2014, 2009; Osei, 2005; Schweinberger, 1990; Selbervik and Nygaard, 2006). According to this literature, the proportion of tied aid has decreased in the last decades, but *de facto* tied aid is still significant. Some studies also suggest the prevalence of this practice on climate finance (de Sépibus, 2014; Whitley, 2013, 2012; Whitley et al., 2012; Whitley and Mohanty, 2013, 2012). Since tied aid affects international trade, this topic occupies the intersection between climate finance and international trade in **Figure 1**. We are not aware of previous studies assessing the effects of tied aid on the economic impacts of climate finance disbursements.

On the other hand, LCR are provisions, often associated to public support schemes, which impose the obligation of using a certain percentage of local products. Although explicitly prohibited by the World Trade Organization (WTO), this is an extended practice aimed at maximizing the impact of foreign financing and at protecting local industries. Several papers provide evidence of the use of this instrument for promoting green industries (Elms and Low, 2013; Johnson, 2013; Kuntze and Moerenhout, 2012; Mathews, 2015; Pérez, 2013). For this reason, LCR are located in the intersection between green economy and international trade in **Figure 1**. Again, so far this is an unexplored territory in climate finance literature.

1.2. Hypothesis and objectives

Our research departs from the following set of hypothesis:

- A disbursement of climate finance constitutes an influx of financial resources that is spent on the implementation of mitigation and adaptation actions in the recipient country.

- Mitigation and adaptation actions require expenditures in a mix of goods and services that need to be produced. These expenditures end up as income for the production factors (i.e. capital and labour) involved in the production of those goods and services, creating a positive economic impact in the recipient country.

- Part of this economic impact crosses the border of the recipient country, since some stages of the supply chain are undertaken abroad, and thus, the factors participating in those stages are also located in other countries.

- The distribution of the impact between local and foreign factors depends on the climate actions implemented (because these determine the composition of the demand shock) and on the characteristics of the recipient country (including its interconnection with other economies).

- The distribution of the impact is also affected by the characteristics of the rest of the countries (and their role within the global economy) and by the conditions imposed (by donors or recipients) on the origin of the supplies for climate actions.

Departing from these hypotheses, the general objective of this thesis is to study the economic impact of climate actions enabled by climate finance disbursements at a global scale. This constitutes a novel topic of research that occupies the intersection between the streams of literature illustrated in **Figure 1**. We expand the study of climate finance by addressing the economic impact of disbursements, putting the emphasis on its international dimension and the consequences of GVC.

This general objective is addressed by answering several specific questions: How is the economic impact (in terms of value-added creation) of climate finance geographically distributed depending on the type of climate action? How much value-added remains in the recipient country's economy and how much spills over to other countries? How much value-added returns to the donor country? What is the contribution of each of the factors explaining the differences between countries' share of the economic impact? What factors and industries offer the highest potential for increasing the economic impact of climate finance in each country? What is the effect of tied aid and LCR on the value-added captured by donor countries? What locations and industries are more sensitive to these practices?

Ultimately we aim at providing new insights to inform decisions about climate finance allocation, informing the design of national adaptation and mitigation plans to exploit the potential economic co-benefits, and making visible the opportunities that climate finance offers for the economic development of both developed and developing countries, and for the development of globally competitive green industries.

1.3.Methods and data

The study of the economic impact of policies (and other types of external shocks, such as natural disasters) has a long history. Most extended modelling approaches for impact assessment are the Leontief (1936) Input-Output (IO) model and Computable General Equilibrium (CGE) models (Rose, 2004). The first one, despite being already a classic approach in economic analysis, does not become outdated, and is still widely applied to different research topics (Dietzenbacher et al., 2013a; Han et al., 2004; Miller and Blair, 2009).

IO models constitute a top-down and macroeconomic based approach of impact assessment, which uses the information on the interdependencies between industries contained in IO tables to provide estimates of the impacts in all industries directly or indirectly related to a specific intervention. The IO model represents one economy as a set of relationships between producers (industries or sectors) and consumers (households, government, etc.). It represents all sales and purchases in that economy, reflecting the interdependencies between sectors in the production. In the simplest version of the IO model, interdependencies between sectors are reflected through constant technical coefficients, implying that substitution between inputs is not possible, and reflecting constant returns to scale (proportional relationship between inputs and output). In the standard IO model demand is not determined by income, but it is exogenously fixed. It reflects a partial equilibrium of the economy, between supplied and demanded quantities, without a mechanism linking prices and quantities. Moreover, the model does not include input and factor supply restrictions that could impede the satisfaction of additional demand.

CGE models constitute an alternative approach, which has been also extensively used for assessing the economic impact of policy interventions and other exogenous changes (Rose, 1995). Different authors have compared these two types of models, both theoretically and empirically. Empirical comparisons have shown that results are very sensitive to the choice of model (Koks et al., 2015). Theoretical analyses conclude that none of them is inherently superior to the other in all circumstances. But instead, their different characteristics make them suitable for different purposes. It is the responsibility of the researcher to make the correct model choice depending on the specific objectives and scope of each investigation (Okuyama and Santos, 2014; Rose, 1995; West, 1995).

In this case, we consider that the IO approach is more adequate for our purpose for four reasons:

1. We are interested in chain reactions across different sectors, and in the empirical relationships between different parts of the economy “as it is”, something that is captured by the IO model.

2. The IO model is transparent and almost free of assumptions.

3. The assumptions of IO are acceptable in our case, where the focus is on the short term effects of climate finance disbursements, which can be considered relatively limited in relation to the size of the economy of donors and recipient countries. In the short term the linearity in the production system and the impossibility of substitution are acceptable because the change in the economic structure can be assumed to occur relatively slowly. The partial equilibrium and the absence of input and factor supply restrictions are acceptable for small interventions, which cannot be expected to put pressure on wages and prices (Ciorba et al., 2004; Tourkolias and Mirasgedis, 2011).

4. Its mathematical simplicity enables a high level of disaggregation of industries and goods.

On the contrary, industries in GCE models are usually more aggregated than in IO models due to the mathematical complexity of interrelations between them. Besides, CGE rely on a scarce empirical base, and its implementation requires a large number of assumptions for the specification of parameters and elasticities. The general equilibrium on the economy and the optimizing behaviour of economic actors are also very strict assumptions. However, they are more appropriate than IO for assessing effects on the medium and long term, since the price mechanism enables to represent the reaction of economic agents to changes.

There are previous applications of the IO model for the quantification of the impact of climate-related investments (Allan et al., 2008; Caldés et al., 2009; Hienuki et al., 2015; Markaki et al., 2013; Neuwahl et al., 2008; Oliveira et al., 2013; Scott et al., 2008; Tourkolias and Mirasgedis, 2011). Most of them use national IO tables, which are appropriate for the assessment of domestic effects of new investments, but do not enable to distinguish the impact in other countries (Herreras Martínez et al., 2013; Ziegelmann et al., 2000). These effects, also called spill-over effects, refer to economic impacts outside the economy where the expenditure is made, and are driven by international trade.

In order to broaden the geographic scope of the assessment and capture spill-over effects, we need to track the flow of products across industries and countries. For that reason we use Global Multiregional IO (GMRIO) tables. These tables have been especially constructed to reflect the current interconnectivity of world's economies. They reflect the participation of the different sectors and countries in the production process of each product. They contain information about inter-linkages between industries and countries, something that enables to track the effect of a demand shock throughout the global productive system, beyond domestic frontiers. GMRIO models enable to trace the value-added[2] directly or indirectly needed for the production of final goods. This methodology to trace value-added, which is also used in Dietzenbacher et al. (2012) and Timmer et al. (2014), is exposed with detail in Chapter 2.

The value-added created by climate actions in each country depends on several factors which can be identified using a Structural Decomposition Analysis (SDA). When this technique is used to compare different locations at the same point in time, it is named spatial SDA, and some previous examples are Alcántara and Duarte (2004), de Nooij et al. (2003) and Hasegawa (2006). In this case, we compare all countries with a benchmark country, which is the one that creates more value-added for a specific type of climate action. The procedure of decomposition is explained in detail in Chapter 3.

In order to study the effects of restrictions on the origin of supplies imposed through tied aid and LCR, we apply a comparative static method in the context of a GMRIO model. The specific modifications performed in each case are detailed in Chapter 4. A similar method has been previously used, for example, in Markandya et al. (2016).

Once clarified the methodological aspects, details on the data used are exposed next. Two datasets are required to apply these methods: 1) the GMRIO database that provides the information required to build the GMRIO model; and 2) the data required to define the demand shocks corresponding to each climate action.

From the various GMRIO databases available (see Tukker and Dietzenbacher, 2013), we have chosen the World Input-Output Database (WIOD) because it is freely available and it is considered to be more accurate than others (Timmer et al., 2012,

[2] The value-added reflects the remuneration of primary production factors (i.e. labour and capital), and is a measure of the economic impact of a certain intervention.

2015). World Input-Output Tables (WIOT) from the WIOD cover information for 59 products, 35 industries and 40 countries (representing more than 85% of world gross domestic product (GDP) in 2008) for the period 1995-2011. The WIOT are based on public IO tables, national accounts data and international trade statistics. In addition, the WIOD provides data on factor inputs. This database has been previously used in the GVC literature (Koopman et al., 2014; Los et al., 2015; Timmer et al., 2014).

Demand shocks are defined for the following types of climate actions: renewable energy technologies (biogas, biomass, solar, geothermal, hydropower, ocean and wind power), energy efficiency measures (in buildings, industry and transport) and adaptation options (in agriculture, waste, water, infrastructure, disaster risk reduction, social protection, capacity building and ecosystems management). The demand shock is defined as a cost structure, consisting on the distribution of the total costs of implementation of one action amongst the different industries of the economy. The cost structures of mitigation actions are taken from the literature (Allan et al., 2008; Lehr et al., 2012, 2008; Markaki et al., 2013). Detailed information at project level of National Adaptation Programmes of Action (NAPA) is used for the definition of the cost structures of the rest of the climate actions (UNFCCC, 2014b). Chapter 2 provides additional details on the construction of cost structures of mitigation and adaptation actions.

After this introduction, the rest of the thesis is structured as follows. In Chapter 2 we estimate the geographic distribution of economic benefits for 17 mitigation and nine adaptation options. We use the GMRIO framework to track both domestic as well as spill-over effects of climate finance disbursements. In Chapter 3 we seek to clarify the differences in the capability of both donor and recipient countries to capture the economic benefits of climate finance. With that purpose we perform a spatial SDA. We focus on specific climate actions, and quantify the contribution of four factors: value-added intensity, domestic multiplier, foreign multiplier and trade structure. In Chapter 4 we analyse the effect on the value-added captured by donor countries of tied aid and LCR using the GMRIO framework for a scenario analysis. Finally, Chapter 5 gathers the main conclusions and potential future extensions.

2. International trade and the distribution of climate finance benefits

2.1.Introduction

Financial resources are needed for both climate change mitigation and adaptation. Large-scale investments are required to significantly reduce emissions, notably in sectors that emit large quantities of GHGs. The International Energy Agency estimates that achieving a low-carbon energy sector will require an average of USD 1.2 trillion in additional investments annually up to 2050 (IEA, 2014). On the other hand, the global cost of adaptation is currently estimated to range between USD 70 billion and more than 100 billion per year by 2050. However, the dispersion and heterogeneity of adaptation measures make cost estimates very uncertain and probably biased downwards, according to the Adaptation Gap Report (UNEP, 2014a).

Most developing countries face financial constraints (public as well as private), and significant additional costs imposed on their development by the impacts of climate change. Therefore, bilateral/multilateral public and private financing are all likely to be important sources of funding for their mitigation and adaptation activities. Climate finance is a critical topic in the United Nations' climate talks and industrialised countries have committed to assistance of developing countries at the Copenhagen Accord (UNFCCC, 2009) and the Cancun and Paris Agreements of the UNFCCC (UNFCCC, 2015, 2010). In these international agreements the higher-income countries have jointly pledged up to USD 30 billion in FSF for lower-income countries in the period 2010-2012 and, in terms of Long-term Finance, USD 100 billion annually from 2020 onwards (and a larger amount, still to be determined, after 2025).

Some governments have started to mobilize financial resources to support developing countries' mitigation and adaptation actions. The commitment for the FSF period was reached, especially due to the contributions by Germany, Japan, Norway, the United Kingdom (UK) and USA (Gupta et al., 2014). However, developed countries are far from reaching the Long-term Finance goal of USD 100 billion per year. According to OECD/CPI estimates, developed countries were able to mobilize and transfer USD 57 billion on average in 2013-2014 (OECD and CPI, 2015). This estimate does not include the recent initial capitalisation of the GCF, which accounts for USD 10.3 billion as of December 2016 (GCF, 2016). In October 2016, the five main contributors to climate funds (including the GCF) were UK (USD 11,228 million), Norway (USD 6,606 million), USA (USD 5,750 million), Germany (USD 4,203 million) and Japan (USD 3,208 million)[3]. Experts agree that climate finance must be accelerated and scaled up to put the world on track to attain a climate-neutral and resilient development in this century (Gupta et al., 2014).

So far, mitigation projects have accumulated the largest share of climate finance flowing from developed to developing countries. This bias towards mitigation was already detected in the FSF period, when mitigation was receiving 72% of contributions (Nakhooda et al., 2013). According to the OECD estimates of the 2013-2014 flows, the thematic distribution of these transfers has been 77% to mitigation, 16% to adaptation and 7% to cross-cutting actions (OECD and CPI, 2015). Buchner et al. (2015), accounting not only for internationally provided funding but also for domestically mobilized resources, found a strong bias towards mitigation in 2014, particularly towards renewable energy. Adaptation projects seem to have more difficulties in attracting funding than mitigation projects. Exceptions are East Asia (EA), the Pacific and Sub-Saharan Africa where 56% of total climate finance is for adaptation, especially for measures in the water- and wastewater sector (ibid).

A rapidly growing body of literature on climate finance is emerging, including the study of the drivers of international transfers. Authors addressing this question from a theoretical perspective have identified different causes for the current bias towards the financing of mitigation over adaptation. These causes include the “global public good” nature of mitigation in contrast with the local scope of adaptation, the cheap mitigation opportunities in developing countries, the existence of established business models and carbon markets, and the possibility to reduce future adaptation needs with investments in mitigation (Abadie et al., 2013; Pickering and Rübbelke, 2014; Pittel and Rübbelke, 2013; Rübbelke, 2011). Empirical analysis highlight the relevance of country-specific factors, like their institutional, economic and political characteristics (Halimanjaya, 2015; Pickering et al., 2015b).

[3] Accounting for the current pledges according to the web site Climate Funds Update (2016).

This chapter contributes to this body of literature by studying an aspect of climate finance that, to the best of our knowledge, has not been considered yet: the economic effects of expenditures driven by the financed climate actions, taking into account the role of international trade. Like any other type of expenditure, projects and programmes aimed at reducing emissions and/or enhancing climate-resilience require the production of goods and services, and hence, the creation of value-added in various economic sectors at different locations. This chapter quantifies the extent to which the benefits of climate action, in terms of value-added creation, are retained by recipient countries of climate finance or, by contrast, are captured by companies from other countries via international trade. Moreover, by assessing the economic effects of different types of climate actions in different locations, this chapter provides information for climate finance allocation decisions. Note that we limit the scope of the assessment of economic effects to the phase of disbursement of climate finance. Another branch of the climate finance literature deals with the economic consequences of the mobilization of financial resources in donor countries (Basu et al., 2011; IMF, 2011; Jones et al., 2013; Parker et al., 2010).

The specific objectives of this chapter can be summarized in three questions. First, how are the economic impacts of climate actions distributed between countries? Second, distinguishing for different types of mitigation and adaptation actions, how much of the impact spills over to non-recipient countries? And third, distinguishing for different disbursement options (i.e. combinations of recipient country and climate action), how much impact is captured by each donor country?

The chapter is divided into five sections. After this introduction (Section 2.1), the methods and materials are introduced (Section 2.2). Results are presented in Section 2.3, and discussed in Section 2.4. Section 2.5 presents conclusions and policy implications.

2.2. Methods and materials

2.2.1. The Input-Output Model

The IO approach has been widely applied to various areas over the last 50 years (Han et al., 2004; Miller and Blair, 2009). This approach is the most widely utilized for the analysis of macro-economic implications of major new expenditures, as is the case of investments driven by climate policies (Allan et al., 2008; Caldés et al., 2009; Hienuki et al., 2015; Markaki et al., 2013; Neuwahl et al., 2008; Oliveira et al., 2013; Scott et al., 2008; Tourkolias and Mirasgedis, 2011).

An IO table provides a picture of the market transactions taking place between the different actors (producers, households, government, etc.) of one economic system in a specific year. National IO tables, representing the national economic system, are appropriate for the assessment of domestic effects of new investments, but do not enable to distinguish the impact in other countries (Herreras Martínez et al., 2013; Ziegelmann et al., 2000). These effects, also called spill-over effects, refer to economic impacts outside the economy where the expenditure is made, and are driven by international trade.

Given the growth of vertical specialization and the increasingly global nature of current supply chains (Francois et al., 2015; Johnson and Noguera, 2012; Koopman et al., 2014, 2012; Los et al., 2015; Nagengast and Stehrer, 2016)[4], GMRIO tables are a highly suitable tool for studies with a global scope, since they inherently reflect the current interconnectivity of the world's economies. They comprise information on global supply chains, reflecting the participation of the different sectors and countries in the production process of each single good or service. The information about inter-linkages between industries enables to comprehensively track the effect of an exogenous increase in demand throughout the global productive system. GMRIO tables enable to trace the value-added created by all the labour and capital directly or indirectly needed for the production of final goods along their GVC. This feature makes this framework suitable for the purpose of this chapter (Timmer et al., 2014). Spill-over effects of climate policy have been previously assessed using this framework at the European Union (EU) level (Arto et al., 2015; Markandya et al., 2016).

Next, we illustrate the structure of a multiregional IO model with the example of a three-country model. It consists of a system of linear equations that describe the

[4] For example, Timmer et al. (2014) using the GMRIO framework show that the process of international production fragmentation is pervasive: between 1995 and 2008 the content of foreign value-added in manufactures increased in 85% of the examined goods.

relation between inputs and final products in each sector. In this case, the standard demand-driven model can be written as $\mathbf{x} = (\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{F} = \mathbf{LF}$

With $\mathbf{x} = \begin{pmatrix} \mathbf{x}^1 \\ \mathbf{x}^2 \\ \mathbf{x}^3 \end{pmatrix}$, $\mathbf{I} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$, $\mathbf{A} = \begin{pmatrix} \mathbf{A}^{11} & \mathbf{A}^{12} & \mathbf{A}^{13} \\ \mathbf{A}^{21} & \mathbf{A}^{22} & \mathbf{A}^{23} \\ \mathbf{A}^{31} & \mathbf{A}^{32} & \mathbf{A}^{33} \end{pmatrix}$, $\mathbf{F} = \begin{pmatrix} \mathbf{f}^{11} & \mathbf{f}^{12} & \mathbf{f}^{13} \\ \mathbf{f}^{21} & \mathbf{f}^{22} & \mathbf{f}^{23} \\ \mathbf{f}^{31} & \mathbf{f}^{32} & \mathbf{f}^{33} \end{pmatrix}$ and

$$\mathbf{L} = \begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} & \mathbf{L}^{13} \\ \mathbf{L}^{21} & \mathbf{L}^{22} & \mathbf{L}^{23} \\ \mathbf{L}^{31} & \mathbf{L}^{32} & \mathbf{L}^{33} \end{pmatrix}$$

Where $\mathbf{x}^r$ is the column vector of gross outputs in country r with elements x_i^r indicating the production in country r of products of sector i. $\mathbf{I}$ is an identity matrix of the appropriate dimension (in this case, three). $\mathbf{A}^{rs}$ is the matrix of input coefficients calculated as $\mathbf{A}^{rs} = \mathbf{Z}^{rs}(\hat{\mathbf{x}}^s)^{-1}$, where $\mathbf{Z}^{rs}$ 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 and $(\hat{\mathbf{x}}^r)^{-1}$ is the inverse of the diagonal matrix of the gross outputs vector. $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is also known as the matrix of production multipliers or Leontief inverse matrix $\mathbf{L}$, where each element l_{ij}^{rs} indicates the increase in the production of sector i in country r due to a unitary increase of demand of sector j in country s. $\mathbf{f}^{st}$ is the column vector with the final demand, with elements f_j^{st} indicating the final demand in country t for products of sector j produced by country s. This model is called demand-driven because for any new exogenous final demand $\mathbf{F}'$, the total output $\mathbf{x}'$ can be estimated as $\mathbf{x}' = \mathbf{LF}'$.

Value-added reflects the contribution of an industry to an economy (Miller and Blair, 2009). Using value-added coefficients it is possible to differentiate the contribution of each country to the value-added embodied in a certain new expenditure (Dietzenbacher et al., 2012). To calculate value-added coefficients we use the column vector of value-added in country r $\mathbf{w}^\mathbf{r}$, with elements w_i^r indicating the value-added created in each sector i of that country. With this information and the inverse of the diagonal matrix of the gross outputs, value-added coefficients are obtained as $\mathbf{v}^r = \left(\hat{\mathbf{x}}^r\right)^{-1} \mathbf{w}^r$. The vector of value-added effects is calculated as $\mathbf{w} = \hat{\mathbf{v}}\mathbf{x}' = \hat{\mathbf{v}}\mathbf{L}\mathbf{F}'$. Thus, the value-added created in the country r as a consequence of a demand shock in country t is $\mathrm{w}^{rt} = \sum_s \mathbf{v}^r{}' \mathbf{L}^{rs} \mathbf{f}'^{st}$

The IO method is based on the hypotheses of a linear relationship between inputs and production. It is also assumed that each sector produces one product, and that each sector has a single and constant input structure. The model ignores the possibility of substitution between inputs or the possibility of increasing/decreasing returns to scale and technical change. A change in output is supposed to produce a proportional change in inputs without affecting prices. These assumptions are only reasonable in the medium term (since the change in the economic structure can be assumed to occur relatively slowly), and in economies with excess capacity and involuntary unemployment, or for the study of relatively small interventions that will not affect prices (Ciorba et al., 2004; Tourkolias and Mirasgedis, 2011). These requisites are met in our case, since the focus is on short-term effects of expenditures that, due to their limited volume, cannot be expected to put pressure on wages and prices. Note that, in order to avoid arbitrary assumptions, we limit the analysis to the gross effects, ignoring the effect of expenditures potentially displaced by the climate finance disbursements. The assessment of net effects free of assumptions is possible using a retrospective approach when historical data on the actual transformations of the economy is available (as shown by Markandya et al., 2016).

2.2.2. The database

In order to apply this model we depart from two sets of data: 1) the GMRIO database, that provides information at industry level on production, technical coefficients, final demand and value-added for different countries; and 2) the data required to define the demand shock ($\mathbf{f}'^{st}$) by climate action and recipient country.

2.2.2.1. The GMRIO database

From the various GMRIO databases (see Tukker and Dietzenbacher, 2013), we have chosen the WIOD. Two important advantages of WIOD are the following: first, it is public and freely available; and, second, it is based on national Supply and Use Tables (SUT), which contain information in terms of commodities that is required for the definition of the demand shocks. WIOT from the WIOD combine information on national production activities for 59 products and 35 industries with international trade data for 40 countries (27 EU countries[5] and 13 other major countries) for the period 1995-2011. The WIOD has certain weaknesses related to measurement issues[6] and an important limitation for our analysis: the absence of least developed countries, where climate finance disbursements are most needed.

The analysis focuses on the most recent data (i.e. year 2011) and on all the countries included in the WIOD. Brazil, China, Indonesia, India and Mexico are considered climate finance recipient countries, and the rest of the countries are considered donor countries. Donors are divided into four groups: USA, EU, EA (Japan, Korea and Taiwan) and other developed countries (ODC: Australia, Canada, Russia and Turkey). While this set does not include all countries, it represented approximately 84% of global GDP and 72% of global GHG emissions in 2011. The set of recipient countries represented around 60% of the emissions as well as GDP from developing countries in 2011 (World Bank Indicators).

2.2.2.2. Demand shocks

Demand shocks defined as $\mathbf{f}'^{st}$ are calculated for different types of climate actions using different sources of information. Following previous categorizations of climate action measures (Blazejczak et al., 2014; Buchner et al., 2013; OECD/IEA, 2014; Prowse and Snilstveit, 2010; REN21, 2014, p. 21; UNFCCC, 2014b), we consider 26 climate actions and divide them into three groups:

[5] In the WIOD and in this thesis the UK is still considered a Member State of the European Union.
[6] For a detailed description of the WIOD project, the WIOT and their main weaknesses see Dietzenbacher et al. (2013b) and Timmer et al. (2012, 2015).

- Mitigation: This group consists of those actions with benefits in terms of GHG emissions reductions, including 14 renewable energy technologies (biogas power; biomass energy at large scale; biomass energy at small scale; concentrated solar power (CSP); deep geothermal energy; surface geothermal energy; hydropower; ocean power; offshore wind power; onshore wind power; photovoltaics; renewable energy in buildings; renewable energy in transport; solar thermal energy) and three energy efficiency measures (building insulation; energy efficiency in industry; transport infrastructures).

- Adaptation: This group consists of those actions that improve the resilience of societies, including measures in six sectors (coastal protection; disaster risk reduction; human settlements, infrastructure and spatial planning; social protection; waste and wastewater; water supply and management).

- Mitigation and adaptation (M&A): This group contains three actions with benefits in both aspects (agriculture, fishing and livestock; capacity building; forestry and land use, terrestrial ecosystems).

For each climate action, a particular cost structure has to be determined. Cost structures consist in the distribution of the total costs of implementation of one action amongst the IO industries or commodities. We need cost structures defined in terms of the commodities classification of the SUT of WIOD (i.e. the Statistical Classification of Economic Activities in the European Community or NACE[7]). The cost structures of mitigation actions are taken from the literature: most renewable energy technologies from Lehr et al. (2012, 2008); ocean energy from Allan et al. (2008); renewable energy in transport and buildings and energy efficiency measures from Markaki et al. (2013). Detailed information at project level of NAPA (UNFCCC, 2014b) is used for the definition of the cost structures of the rest of the climate actions. Since each climate action in adaptation comprises very different types of interventions, one particular NAPA project has been selected for each type, as shown in **Table 1.**

[7] Table 5 in the Appendix (Section 2.6) displays the NACE classification of commodities. NACE stands for Nomenclature statistique des activités économiques dans la Communauté européenne.

Table 1. Types of adaptation projects and sources of information

	Climate action	Type of intervention	NAPA Project
Adaptation	Coastal protection	Beach nourishment	GAMBIA #9
		Coastal protection structures	CAPE VERDE #3
		Rehabilitation of coastal areas	SIERRE LEONE #18
	Disaster risk reduction	Early warning or emergency response systems	GAMBIA #1
		Construction or improvement of drainage systems	BHUTAN #5
		Flood protection	BHUTAN #7
		Hazard mapping and monitoring technologies	BHUTAN #9
		Improved climate services	SIERRE LEONE #2
	Water supply and management	Rainwater harvesting and storage	SUDAN #2
		Rehabilitation of water distribution networks	SIERRE LEONE #12
		Desalinization, water recycling and water conservation	TUVALU #3
	Human settlements, infrastructure and spatial planning	Energy security (hydropower)	TANZANIA #5
		Energy security (solar energy)	SIERRE LEONE #8
		Energy security (biomass)	GAMBIA #6
		Transport and road infrastructure adaptation	MALDIVES #10
		Protection of infrastructure	BHUTAN #6
		Zoning	SAMOA #6
		Improving the resilience of existing infrastructures/buildings	MALDIVES #8
	Social protection	Livelihood diversification	MALAWI #1
		Food storage and preservation facilities	LESOTHO #8
		Health, vaccination programmes	SIERRE LEONE #23
	Waste and wastewater	Sanitation	SIERRE LEONE #22
		Storm and wastewater	MALDIVES #5
Mitigation & adaptation	Forestry and land use, Terrestrial Ecosystems	Afforestation and reforestation	ERITREA #3
		Ecological restoration and soil conservation	LESOTHO #6
		Protection of biodiversity	TUVALU #5
		Forest management, management of slopes and basins	BURUNDI #3
		Forest fires reduction	BHUTAN #11
	Capacity building	Awareness raising and integrating into education	BURUNDI #11
		Technical assistance	MALAWI #5
		Planning, policy development and implementation	SIERRE LEONE #19
	Agriculture, fishing and livestock	Crop / animal diversification	SIERRE LEONE #5
		Crop, grazing land, livestock and fisheries enhanced management	ERITREA #2
		Research	MALDIVES #9
		Irrigation and drainage system	SIERRE LEONE #7

Source: Own work

Table 2. Correspondence between NAPA and NACE categories

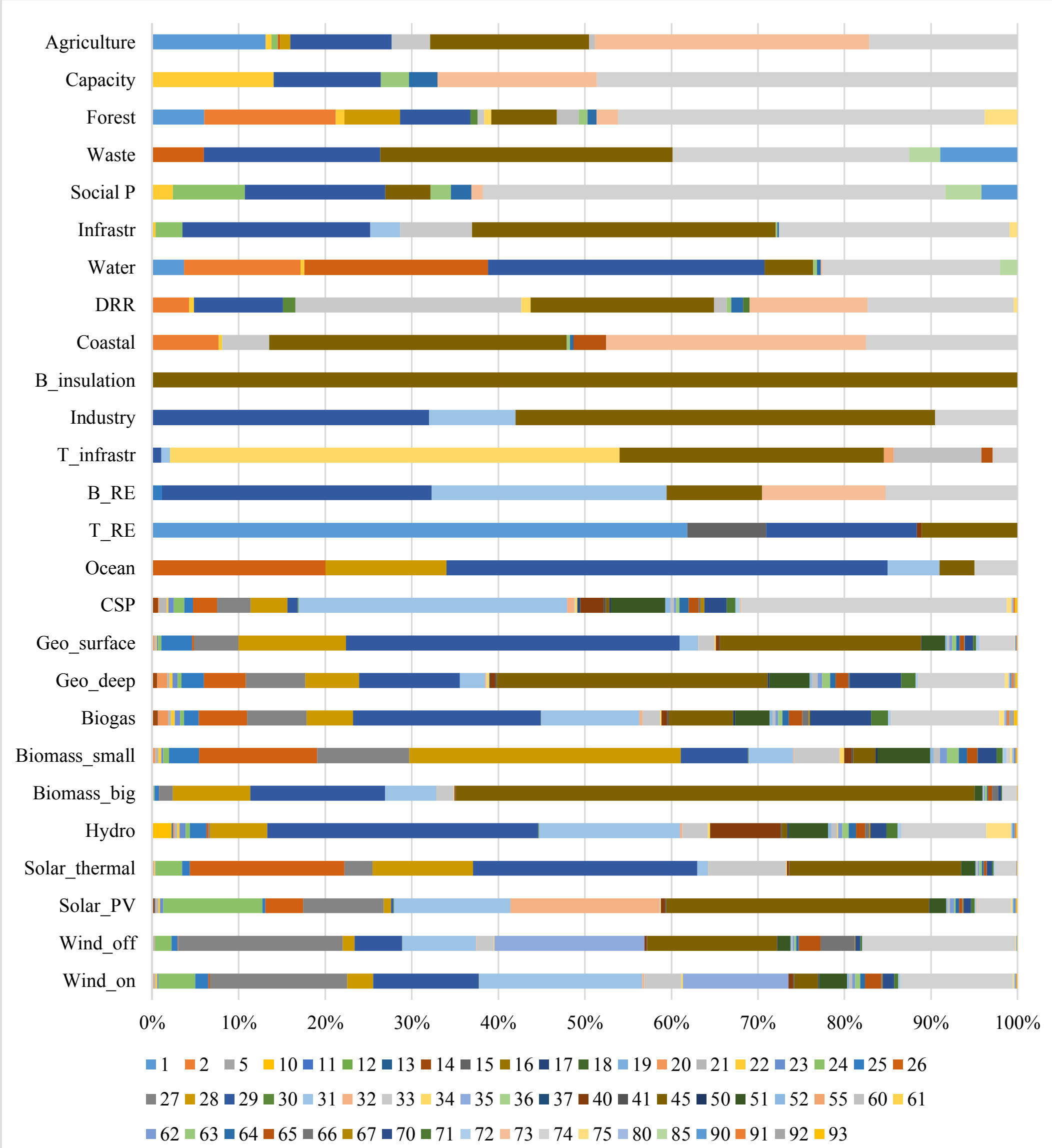
NAPA expenditure categories	NACE commodities code
Breeding animals, forage seeds, planting, crop management	1
Forest nurseries, re/afforestation, rehabilitation, beach stabilization, plantations	2
Materials, reporting, communication, awareness creation, training	22
Chemicals, drugs, raw materials	24
Materials for construction and rehabilitation	26
Tools	28
Machinery and installation	29
Office equipment	30
Transmission and distribution network	31
Laboratory/field/data processing equipment, hydrology/meteorology stations, telecommunication, remote sensing	33
Vehicles	34
Construction, rehabilitation, beach stabilisation, improve facilities/infrastructure	45
Logistics	60
Communication (campaign, networks, workshops)	63
Communication (telephone, internet and postal charges)	64
Micro-credit fund	65
Vehicle hiring charges	71
Research, experimentation, mapping	73
Technical support, design, management, planning, training	74
Institutionalisation of policies, support to collaborating agencies	75
Sanitary inspections, vector control measures, medical/veterinary services	85
Waste collection, sanitation	90

Source: Own work

The cost structure of each climate action is calculated as the average of the cost structures of the different types of interventions it comprises. The allocation of expenditures contained in NAPA projects to the commodity categories of the SUT is done following the correspondence in **Table 2**.

Figure 2 shows the obtained cost structures in terms of commodities, showing clearly the differences between the types of climate action envisaged. It shows, for example, that almost any type of project requires some construction work (commodity code 45), machinery (commodity code 29) and other business services (commodity code 74). On the contrary, only a few actions, such as introducing biofuels in transport, require agricultural products (commodity code 1).

Figure 2. Cost structure by climate action (NACE classification)[8]



Source: Lehr et al. (2012, 2008), Allan et al.(2008), Markaki et al. (2013) and UNFCCC (2014b)

There is uncertainty regarding the cost structures defined for each climate action. The cost structure of renewable energy technologies depends on where and when the data on costs was gathered, due to differences in the costs of raw materials and labour, the different levels of commercial maturity of technologies, the evolution of global markets, etc. Adaptation projects or programmes are very heterogeneous, and the site-specific circumstances influence costs. The approach here proposed can be used to

[8] The description of commodity codes is detailed in Table 5 of the Appendix (Section 2.6).

undertake concrete case studies departing from data of particular projects, something that would enhance the accuracy of results. However, the ambition of this chapter is to extract general conclusions about the sharing of economic benefits of climate finance that are not evident at first glance.

Obtained cost structures are based on cost data that include taxes and trade margins. Since the WIOT are expressed at basic prices (i.e. the amount actually received by producers), trade and transport margins and taxes need to be reallocated. WIOD International Supply Tables contain the information required to calculate tax and margins rates for each recipient country[9] and commodity. The part of the expenditure corresponding to taxes is reallocated according to the government expenditure structure in each recipient country, which is calculated with information from the WIOD International Use Tables. The amount corresponding to trade margins (calculated with margins rates and the expenditure net of taxes) is reallocated according to the share of the total margins corresponding to each trade and transport service in each recipient country, which is calculated with information from the WIOD International Supply Tables.

Once the cost structures are expressed at basic prices, the next step is to differentiate where commodities are produced. Using the WIOD International Use Tables, we calculate for each recipient country and each commodity the portion of the total demand that is domestically produced, and the portion that is imported from all the other countries. Finally, we allocate the demands of each commodity and country to the WIOT industries according to the market shares calculated with the information of the International Supply Tables. The resulting demand shocks ($\mathbf{f}'^{st}$) contain additional final demands, at basic prices, to different sectors (in different countries) that each climate action entails in each recipient country.

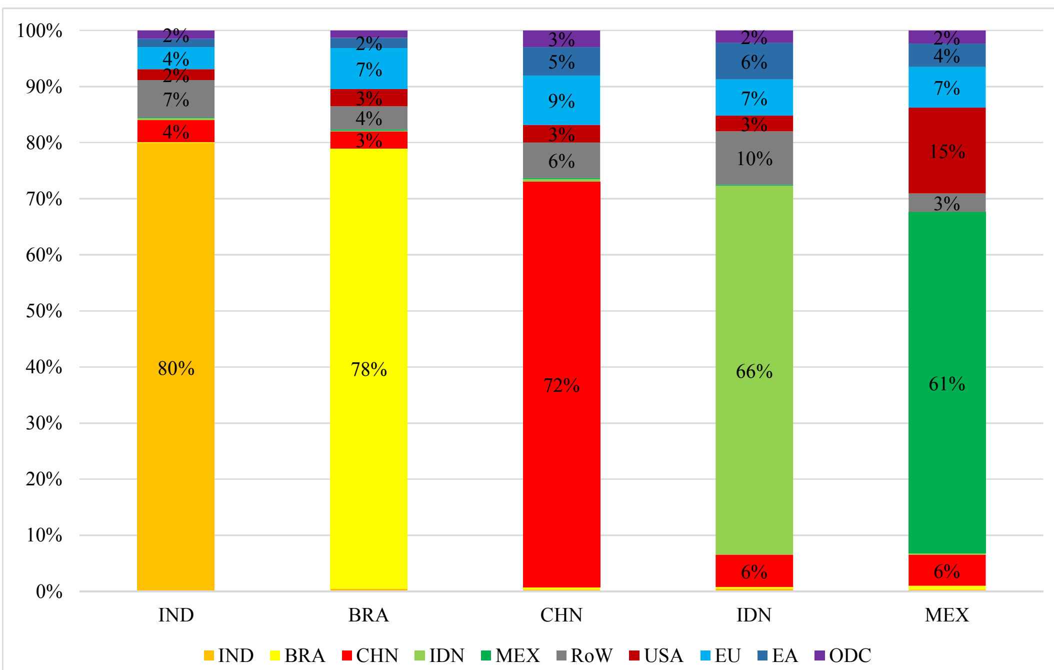
2.3.Results

Using this multiregional framework we obtain the amount of value-added generated by each country contributing (directly or indirectly) to the production of the goods and services needed for the climate actions. In this section, the research questions listed in the introduction are answered. Since impacts at the sector level are not the focus of this research, results are aggregated at country level.

2.3.1. Geographic distribution of the value-added impact

The first question is how the economic impacts caused by the implementation of climate actions are distributed between countries. **Figure 3** displays the geographic distribution of the value-added impact for the average of the 26 climate actions considered, depending on where climate finance is disbursed. For example, out of every USD 100 spent in climate actions in India, USD 80 remain in the Indian economy, China and the EU capture four dollars each, the USA and ODC capture two dollars each, EA countries capture one dollar and the remaining seven dollars go to the rest of the world (ROW).

Figure 3. Geographic distribution of the impact by recipient country



Source: Own work. Abbreviations: BRA (Brazil), CHN (China), EA (East Asia), EU (European Union), IDN (Indonesia), IND (India), MEX (Mexico), ODC (other developed countries), USA (United States of America).

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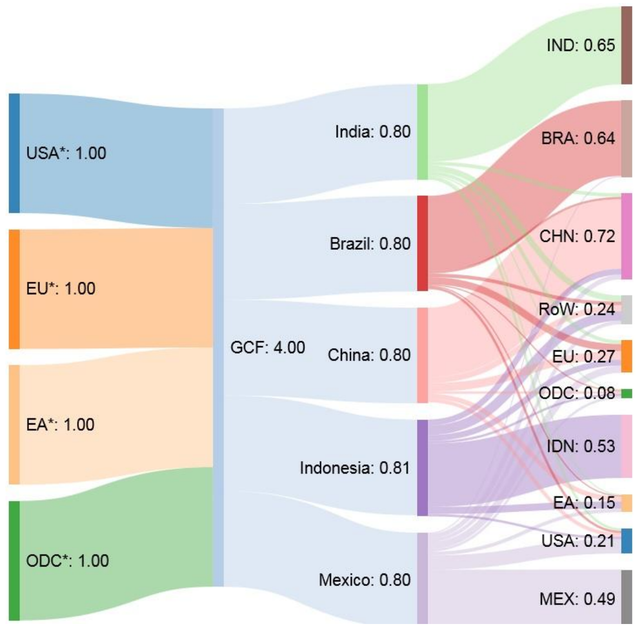
[9] Since this information is not available for two recipient countries (China and Indonesia), average values of the other recipient countries (Brazil, India and Mexico) are used instead.

On the one hand, the figure shows the differences in the ability of the economies of recipient countries to hold on to the value-added: in India and Brazil around 80% of the benefit remains within the domestic economy, but Mexico and Indonesia retain no more than two thirds. China is in an intermediate position among recipient countries, retaining 72% of the impact of its climate actions. On average, spill-overs account for 28.6% of the total impact.

On the other hand, the ability of the countries to attract spill-over effects also varies. The EU is the region that benefits most from international spill-overs in most cases. It captures 9% of the impacts generated when climate actions are implemented in China and 7% in the cases of Brazil, Indonesia and Mexico. It is also the donor that captures the highest share of spill-overs from India, where these are in any case very low for all donors. Note that the USA captures 15% of the impacts when climate actions are implemented in Mexico, but less than 3% from other recipient countries. EA captures 6% of the impacts generated by climate actions in China and 5% in the case of Indonesia. In fact, EA captures more spill-overs than the USA in these two countries. China also substantially benefits from spill-overs independently of the destination of climate finance. Spill-overs attracted by China are among the largest when climate finance goes to India, Brazil and Indonesia. For example, China attracts more spill-overs from India and Indonesia than the USA does, and a similar level of spill-overs from Brazil.

In order to clarify how impacts generated by climate finance are distributed among countries, we use the following example, illustrated in **Figure 4**: if each of the four donor countries (or group of countries) transferred one dollar to a hypothetical GCF and this four-dollars fund was equally distributed among the five recipient countries, each of the donors would recover the following amounts in the form of spill-overs: USD 0.27 for the EU, USD 0.21 for the USA, USD 0.15 for EA and USD 0.08 for ODC. The amounts obtained by recipient countries would be USD 0.72 for China, USD 0.65 for India, USD 0.64 for Brazil, USD 0.53 for Indonesia and USD 0.49 for Mexico.

Figure 4. Example of financial flows from donors to recipients



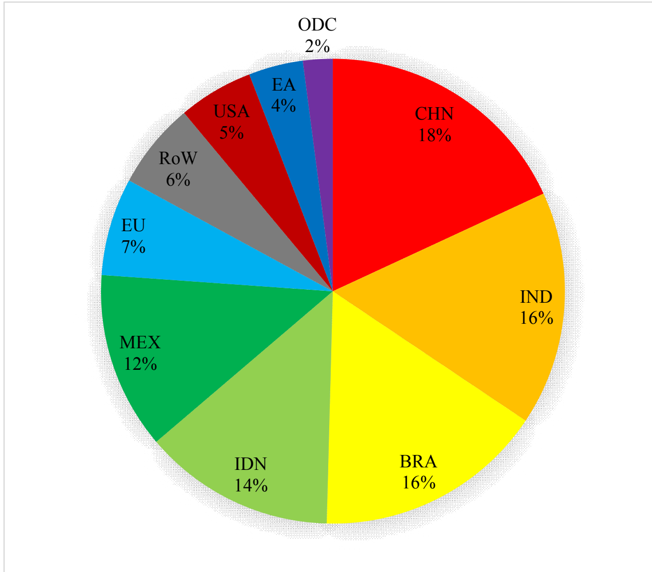
Source: Own work. Abbreviations: BRA (Brazil), CHN (China), EA (East Asia), EU (European Union), GCF (Green Climate Fund), IDN (Indonesia), IND (India), MEX (Mexico), ODC (other developed countries), USA (United States of America), ROW (rest of the world).

Figure 5 summarises the distribution of the value-added impacts of this hypothetical climate finance architecture. This example clearly shows that international trade redirects the value-added impacts from recipient countries to the countries that produce the inputs required for the deployment of climate actions.

2.3.2. Spill-overs by type of climate action

So far, average impacts across a wide range of climate actions have been presented. But the geographic distribution of value-added is different for each type of climate action: some of them mainly produce domestic impacts, whereas others generate a large proportion of spill-overs. **Figure 6** shows the spill-overs associated with each type of investment on average for the considered recipient countries.

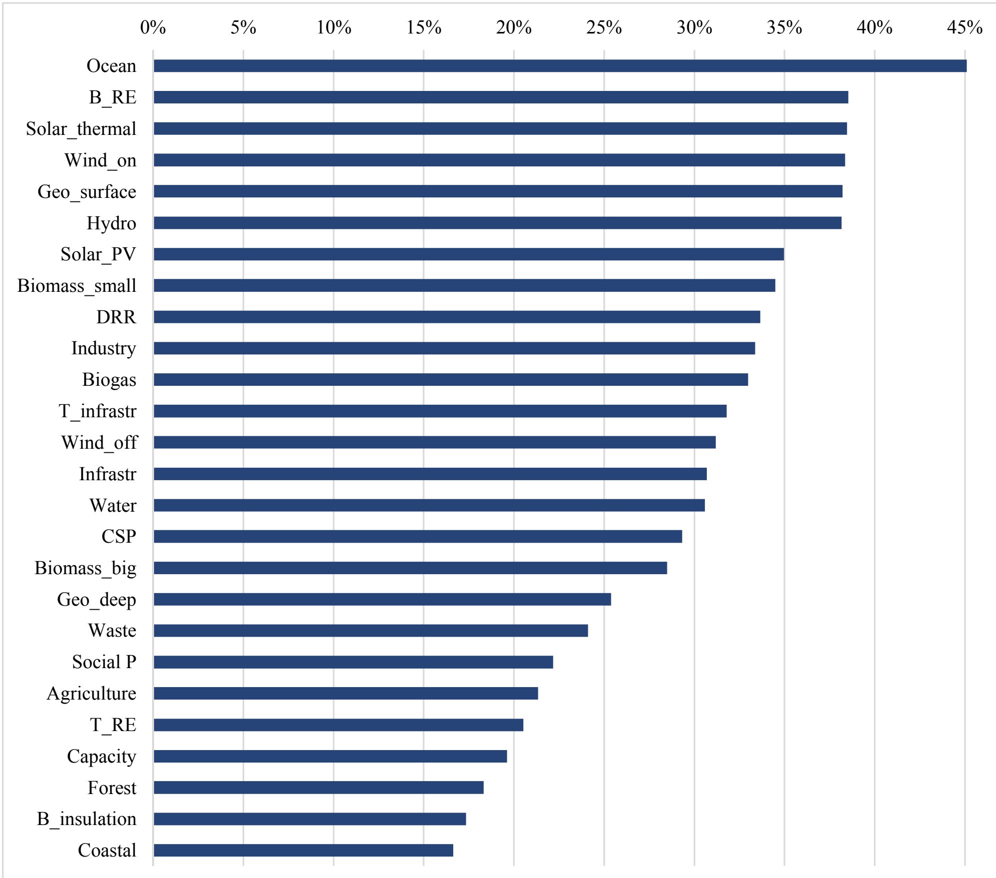
Figure 5. Distribution of the impact of a hypothetical climate fund



Source: Own work. Abbreviations: BRA (Brazil), CHN (China), EA (East Asia), EU (European Union), IDN (Indonesia), IND (India), MEX (Mexico), ODC (other developed countries), USA (United States of America).

For example, out of every USD 100 spent in ocean power plants, USD 45 (on average for our set of recipient countries) go to other countries different from the host country. Spill-overs range from 17% to 45%. Several actions related to renewable energy sources (ocean power, solar thermal power, onshore wind, geothermal surface, hydropower and the introduction of renewable energy in buildings) produce spill-overs in excess of 35%. The spill-overs from other renewable energy technologies (photovoltaics, small biomass, biogas and offshore wind), energy efficiency measures in industry, construction of infrastructures for transport and adaptation, disaster risk reduction actions and adaptation measures in the water sector range from 30% to 35%. The spill-overs from some renewable energy technologies (CSP, large biomass, deep geothermal and biofuels), adaptation measures (waste management and social protection) and M&A actions (agriculture and capacity building) range from 20% to 30%. Finally, spill-overs of less than 20% are generated in the forestry sector, insulation of buildings and protection of coasts.

Figure 6. Average spill-overs by type of climate action



Source: Own work. Abbreviations: Agriculture (agriculture, fishing and livestock), B_insulation (building insulation), B_RE (renewable energy in buildings), Biogas (biogas power), Biomass_big (biomass energy large scale), Biomass_small (biomass energy small scale), Capacity (capacity building), Coastal (coastal protection), CSP (concentrated solar power), DRR (disaster risk reduction), Forest (forestry and land use/ terrestrial ecosystems), Geo_deep (deep geothermal energy), Geo_surface (surface geothermal power), Hydro (hydropower), Industry (energy efficiency in industry), Infrastr (human settlements, infrastructure and spatial planning), Ocean (ocean power), Social P. (social protection), Solar PV (photovoltaics), Solar_thermal (solar thermal energy), T_infrastr (infrastructures for transport), T_RE (renewable energy in transport, biofuels), Waste (waste and wastewater), Water (water supply and management), Wind_off (offshore wind power), Wind_on (onshore wind power).

Table 3 presents for each type of action the portion of the impact that occurs in each country. Figures for recipient countries reflect the percentage of impact that each one holds on to from domestic climate actions. For example, out of every USD 100 spent in capacity building projects in China, USD 78 remain in the Chinese economy. Figures for donor countries reflect the percentage of impact that each donor country attracts on average from the recipient countries considered. For example, the USA captures on average four dollars out of every USD 100 spent in adaptation of the agriculture sector of the considered recipient countries. These figures do not add up to 100%, since spill-overs captured by countries other than donors are not included. Recall that a significant share of the impact of climate actions in different recipient countries ends up in China.

This table clearly illustrates that measures with larger impacts on the economies of recipients offer limited benefits for donor countries in terms of spill-over effects. Depending on the type of action, the average domestic share of the impact ranges from 57% to 84% (see column 6 in **Table 3**). Differences exist depending on the regions where actions are implemented. Brazil and India retain between 68% and 89% of the impact, while Mexico holds on to between 39% and 83%, depending on the type of action.

Average figures are included for broader categories of climate action (last four rows in **Table 3**). Depending on the recipient country, the domestic share of the impact of M&A actions is between 76% and 86%. Other adaptation measures and energy efficiency actions enable countries to hold on to between 64% and 82% of the impact. In the case of deployment of renewable energy sources recipient countries retain only between 53% and 77% of the impact.

According to our results, the climate actions with the highest impact for recipient countries are the following: forestry sector and capacity building actions in the case of M&A; coastal protection, social protection and waste management actions in the case of adaptation; building insulation in the case of energy efficiency; and the use of biofuels, deep geothermal, large biomass and CSP generation in the case of renewable energy.

Table 3. Portion of impact captured by each country by climate action[10]

	1	2	3	4	5	6	7	8	9	10	11
(percentage)	IND	BRA	CHN	IDN	MEX	**AVG Recipient**	EU	USA	EA	ODC	**AVG Donor**
Coastal (A)	86	88	80	83	82	84	4	3	2	1	2
B_insulation (EE)	82	89	81	81	83	83	3	3	2	2	2
Forest (M&A)	87	87	80	79	78	82	4	4	2	1	3
Capacity (M&A)	86	87	78	78	76	81	5	4	2	1	3
T_RE (RE)	89	84	83	77	68	80	4	4	2	1	3
Social P (A)	84	85	73	75	74	79	6	4	2	1	3
Agriculture (M&A)	85	84	78	76	74	79	5	4	2	1	3
Waste (A)	81	84	77	72	72	77	6	4	3	2	4
Geo_deep (RE)	81	83	76	67	71	76	5	4	3	2	4
Biomass_big (RE)	80	80	74	66	63	73	6	5	4	2	4
CSP (RE)	83	77	72	70	60	72	6	5	5	2	4
Water (A)	75	78	73	65	62	71	8	5	3	2	5
Infrastr (A)	80	78	70	65	60	70	8	5	4	2	5
Wind_off (RE)	81	77	71	65	57	70	7	6	4	3	5
T_infrastr (EE)	79	74	70	70	53	69	8	6	4	2	5
Biogas (RE)	80	76	71	58	57	68	7	6	4	2	5
Industry (EE)	79	76	72	60	53	68	8	6	4	2	5
DRR (A)	78	76	67	63	55	68	8	6	4	2	5
Biomass_small (RE)	75	77	68	56	59	67	7	5	5	3	5
Solar_PV (RE)	73	75	65	67	55	67	6	5	5	2	5
Hydro (RE)	80	71	68	54	44	63	9	7	5	2	6
Wind_on (RE)	79	71	65	57	45	63	8	7	5	3	6
Geo_surface (RE)	77	74	68	50	47	63	9	7	5	3	6
B_RE (RE)	79	69	68	57	42	63	9	7	6	2	6
Solar_thermal (RE)	70	73	66	54	52	63	9	6	5	3	6
Ocean (RE)	68	68	65	44	39	57	11	8	6	3	7
Average M&A	86	86	79	78	76	81	5	4	2	1	3
Average A	80	81	73	70	66	75	7	5	3	2	4
Average EE	82	81	77	72	64	73	6	5	3	2	4
Average RE	77	75	69	59	53	68	8	6	5	2	5

Source: Own work. Abbreviations: BRA (Brazil), CHN (China), EA (East Asia), EU (European Union), IDN (Indonesia), IND (India), MEX (Mexico), ODC (other developed countries), USA (United States of America), AVG (average), A (adaptation), Agriculture (agriculture, fishing and livestock), B_insulation (building insulation), B_RE (renewable energy in buildings), Biogas (biogas power), Biomass_big (biomass energy large scale), Biomass_small (biomass energy small scale), Capacity (capacity building), Coastal (coastal protection), CSP (concentrated solar power), DRR (disaster risk reduction), Forest (forestry and land use/ terrestrial ecosystems), EE (energy efficiency), Geo_deep (deep geothermal energy), Geo_surface (surface geothermal power), Hydro (hydropower), Industry (energy efficiency in industry), Infrastr (human settlements, infrastructure and spatial planning), M&A (mitigation and adaptation), ocean (ocean power), RE (renewable energy), Social P. (social protection), Solar PV (photovoltaics), Solar_thermal (solar thermal energy), T_infrastr (infrastructures for transport), T_RE (renewable energy in transport, biofuels), Waste (waste and wastewater), Water (water supply and management), Wind_off (offshore wind power), Wind_on (onshore wind power).

[10] Figures for recipient countries (columns 1-5) reflect the percentage of impact that is retained by each country when it receives climate finance. Figures for donor countries (columns 7-10) reflect the percentage of impact that each donor country attracts on average when climate finance is disbursed to the recipient countries considered. The colour scale reflects the attractiveness of each climate action for each country (from the point of view of its potential for creating domestic impacts in the case of recipient countries, and spill-overs in the case of donors). So, the colour scale ranks values column-wise. The most attractive options are in darker tones and the least attractive ones in lighter tones. The table is sorted by the value of column 6 (Average Recipient) in descending order.

Depending on the type of action, the average spill-overs that accrue to donor countries range from 2% to 7%, with substantial differences between donors (last column in **Table 3**). Hence, depending on the donor country, renewable energy investments may provide spill-overs of between 2% and 8%, energy efficiency measures and adaptation between 2% and 7% and M&A actions between 1% and 5% (last four rows in **Table 3**). From the point of view of donor countries, the types of climate actions that result in a significant portion of impacts taking place in their economies are the following ones: ocean, wind, solar and hydropower for renewable energy sources; those in the industry sector and transport infrastructures for energy efficiency projects; actions in the water sector, infrastructures and disaster risk reduction measures for adaptation; and actions in the agriculture sector for M&A.

Although there is a common pattern for all countries included on the same side of the climate finance transfer (i.e. recipients or donors) regarding the effects of each type of action, there are slight variations. For example, India experiences a larger impact than the average recipient country due to the introduction of biofuels and water supply and management investments. China also stands out because of the size of the local impact of biofuels and photovoltaics. The same occurs with donors. For instance the EU stands out because of the size of the spill-overs received from ocean power investments.

2.3.3. Spill-overs by disbursement option

In the previous section, spill-overs were given as average, and did not enable to distinguish differences caused by the location where actions are implemented. The size of spill-overs captured by a donor country depends not only on the type of climate action, but also on the recipient country where it is undertaken. **Table 4** gathers the results relative to the portion of spill-overs that each donor country can expect from climate-related expenditures in the different recipient countries. This table could help to rank climate finance disbursement alternatives according to potential of generating value-added spill-overs for each donor country.

Table 4. Impact captured by donor country, location and climate action[11]

(percentage)	USA					EU					EA					ODC				
	IND	BRA	CHN	IDN	MEX	IND	BRA	CHN	IDN	MEX	IND	BRA	CHN	IDN	MEX	IND	BRA	CHN	IDN	MEX
Ocean	3	5	3	5	24	7	11	13	12	13	2	3	6	11	6	2	2	4	4	4
Geo_surface	2	4	3	4	22	5	9	11	10	11	2	2	6	11	5	2	2	4	3	3
B_RE	2	4	3	4	22	4	10	11	9	11	2	4	7	9	7	1	1	3	3	3
Hydro	2	4	3	4	21	4	9	11	9	11	2	3	7	9	6	1	1	3	3	3
Wind_on	2	5	4	4	19	4	9	11	7	10	2	3	7	9	6	2	2	4	3	4
Solar_thermal	2	4	3	4	18	6	9	12	9	10	2	2	6	9	5	2	2	4	3	3
Industry	2	3	3	3	19	4	9	9	8	9	2	2	5	8	5	2	1	3	3	3
T_infrastr	2	4	3	2	21	4	10	11	5	8	2	3	5	6	7	2	1	3	2	3
DRR	3	4	4	3	15	5	9	11	8	8	2	2	7	6	5	1	1	3	2	2
Biomass_small	2	3	3	3	15	5	7	10	7	7	2	2	5	10	4	2	2	5	3	3
Biogas	2	3	3	3	17	4	8	10	8	8	2	2	5	8	5	1	1	3	3	2
Infrastr	2	3	3	3	15	4	8	10	8	8	1	2	6	6	4	2	1	3	2	2
Wind_off	2	4	3	3	16	4	8	9	5	8	2	2	5	7	4	2	2	4	2	3
Solar_PV	2	3	4	2	14	5	6	10	5	6	2	3	7	6	6	2	2	4	2	2
Water	2	3	3	3	16	5	8	10	8	8	2	1	4	6	3	2	1	2	2	2
Biomass_big	2	3	3	2	14	4	7	7	6	7	1	2	5	7	4	2	1	3	2	2
CSP	2	3	3	2	14	3	7	8	4	6	1	3	6	6	6	1	1	3	2	2
Waste	2	2	3	2	12	4	6	7	6	6	1	1	4	5	2	2	1	3	2	2
Geo_deep	2	2	3	2	12	3	6	7	5	5	1	1	4	6	3	2	1	3	2	2
Social P	2	2	4	2	11	3	6	9	5	6	1	1	4	4	2	1	1	2	2	1
Agriculture	2	2	3	2	11	3	6	7	5	5	1	1	4	4	2	1	1	2	2	2
Capacity	2	2	4	2	12	3	5	7	4	5	1	1	3	4	2	1	1	2	2	1
T_RE	1	2	2	2	15	2	5	5	4	5	1	1	2	4	2	1	1	2	2	2
Forest	2	2	3	2	10	2	4	6	4	4	1	1	3	4	2	1	1	2	2	1
Coastal	1	2	2	1	7	3	5	5	3	3	1	1	4	2	2	1	1	2	1	1
B_insulation	1	1	2	1	7	3	4	4	3	3	1	1	3	3	2	2	1	3	2	1

Source: Own work. Abbreviations: BRA (Brazil), CHN (China), EA (East Asia), EU (European Union), IDN (Indonesia), IND (India), MEX (Mexico), ODC (other developed countries), USA (United States of America), AVG (average), Agriculture (agriculture, fishing and livestock), B_insulation (insulation of buildings), B_RE (renewable energy in buildings), Capacity B. (capacity building), Coastal (coastal protection), CSP (concentrated solar power), DRR (disaster risk reduction), Forestry (forestry and land use/ Terrestrial Ecosystems), Geo_deep (geothermal deep), Geo_surface (geothermal surface), Hydro (hydropower), Infrastr (human settlements), infrastructure and spatial planning), Ocean (ocean power), Social P. (social protection), Solar PV (photovoltaics), T_infrastr (transport infrastructure), T_RE (renewable energy in transport), Waste (waste and wastewater), Water (water supply and management), Wind_off (offshore wind), Wind_on (onshore wind).

[11] The colour scale reflects the attractiveness of each climate action for each donor country (from the point of view of its potential for creating spill-overs). So, the colour scale ranks the values referred to one donor (including different climate actions in different locations). The most attractive options are in darker tones and the least attractive ones in lighter tones.

The USA benefits especially from climate projects in Mexico, regardless of their type, as it captures between 7% (coastal protection) and 24% (ocean energy) of the total impact in the form of spill-overs. Other investment options that offer good returns to the USA are ocean energy projects in Brazil and Indonesia and onshore wind projects in Brazil (5% each). China is the country that generates the largest spill-overs for the EU and ODC. The action that offers the largest spill-overs for the EU is ocean power in China and in Mexico (13%). Indonesia, Mexico and Brazil offer spill-overs of 7% on average for the EU. ODC's best options are small biomass projects in China (5%), ocean power and onshore wind in Mexico (4%) and ocean power in Indonesia (4%). EA benefits especially from ocean energy and surface geothermal investments in Indonesia (11%), but also from several types of projects in China and Mexico (7%).

Several combinations of location/type of action have a very limited potential to generate spill-overs for donors. Cases with average spill-overs below 2% include most climate actions in India, several in Brazil (social protection, renewable energy in transport, capacity building and forest adaptation, building insulation and coastal protection), and building insulation and coastal protection in Indonesia[12].

2.4. Discussion

We have shown that the stimulus generated by climate-related expenditures is shared out between the recipient country and other economies, including donor countries, due to international trade. This fact might be taken into account by both donors and recipients when making decisions about climate finance allocation.

From the point of view of a potential donor, as long as its ability to capture spill-overs is substantial, contributing to climate finance might be a way to stimulate exports and growth. Since the size of potential benefits differs from one donor to another, as results on spill-overs show, the influence of this factor on climate finance decisions might also vary.

Even though spill-overs might currently be only receiving marginal attention from the donors, it is remarkable that those donors benefitting from significant spill-

[12] See original contribution in Román et al. (2016a)

overs are also major contributors to climate funds (i.e. UK, USA, Germany and Japan). The great ability of China to capture spill-overs may also be somehow related to the prominence of China as donor in South-to-South cooperation. In fact, China does not hide that it sees foreign aid as a way to expand exports (Minas, 2014; The Climate Group, 2013).

Our results indicate the potential of each type of action and alternative location for generating spill-over effects via demand for donors' industries products. The group of measures that produce the largest spill-overs includes several mitigation and adaptation options requiring goods with high technology content that are not usually domestically produced in many recipient countries, such as machinery (commodity code 29), electrical, communication and precision equipment (commodities code 31-33) and motor vehicles (commodity code 34).

So far, investments in the energy sector have been a priority in the use of climate finance (UNFCCC, 2014a). According to our results, this may have produced substantial spill-overs for donors. Agriculture and water, the main sectors receiving finance for adaptation, are also associated with the generation of substantial spill-overs due to the requirements of machinery (commodity code 29) and research and development services (commodity code 73) (see **Figure 2**). Asia and the Pacific region (including two recipients that generate large spill-overs, such as China and Indonesia) are the main recipients of past climate finance. This would suggest that the search for spill-overs has been one of the factors determining the international allocation of climate finance. However, a significant proportion of funds has been used for mitigation in the forestry sector in Latin America, a fact that would not be consistent with the prospects of spill-over effects.

On the other hand, projects that are most able to stimulate recipient countries' economies are those intensive in locally produced services like construction work (commodity code 45) and other business services (commodity code 74), as it is the case for many adaptation options. Allocating the same priority to support for adaptation as to mitigation has recently become a core element rather than a peripheral issue in the United Nations' climate talks, especially due to developing countries' demands (Galarraga and Román, 2015, 2013; GCF, 2014). This position in favour of increased support for adaptation by developing countries would make sense from the perspective of trying to increase the local impact of climate finance disbursements.

To sum up, the donor's bias towards funding renewable energy projects and the developing countries' demand for more funding for adaptation would be consistent with the economic interests of each group of countries, in the light of our results. Results also provide insights about an additional aspect that should be borne in mind when assessing alternative investment options from the point of view of both donors and recipients.

Our results reinforce the idea that the impacts of climate finance are best assessed on a global scale, and demonstrate the potential of GMRIO databases as tools for analysing economy-wide impacts of climate finance. However, the already mentioned shortcomings of the IO method apply here too. Also recall that our assessment only considers the positive short-term effects associated with new expenditures, but it does not account for other impacts on the medium/long term associated with potential displaced expenditures, changes in prices or income.

There are several ways to extend the present research: first, by broadening the scope of analysis to include additional countries. Our analysis only considers five major recipient countries. This might lead to an underestimation of the size of spill-over effects, since it has already been argued that small countries generate more spill-overs (see, for example, Dietzenbacher et al., 2012).

This connects with a second possible extension of our research: identifying factors that can explain the results. Despite the fact that all recipient countries considered are big economies, **Table 3** shows differences in the ability of these countries to retain the impacts of similar types of investment. Apart from size, Dietzenbacher et al. (2012) point to the openness of economies to explain the size of spill-overs. The small spill-overs generated by Brazil could thus be a consequence of the big size of its economy and the low dependency on imports (ibid). Beutel (2002) points to two additional factors: development level and competitiveness. In fact, competitiveness might provide an explanation of results for Mexico: despite the big size of the Mexican economy, its weaker competitive position in relation to the USA economy could explain the size of the spill-overs between the two countries.

Competitiveness might also help us understand why EU countries and the USA, among the donors, and China, among the recipients, are where most relevant spill-overs occur[13]. Other factors that could be included in the study of the determinants of the magnitude of spill-overs are the productive specialization and the geographic location.

As previously explained, value-added includes labour remuneration and capital compensation. Thus, one part of the impact accrues to workers and the rest to owners of capital. According to Timmer et al. (2014), from 1995 to 2008 the capital share of value-added has increased globally, but especially in emerging countries such as China, India, Brazil and Mexico. Given the sizeable foreign investment flows, it can be imagined that a significant part of the domestic impact of climate actions in emerging regions is in the form of revenues of multinational companies, whose headquarters are in the most economically advanced regions. Our results do not enable to observe these kind of spill-overs. So, a third possible extension of this chapter would consist in separating labour and capital impacts and, within the latter, differentiating the part corresponding to foreign capital.

2.5.Conclusions

Studies assessing the economic impacts of climate-related expenditures at the national level have noted the relevant role of international trade. For instance, Lehr et al. (2008) conclude that if low-carbon technologies create employment in Germany, this is due to exports. Other studies also show that the ability to retain economic gains depends on the share of components that can be domestically manufactured (Ciorba et al., 2004; Markaki et al., 2013; Oliveira et al., 2013). These previous findings point to the relative position of economies in international markets as a factor determining the economic gains from climate investments.

Our results confirm that international trade has an important role in the distribution of the economic benefits of climate finance. While the largest portion of the value-added generated by climate actions is domestic (71% on average), a significant

[13] Six European countries, the USA and Japan were in the top-ten global competitiveness ranking 2011-2012. China occupies the highest position amongst the BRICS, and Mexico is on the 58th place out of 144 in the global ranking (Schwab, 2011).

share (29% on average) spills over to other economies. Spill-overs accruing to the group of donor countries range from 10% to 28%, depending on the recipient country.

The magnitude of the spill-overs varies with the nature of the project. Deployment of renewable energy technologies generates large spill-over effects, while M&A actions produce substantial domestic impact and limited spill-overs. The type of actions that offer recipient countries the best opportunities to grow do not coincide with those that benefit donor countries the most, with substantial spill-overs. Nevertheless, there are some mitigation and adaptation options that involve substantial benefits in terms of value-added in both donor and recipient countries (i.e. renewable energy sources like CSP and offshore wind, infrastructures for transport and adaptation, and water supply and management projects).

While renewable energy deployment is the type of intervention with better return in terms of spill-overs for all donors, some differences have been identified. The USA benefits from substantial spill-overs from any type of climate project that is implemented in Mexico. Largest spill-overs to the EU come from renewable energy projects implemented in China and Mexico. ODC similarly benefit from renewable energy investments in China, Mexico and Indonesia, while EA benefits especially from renewable energy in Indonesia.

Several climate actions have been identified to be unlikely to find funding opportunities if donors made their decisions exclusively based on the prospects of capturing value-added impacts. This is the case of coastal protection in Indonesia, where two million people are exposed to rising sea level (IPCC, 2001b). For that reason, the international community should implement mechanisms to ensure that sufficient climate financial flows reach the most vulnerable regions.

Taking into account that the Long-term Finance commitments of higher-income countries under the United Nations' climate talks entail reaching USD 100 billion per year by 2020[14], spill-over effects may add up to several billion USD per year. Thus, our results constitute valuable information for governments to help them

[14] This amount is similar to the level of total net official development assistance and official aid received in 2005: USD 108.45 billion (The World Bank, 2016).

understand the economic consequences of decisions about climate finance allocation. For example, our results suggest that correcting the current bias towards mitigation in climate finance flows would not only enhance developing countries' climate resilience, but also it would contribute to their economic growth.

Finally, our results also suggest that some recipient countries have significant room for manoeuvre for improving their ability to retain the value-added generated by capital-intensive projects, such as those involving renewable energy technologies. Such projects require machinery, transportation and communication equipment, and mineral and metal inputs that must typically be brought from abroad. Thus, in order to maximise the domestic impact of climate finance, recipient countries could pursue strategies aimed at improving the competitiveness of their industrial sectors. Technology transfer programmes may also enhance the ability of these countries to decrease their dependency on imports of capital goods that generate relevant spill-overs. As long as such programmes help to build up competitive industries that can provide substitutes for the imported goods, the domestic impact of climate finance may multiply.

2.6. Appendix

Table 5. NACE classification of commodities

Code	Description
1	Products of agriculture, hunting and related services
2	Products of forestry, logging and related services
5	Fish and other fishing products; services incidental of fishing
10	Coal and lignite; peat
11	Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying
12	Uranium and thorium ores
13	Metal ores
14	Other mining and quarrying products
15	Food products and beverages
16	Tobacco products
17	Textiles
18	Wearing apparel; furs
19	Leather and leather products
20	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials
21	Pulp, paper and paper products
22	Printed matter and recorded media
23	Coke, refined petroleum products and nuclear fuels
24	Chemicals, chemical products and man-made fibres
25	Rubber and plastic products
26	Other non-metallic mineral products
27	Basic metals
28	Fabricated metal products, except machinery and equipment
29	Machinery and equipment not elsewhere classified (n.e.c.)
30	Office machinery and computers
31	Electrical machinery and apparatus n.e.c.
32	Radio, television and communication equipment and apparatus
33	Medical, precision and optical instruments, watches and clocks
34	Motor vehicles, trailers and semi-trailers
35	Other transport equipment
36	Furniture; other manufactured goods n.e.c.
37	Secondary raw materials
40	Electrical energy, gas, steam and hot water
41	Collected and purified water, distribution services of water
45	Construction work
50	Trade, maintenance and repair services of motor vehicles and motorcycles; retail sale of automotive fuel
51	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
52	Retail trade services, except for motor vehicles and motorcycles; repair services of personal and household goods
55	Hotel and restaurant services
60	Land transport; transport via pipeline services
61	Water transport services
62	Air transport services
63	Supporting and auxiliary transport services; travel agency services
64	Post and telecommunication services
65	Financial intermediation services, except insurance and pension funding services
66	Insurance and pension funding services, except compulsory social security services
67	Services auxiliary to financial intermediation
70	Real estate services
71	Renting services of machinery and equipment without operator and of personal and household goods
72	Computer and related services

Table 5. NACE classification of commodities (cont.)

Code	Description
73	Research and development services
74	Other business services
75	Public administration and defence services; compulsory social security services
80	Education services
85	Health and social work services
90	Sewage and refuse disposal services, sanitation and similar services
91	Membership organisation services n.e.c.
92	Recreational, cultural and sporting services
93	Other services
95	Private households with employed persons

3. Spatial decomposition analysis of the economic benefits of climate finance

3.1. 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. The Copenhagen Accord (UNFCCC, 2009) acknowledges that supporting developing countries' efforts to reduce emissions and adapt to the impacts of climate change will be essential to any new climate deal. The Paris Agreement (UNFCCC, 2015) confirms the commitment by developed countries to transfer USD 100 billion to developing countries from 2020 on and stipulates that, for the period after the year 2025, a more ambitious goal will be set.

As climate finance has started to flow, a growing body of literature seeks to understand the role and the effectiveness of international climate funds in enabling a climate compatible development. Climate finance literature encompasses different aspects, covering climate finance architecture (Buchner et al., 2015; Schalatek et al., 2015), the estimation of climate finance needs (UNEP, 2014a, 2014b), the assessment of climate finance effectiveness (Chaum et al., 2011; Urpelainen, 2012a; Vandeweerd et al., 2012), the compatibility of climate finance with countries' interests (Buob and Stephan, 2013; Heuson et al., 2012; Schenker and Stephan, 2014), the role of climate finance in international agreements on climate change (Barrett, 2009; Barrett and Stavins, 2003; de Zeeuw, 2015; Pittel and Rübbelke, 2013; Rübbelke, 2011) or the assessment of different options for climate finance mobilisation and disbursement (Hof et al., 2011; Urpelainen, 2012b).

The present chapter 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. Value-added creation, which reflects the remuneration of primary production factors (i.e. labour and capital), can be used 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 spill-over effect resulting from international trade[15].

The geographic distribution of value-added creation differs depending on where climate finance is disbursed. In Chapter 2, we quantified the domestic impact and spill-overs of different types of climate actions for different countries. The present chapter supplements this previous research by explaining the observed differences between countries' ability to capture economic impacts. In order to do this, we apply a technique based on IO tables, i.e. the SDA, that has extensively been used in climate change literature to quantify the contribution of different factors to the growth in GHG emissions, and to assess the outsourcing of emissions phenomenon and carbon footprints (as Lenzen, 2016 explains), but that, to the best of our knowledge, 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 in both donors and recipients by climate finance disbursements. Our specific research questions are the following: (1) What is the contribution of each of these factors to the differences observed between countries? (2) What factors and industries offer the highest potential for increasing the economic impact of climate finance in each country?

The rest of the chapter is structured as follows: Section 3.2 describes the methodology; Section 3.3 contains the results at both aggregated and sectoral levels; Section 3.4 discusses the main outcomes and contains some conclusions.

3.2.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 GMRIO framework. This technique is normally used to decompose changes in a variable over

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

time. For example, Xu and Dietzenbacher (2014) and Arto and Dietzenbacher (2014) used this method to identify the factors driving the change in GHG 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.

The main data source for our analysis is the WIOD for the year 2011 (Timmer et al., 2012)[16]. We consider as climate finance recipient countries the five developing countries for which data are available in the WIOD: India, Brazil, China, Indonesia and Mexico[17]. We include Germany, UK, Japan and USA as donors, since these are the most important donors for which data are available in the WIOD (Climate Funds Update, 2016)[18]. 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.

Demand shocks are defined for different types of climate actions as a specific distribution of the budget between the different industries in the economy (or cost structure). 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., 2012, 2008), 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 9** in the Appendix (Section 3.5.2) contains all the adaptation measures considered and the sources of information used, which are specific

[16] For a detailed description of the WIOD project, the WIOT and main weaknesses see also Dietzenbacher et al. (2013b) and Timmer et al. (2015).

[17] Note that China appears here only as recipient, but it is also an important donor in South-to-South cooperation (Buchner et al., 2015; Zadek and Flynn, 2013).

[18] Another relevant contributor to climate finance is Norway, but it is not included in the WIOD. Analysed donors together represent 62% of the climate finance pledged as for October 2016 (Climate Funds Update, 2016).

Priority Project Profile documents from NAPA (UNFCCC, 2014b) [19]. The cost structure for hard and soft adaptation is the average cost structure of the selected projects.

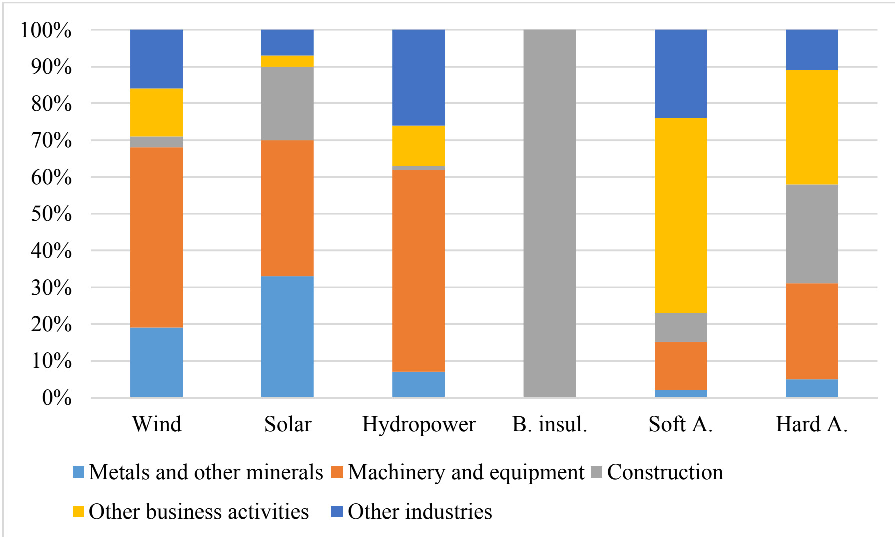
Since some sources of information report budget allocations in terms of commodities, the correspondence reported in **Table 10** of the Appendix (Section 3.5.2) is used to express cost structures in terms of industries. We use the same classification as the WIOD (CPA-NACE) in order to connect this information with the GMRIO framework[20]. **Figure 7** illustrates the distribution of the expense in each type of climate action between the different industries.

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 $t_j^{st} = \frac{f_j^{st}}{\sum_s f_j^{st}}$.

[19] 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, p. 21).

[20] CPA is the statistical classification of products by activity, and each CPA product is related to activities defined by the NACE.

Figure 7. Distribution to industries of expenses by climate action



Source: Own work based on Lehr et al. (2012, 2008), Markaki et al. (2013) and UNFCCC (2014b). Notes: Metals and other minerals includes industries c11 and c12; Machinery and equipment includes industries c13, c14 and c15; Construction corresponds to industry c18; Other business activities corresponds to industry c30; Other industries includes industries c1, c2, c7, c8, c9, c10, c17, c20, c23, c26, c27, c28, c29, c31, c33 and c34. See **Table 10** for the explanation of the codes. Abbreviations: B. insul. means building insulation; Soft A. and Hard A. mean soft and hard adaptation.

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

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

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 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 spill-over 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:

$$\Delta \mathrm{w}^{ta} = \sum_s \mathbf{v}^B{}'\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^a - \sum_s \mathbf{v}^C{}'\mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^a \qquad \textbf{(2)}$$

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

$$\Delta \mathrm{w}^{a} = \sum_s \mathbf{v}^B{}'\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^a - \sum_s \mathbf{v}^C{}'\mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^a \qquad \textbf{(3)}$$

$$\Delta \mathrm{w}^{ta} = \sum_s \mathbf{v}^B{}'\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^a - \sum_s \mathbf{v}^C{}'\mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^a \qquad t \neq B,C \qquad \textbf{(4)}$$

We can operate in Equation 3 and Equation 4 in order to decompose the differences in the value-added as the sum of a series of factors[21]. For instance, for the case of recipients, and following Dietzenbacher and Los (1998), Equation 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

$$\Delta w_1^a = \sum_s (\Delta \mathbf{v}')\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^a + \sum_s \mathbf{v}^C{}'(\Delta \mathbf{L}^{\cdot s})\mathbf{t}^{sB} \otimes \mathbf{e}^a + \sum_s \mathbf{v}^C{}'\mathbf{L}^{Cs}(\Delta \mathbf{t}^{s\cdot}) \otimes \mathbf{e}^a \qquad \textbf{(5)}$$

$$\Delta w_2^a = \sum_s (\Delta \mathbf{v}')\mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^a + \sum_s \mathbf{v}^B{}'(\Delta \mathbf{L}^{\cdot s})\mathbf{t}^{sC} \otimes \mathbf{e}^a + \sum_s \mathbf{v}^B{}'\mathbf{L}^{Bs}(\Delta \mathbf{t}^{s\cdot}) \otimes \mathbf{e}^a \qquad \textbf{(6)}$$

And

$$(\Delta \mathbf{v}') = \left(\mathbf{v}^B{}' - \mathbf{v}^C{}'\right) \qquad \textbf{(7)}$$

$$(\Delta \mathbf{L}^{\cdot s}) = (\mathbf{L}^{BB} - \mathbf{L}^{CC}) + (\mathbf{L}^{BC} - \mathbf{L}^{CB}) + \sum_{\mathrm{s \neq B, s \neq C}} (\mathbf{L}^{Bs} - \mathbf{L}^{Cs}) \qquad \textbf{(8)}$$

[21] For the sake of simplicity we just show the differences in recipient countries; the procedure to compare donor countries is very similar (see Appendix in Section 3.5.1).

$$\Delta \mathbf{t}^{s\bullet} = \left(\mathbf{t}^{BB} - \mathbf{t}^{CC}\right) + \left(\mathbf{t}^{CB} - \mathbf{t}^{BC}\right) + \sum_{\mathrm{s \neq B, s \neq C}} (\mathbf{t}^{sB} - \mathbf{t}^{sC}) \tag{9}$$

Thus, the average of the polar decomposition is

$$\begin{aligned}\Delta w^a &= \frac{1}{2}\sum_s \Delta \mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^a + \mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^a\right) + \frac{1}{2}\sum_s \mathbf{v}^C{}' \Delta \mathbf{L}^{\bullet s}\mathbf{t}^{sB} \otimes \mathbf{e}^a \\ &+ \frac{1}{2}\sum_s \mathbf{v}^B{}' \Delta \mathbf{L}^{\bullet s}\mathbf{t}^{sC} \otimes \mathbf{e}^a + \frac{1}{2}\sum_s \left(\mathbf{v}^C{}'\mathbf{L}^{Cs} + \mathbf{v}^B{}'\mathbf{L}^{Bs}\right)\Delta \mathbf{t}^{s\bullet} \otimes \mathbf{e}^a\end{aligned} \tag{10}$$

The second and third terms of Equation 10 can be further decomposed. The resulting expression is

$$\begin{aligned}\Delta w^a &= \frac{1}{2}\sum_s \Delta \mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^a + \mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^a\right) \\ &+ \frac{1}{2}\mathbf{v}^B{}'\left(\mathbf{L}^{BB} - \mathbf{L}^{CC}\right)\mathbf{t}^{CC} \otimes \mathbf{e}^a + \frac{1}{2}\mathbf{v}^C{}'\left(\mathbf{L}^{BB} - \mathbf{L}^{CC}\right)\mathbf{t}^{BB} \otimes \mathbf{e}^a \\ &+ \frac{1}{2}\mathbf{v}^B{}'\left(\mathbf{L}^{BC} - \mathbf{L}^{CB}\right)\mathbf{t}^{CC} \otimes \mathbf{e}^a + \frac{1}{2}\mathbf{v}^C{}'\left(\mathbf{L}^{BC} - \mathbf{L}^{CB}\right)\mathbf{t}^{BB} \otimes \mathbf{e}^a \\ &+ \frac{1}{2}\sum_{s \neq B,C} \mathbf{v}^B{}'\left(\mathbf{L}^{Bs} - \mathbf{L}^{Cs}\right)\mathbf{t}^{sC} \otimes \mathbf{e}^a + \frac{1}{2}\sum_{s \neq B,C} \mathbf{v}^C{}'\left(\mathbf{L}^{Bs} - \mathbf{L}^{Cs}\right)\mathbf{t}^{sB} \otimes \mathbf{e}^a \\ &+ \frac{1}{2}\sum_s \left(\mathbf{v}^C{}'\mathbf{L}^{Cs} + \mathbf{v}^B{}'\mathbf{L}^{Bs}\right)\Delta \mathbf{t}^{s\bullet} \otimes \mathbf{e}^a\end{aligned} \tag{11}$$

Equation 11 decomposes the difference in the value-added generated in donor countries as the sum of series factors, which can be aggregated into four:

$$\mathrm{VAiE} \equiv \frac{1}{2}\sum_s \Delta \mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{sB} \otimes \mathbf{e}^a + \mathbf{L}^{Cs}\mathbf{t}^{sC} \otimes \mathbf{e}^a\right) \tag{12}$$

$$\mathrm{DME} \equiv \frac{1}{2}\mathbf{v}^B{}'\left(\mathbf{L}^{BB} - \mathbf{L}^{CC}\right)\mathbf{t}^{CC} \otimes \mathbf{e}^a + \frac{1}{2}\mathbf{v}^C{}'\left(\mathbf{L}^{BB} - \mathbf{L}^{CC}\right)\mathbf{t}^{BB} \otimes \mathbf{e}^a \tag{13}$$

$$\begin{aligned}\mathrm{FME} &\equiv \frac{1}{2}\mathbf{v}^B{}'\left(\mathbf{L}^{BC} - \mathbf{L}^{CB}\right)\mathbf{t}^{CC} \otimes \mathbf{e}^a + \frac{1}{2}\mathbf{v}^C{}'\left(\mathbf{L}^{BC} - \mathbf{L}^{CB}\right)\mathbf{t}^{BB} \otimes \mathbf{e}^a \\ &+ \frac{1}{2}\sum_{s \neq B,C} \mathbf{v}^B{}'\left(\mathbf{L}^{Bs} - \mathbf{L}^{Cs}\right)\mathbf{t}^{sC} \otimes \mathbf{e}^a + \frac{1}{2}\sum_{s \neq B,C} \mathbf{v}^C{}'\left(\mathbf{L}^{Bs} - \mathbf{L}^{Cs}\right)\mathbf{t}^{sB} \otimes \mathbf{e}^a\end{aligned} \tag{14}$$

$$\mathrm{TSE} \equiv \frac{1}{2}\sum_s \left(\mathbf{v}^C{}'\mathbf{L}^{Cs} + \mathbf{v}^B{}'\mathbf{L}^{Bs}\right)\Delta \mathbf{t}^{s\bullet} \otimes \mathbf{e}^a \tag{15}$$

- 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 by other countries is bigger (smaller) than the amount of production generated in C per unit of goods/services produced by 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 final products on the recipient countries' markets.

3.3. 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 spill-over effects (see Chapter 2). However, since the volume of spill-overs varies widely depending on the country receiving climate finance, results distinguish between the destinations of climate finance[22].

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 spill-overs, the benchmark varies depending on the country receiving climate finance. **Table 6** 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[23].

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

[22] 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.

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.

Table 6. Local impact, spill-overs and benchmark countries[24]

Percentage of locally retained impact					
Climate action	BRA	CHN	IDN	IND	MEX
Wind	70	68	59	72	44
Solar	73	71	55	70	52
Hydropower	71	71	49	72	42
B. insul.	91	82	81	83	82
Soft A.	87	79	76	85	76
Hard A.	82	77	70	79	67
Percentage of impact attracted by non-recipient countries					
Recipient country	CHN	DEU	UK	JPN	USA
BRA	6	3	1	1	4
CHN	-	3	1	4	4
IDN	9	3	1	6	4
IND	7	2	1	2	4
MEX	9	3	1	3	20

Source: Own work. Abbreviations: BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico), DEU (Germany), UK (United Kingdom), JPN (Japan), USA (United States of America), B. insul. (building insulation), Soft A. (soft adaptation), Hard A. (hard adaptation).

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.

[23] 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.

[24] Benchmark countries are indicated in grey.

3.3.1. Aggregated Results

In this section, the results for each climate finance recipient country are shown first, followed by results for each donor country. **Figure 8** and **Figure 9** illustrate the results for recipient and donor countries.

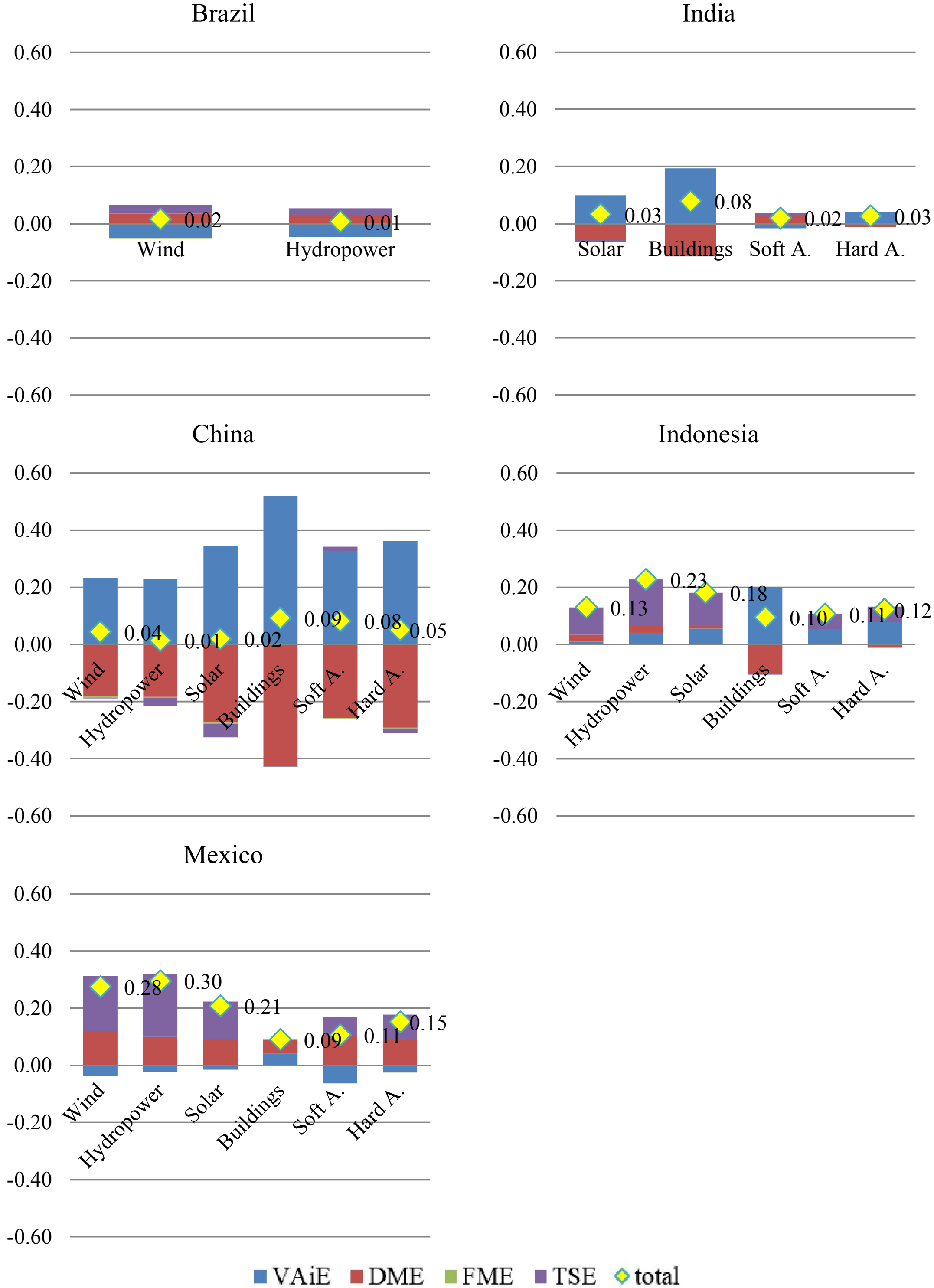
To explain the content of **Figure 8** we continue with the previous example: the USD 28 of difference between the domestic impact in India and Mexico is because the trade structure generates USD 19 more in India than in Mexico, the domestic multiplier generates USD 12 more in India than in Mexico and the value-added intensity generates three dollars more in Mexico than in India.

Brazil 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 DME and the TSE. Counteracting these two factors is the VAiE.

India 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 VAiE contributes to the difference while the DME acts in the opposite direction.

China 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 effects: a positive VAiE (that surpasses 20 pp) and a negative DME effect (almost of the same magnitude).

Figure 8. Results by recipient country and climate action



Source: Own work. Abbreviations: VAiE (value-added intensity effect), DME (domestic multiplier effect), FME (foreign multiplier effect), TSE (trade structure effect), B. insul (building insulation), Soft A. (soft adaptation), Hard A. (hard adaptation).

Indonesia 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 TSE, but also the DME and the VAiE. The difference for building insulation (10 pp) results from the VAiE, which is partially offset by the DME. In the case of adaptation actions, the dominant effects are the VAiE and the TSE.

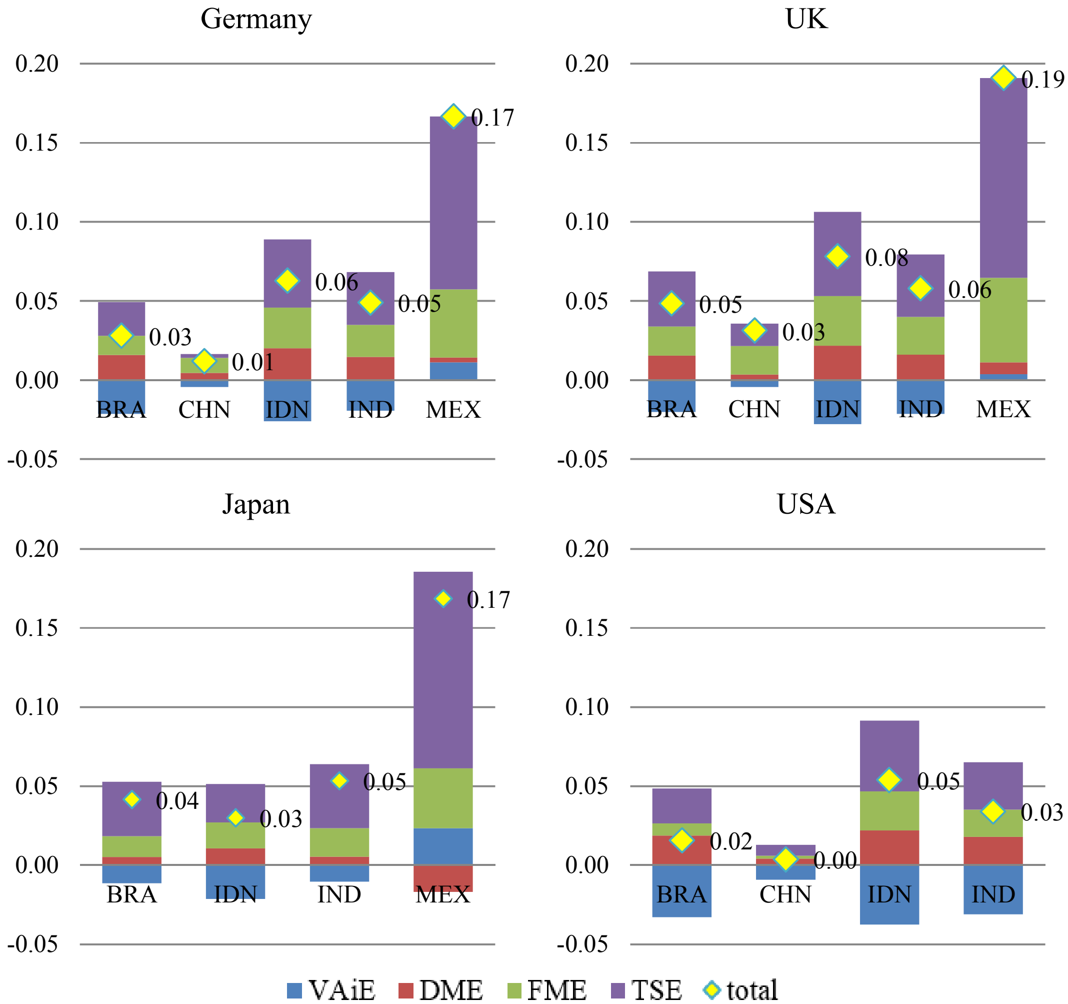
Mexico is the farthest from benchmark countries: between 9-30 pp. Again, the largest differences are for renewable energy technologies (21-30 pp), and the lowest for building insulation (9 pp). This time the dominant effect in most cases is the TSE, with the DME as the other factor that contributes to the difference. In most cases, the VAiE also counteracts these former effects. The case of building insulation is different, with the TSE having no influence, and both the DME and the VAiE contributing positively to the difference. Note that the FME 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 9**, we continue with the previous example: the USD 17 of difference between spill-overs 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 than for Japan, the foreign multiplier creates four dollars more in the USA than in Japan, the higher value-added intensity of the USA production causes two dollars of difference, and the domestic multiplier generates one dollar more in Japan than in the USA.

Spill-overs attracted by Germany 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 effect is the TSE. Two other factors that also contribute positively to the difference are the DME and FME. Finally, the only factor that counteracts those effects is the VAiE, showing that value-added per unit of the German production is generally larger than in benchmark countries (with the exception of the USA). The same happens with the UK, whose results are very similar.

Differences are slightly larger in the case of the UK (between 3 and 19 pp), but the signs and relative magnitude of the different factors are the same than for Germany.

Figure 9. Results by donor and recipient country



Source: Own work. Abbreviations: VAiE (value-added intensity effect), DME (domestic multiplier effect), FME (foreign multiplier effect), TSE (trade structure effect), B. insul (building insulation), Soft A. (soft adaptation), Hard A. (hard adaptation), BRA (Brazil), IDN (Indonesia), IND (India), MEX (Mexico).

Japan is the benchmark country when China receives funding for deploying renewable energy technologies. In other cases, spill-overs captured by Japan are between 3 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 TSE. The FME also contributes positively to the difference. The signs of the other two factors differ depending on the benchmark country: when it is China, the DME increases the difference and the VAiE decreases it; when it is the USA, the opposite occurs.

The USA 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 TSE and VAiE. 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.

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.” [25], “Electrical and Optical Equipment”, “Electricity, Gas and Water Supply” (EGW), “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” (OBA). **Figure 10** and **Figure 11** in the Appendix (Section 3.5.2) illustrate the results for recipients and donor countries.

In Brazil, the largest positive differences with the benchmark (India) appear in trade sectors (due to the VAiE, DME and TSE) and the transport sector (especially due to the DME). The sectors with the largest negative differences (around -2 pp) are metals and EGW (in wind and hydropower, respectively), especially due to the negative VAiE effect.

When comparing India with 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 VAiE. 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 DME.

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

Sectoral results for China 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 OBA sector (13 pp), and those observed in hard adaptation are due to both the construction and OBA sectors (around 8 pp each). These differences are a consequence of a positive VAiE. Also noteworthy is the positive DME 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, metals and machinery sectors contribute to the large difference in renewable energy projects, especially due to the DME in the former and the TSE in the latter. The difference observed in building insulation projects might be explained in part by the VAiE in the construction sector. This effect in this sector might also influence the aggregated results in solar and hard adaptation projects. The VAiE in OBA and the TSE 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) regardless of the type of action, as a consequence of the DME and the VAiE.

According to the sectoral results, the TSE in the machinery sector contributes to the differences observed for renewable energy projects in Mexico. 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 TSE and the DME. In this type of action, the role of the VAiE is negative with the exception of the equipment sector. In adaptation actions, the most influential effect is the TSE in machinery. Regarding negative differences, the OBA sector stands out, especially due to the VAiE 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, the TSE of these three sectors is especially influential, particularly when the benchmark countries are China and the USA. The UK and Japan present very similar results regarding the relative importance of sectors and the signs of effects. The case of the USA is also similar, but with some noteworthy features such as the negative VAiE on the equipment and machinery sector, especially when the benchmark country is China[26].

3.4. Discussion and concluding remarks

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 VAiE. According to the sectoral results, this effect makes the impact of mitigation actions larger in the Brazilian metals, EGW and construction sectors. **Table 7**, 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[27]. 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 EGW sector may be associated with the large share of hydropower in the Brazilian energy mix, an energy source with low requirements for intermediate inputs.

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 8**, which shows the share of domestic production by 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.

[26] See original contribution in Román et al. (2016b)

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

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.

Table 7. Value-added intensity by country and sector[28]

(percentage)	BRA	CHN	IDN	IND	MEX	DEU	UK	JPN	USA
Agriculture	61	59	77	78	58	44	54	50	43
Mining	44	47	82	79	82	47	71	20	57
Pulp	46	25	37	29	46	40	48	45	38
Coke	26	19	59	17	16	19	18	38	28
Chemicals	36	21	31	31	31	39	40	28	35
Rubber	40	19	35	19	33	41	44	25	37
Non-Metallic Mineral	44	28	46	37	54	40	49	33	39
Metals	41	21	31	26	37	35	40	27	33
Machinery n.e.c.	38	24	30	31	38	40	43	36	44
Equipment	37	17	37	30	20	42	42	32	64
Transport Equip.	29	20	41	29	35	27	32	24	22
EGW	57	29	31	36	36	52	38	44	72
Construction	56	23	36	39	50	45	43	46	52
Wholesale Trade	73	60	59	89	75	61	56	69	67
Inland Transport	57	52	39	41	66	50	53	63	49
Other Transport	57	39	78	54	73	42	49	58	65
Post	50	59	65	70	63	50	51	65	58
Financial	68	69	79	77	69	44	54	61	55
Real Estate	93	83	55	92	91	81	67	87	70
Other Business Activities	64	41	58	70	73	67	68	51	68
Public Admin	68	55	56	100	71	68	53	69	60
Health	62	35	55	66	74	72	44	62	63
Personal Services	65	45	54	83	71	62	56	60	54
Average	53	39	51	53	55	48	48	47	51

Source: Own work based on WIOD. Abbreviations: BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico), DEU (Germany), UK (United Kingdom), JPN (Japan), USA (United States of America).

[28] Colour gradients are used to compare values within the same row in order to help distinguish the countries with higher value-added intensities (in darker tones) from those with lower ones (in lighter tones).

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 VAiE makes the impact of climate actions in the Chinese metals, construction and OBA sectors lower than in the benchmark cases. **Table 8** confirms that China is the recipient country with the smallest value-added coefficients in almost all industries, including these three.

Table 8. Proportion of domestic production in final demand by country[29]

(percentage)	BRA	CHN	IDN	IND	MEX
Agriculture	98	98	97	99	96
Mining	96	98	98	97	97
Pulp	97	83	91	94	85
Coke	88	85	40	97	57
Chemicals	88	62	89	88	80
Rubber	72	85	86	88	47
Non-Metallic Mineral	83	94	93	75	97
Metals	90	93	66	94	78
Machinery n.e.c.	74	85	18	78	18
Equipment	60	74	72	66	23
Transport Equip.	84	85	81	94	40
EGW	99	99	100	100	100
Construction	100	100	100	100	100
Wholesale Trade	100	99	100	99	100
Inland Transport	99	98	96	100	100
Other Transport	99	98	94	100	99
Post	97	98	99	99	100
Financial	99	99	99	98	97
Real Estate	97	100	77	100	100
Other Business Activities	99	95	100	97	99
Public Admin	100	100	99	100	97
Health	100	100	99	100	100
Personal Services	99	98	98	99	98
Average	92	92	87	94	83

Source: Own work based on WIOD. Abbreviations: BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico).

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

[29] Colour gradients are used to compare values within the same row, in order to help distinguish countries with higher proportions of domestic production in their final demand (in darker tones) from lower ones (in lighter tones).

energy and adaptation projects in the metals and machinery sectors due to this effect. **Table 8** 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 OBA sectors (see **Table 7**). This factor reduces the difference with the benchmark for renewable energy and adaptation projects.

Major differences in the distribution of spill-overs 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 8** 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 (TSE). The relevance of trade in intermediate inputs (FME) 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[30]. According to the World Bank (2011), in 2011 the USA was the top

[30] In the comparison of recipient countries, the FME 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).

market for world exports and the second exporting country. 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 7**.

The fact that the largest spill-over effects, when the recipient is China, take place in Japan also reflects the effect of proximity in trade. However, the fact that China attracts spill-overs between 3-8 pp 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.

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, but the characterisation of adaptation actions is the result of an *ad-hoc* selection process from the NAPA 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.

As it has been previously noted, the main aim of this chapter has been to try to understand the underlying factors explaining the different ability 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 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 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 spill-overs. Based on these findings, donors could be tempted to focus climate aid on their specific commercial area. However, given the increasing limitations on donors' discretion to decide the destination of climate finance, 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[31]. 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 spill-overs 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

[31] This is the purpose underlying the choice of a multi-lateral channel such as the GCF, with equal participation of developed and developing countries in their government bodies, as the main channel for future financial aid.

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.

Finally, 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 chapter we explore a different avenue of research that focuses on the opportunities of the required transition towards decarbonized and resilient societies.

3.5. Appendix

3.5.1. Comparison between donor countries

In this case, we depart from Equation 4:

$$\Delta \mathrm{w}^{a} = \sum_{s} \mathbf{v}^{B}{}'\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} - \sum_{s} \mathbf{v}^{C}{}'\mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} \qquad t \neq B,C \tag{16}$$

The two polar decompositions (Δw_1 and Δw_2) are:

$$\Delta w_1^{ta} = \sum_{s} (\Delta \mathbf{v}')\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{C}{}'(\Delta \mathbf{L}^{\bullet s})\mathbf{t}^{st} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{C}{}'\mathbf{L}^{Cs}(\Delta \mathbf{t}^{\bullet t}) \otimes \mathbf{e}^{a} \tag{17}$$

$$\Delta w_2^{ta} = \sum_{s} (\Delta \mathbf{v}')\mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{B}{}'(\Delta \mathbf{L}^{\bullet s})\mathbf{t}^{st} \otimes \mathbf{e}^{a} + \sum_{s} \mathbf{v}^{B}{}'\mathbf{L}^{Bs}(\Delta \mathbf{t}^{\bullet t}) \otimes \mathbf{e}^{a} \tag{18}$$

Where

$$(\Delta \mathbf{v}') = \left(\mathbf{v}^{B}{}' - \mathbf{v}^{C}{}'\right) \tag{19}$$

$$(\Delta \mathbf{L}^{\bullet s}) = (\mathbf{L}^{BB} - \mathbf{L}^{CC}) + (\mathbf{L}^{BC} - \mathbf{L}^{CB}) + \sum_{s \neq B, s \neq C} (\mathbf{L}^{Bs} - \mathbf{L}^{Cs}) \tag{20}$$

$$\Delta \mathbf{t}^{\bullet t} = \left(\mathbf{t}^{Bt} - \mathbf{t}^{Ct}\right) \tag{21}$$

And the average of the polar decomposition is $\Delta w = \frac{1}{2}\left(\Delta w_1 + \Delta w_2\right)$ or

$$\begin{aligned} \Delta w^{ta} &= \frac{1}{2}\sum_{s} \Delta \mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} + \mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^{a}\right) + \frac{1}{2}\sum_{s} \mathbf{v}^{C}{}'\Delta \mathbf{L}^{\bullet s}\mathbf{t}^{st} \otimes \mathbf{e}^{a} \\ &+ \frac{1}{2}\sum_{s} \mathbf{v}^{B}{}'\Delta \mathbf{L}^{\bullet s}\mathbf{t}^{st} \otimes \mathbf{e}^{a} + \frac{1}{2}\sum_{s}\left(\mathbf{v}^{C}{}'\mathbf{L}^{Cs} + \mathbf{v}^{B}{}'\mathbf{L}^{Bs}\right)\Delta \mathbf{t}^{\bullet t} \otimes \mathbf{e}^{a} \end{aligned} \tag{22}$$

Equation 23 to Equation 26 show the decomposition of the difference in value-added created into the four components: VAiE, DME, FME and TSE.

$$\mathrm{VAiE} \equiv \frac{1}{2}\sum_{s} \Delta \mathbf{v}'\left(\mathbf{L}^{Bs}\mathbf{t}^{st} \otimes \mathbf{e}^{a} + \mathbf{L}^{Cs}\mathbf{t}^{st} \otimes \mathbf{e}^{a}\right) \tag{23}$$

$$\mathrm{DME} \equiv \frac{1}{2}\left(\mathbf{v}^{B}{}'\right)\left(\mathbf{L}^{BB} - \mathbf{L}^{CC}\right)\left(\mathbf{t}^{Ct}\right) \otimes \mathbf{e}^{a} + \frac{1}{2}\left(\mathbf{v}^{C}{}'\right)\left(\mathbf{L}^{BB} - \mathbf{L}^{CC}\right)\left(\mathbf{t}^{Bt}\right) \otimes \mathbf{e}^{a} \tag{24}$$

$$\text{FME} \equiv \frac{1}{2}\left(\mathbf{v}^{B}\,'\right)\left(\mathbf{L}^{BC}-\mathbf{L}^{CB}\right)\left(\mathbf{t}^{Ct}\right)\otimes\mathbf{e}^{a}+\frac{1}{2}\left(\mathbf{v}^{C}\,'\right)\left(\mathbf{L}^{BC}-\mathbf{L}^{CB}\right)\left(\mathbf{t}^{Bt}\right)\otimes\mathbf{e}^{a}$$
$$+\frac{1}{2}\sum_{s\neq B,C}\left(\mathbf{v}^{B}\,'\right)\left(\mathbf{L}^{Bs}-\mathbf{L}^{Cs}\right)\left(\mathbf{t}^{st}\right)\otimes\mathbf{e}^{a}+\frac{1}{2}\sum_{s\neq B,C}\left(\mathbf{v}^{C}\,'\right)\left(\mathbf{L}^{Bs}-\mathbf{L}^{Cs}\right)\left(\mathbf{t}^{st}\right)\otimes\mathbf{e}^{a} \quad \textbf{(25)}$$

$$\text{TSE} \equiv \frac{1}{2}\sum_{s}\left(\mathbf{v}^{C}\,'\mathbf{L}^{Cs}+\mathbf{v}^{B}\,'\mathbf{L}^{Bs}\right)\Delta\mathbf{t}^{\cdot t}\otimes\mathbf{e}^{a} \quad \textbf{(26)}$$

3.5.2. Additional tables and figures

Table 9. Types of adaptation actions and sources of information

Hard adaptation		NAPA
Coastal protection	Beach nourishment	GAMBIA #9
	Coastal protection structures	CAPE VERDE #3
	Rehabilitation of coastal areas	SIERRE LEONE #18
Disaster risk reduction	Early warning or emergency response systems	GAMBIA #1
	Construction or improvement of drainage systems	BHUTAN #5
	Flood protection	BHUTAN #7
	Hazard mapping and monitoring technologies	BHUTAN #9
	Improved climate services	SIERRE LEONE #2
Water supply and management	Rainwater harvesting and storage	SUDAN #2
	Rehabilitation of water distribution networks	SIERRE LEONE #12
	Desalinization, water recycling and water conservation	TUVALU #3
Human settlements, infrastructure and spatial planning	Energy security (hydropower)	TANZANIA #5
	Energy security (solar energy)	SIERRE LEONE #8
	Energy security (biomass)	GAMBIA #6
	Transport and road infrastructure adaptation	MALDIVES #10
	Protection of infrastructure	BHUTAN #6
	Zoning	SAMOA #6
	Improving the resilience of existing infrastructures/buildings	MALDIVES #8
Waste and wastewater	Sanitation	SIERRE LEONE #22
	Storm and wastewater	MALDIVES #5
Soft adaptation		NAPA
Forestry and land use/ Terrestrial Ecosystems	Afforestation and reforestation	ERITREA #3
	Ecological restoration and soil conservation	LESOTHO #6
	Protection of biodiversity	TUVALU #5
	Forest management, management of slopes and basins	BURUNDI #3
	Forest fires reduction	BHUTAN #11
Capacity-building	Awareness raising and integrating into education	BURUNDI #11
	Technical assistance	MALAWI #5
	Planning, policy development and implementation	SIERRE LEONE #19
Agriculture, fishing and livestock	Crop / animal diversification	SIERRE LEONE #5
	Crop, grazing land, livestock and fisheries enhanced management	ERITREA #2
	Research	MALDIVES #9
	Irrigation and drainage system	SIERRE LEONE #7
Social protection	Livelihood diversification	MALAWI #1
	Food storage and preservation facilities	LESOTHO #8
	Health, vaccination programs	SIERRE LEONE #23

Source: Own work.

Table 10. Correspondence between industry and commodity codes

Industry NACE classification	Description	Commodity CPA classification	Description
c1	Agriculture, Hunting, Forestry and Fishing	1	Products of agriculture, hunting and related services
		2	Products of forestry, logging and related services
		5	Fish and other fishing products; services incidental of fishing
c2	Mining and Quarrying	10	Coal and lignite; peat
		11	Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying
		12	Uranium and thorium ores
		13	Metal ores
		14	Other mining and quarrying products
c3	Food, Beverages and Tobacco	15	Food products and beverages
		16	Tobacco products
c4	Textiles and Textile Products	17	Textiles
		18	Wearing apparel; furs
c5	Leather, Leather and Footwear	19	Leather and leather products
c6	Wood and Products of Wood and Cork	20	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials
c7	Pulp, Paper, Paper , Printing and Publishing	21	Pulp, paper and paper products
		22	Printed matter and recorded media
c8	Coke, Refined Petroleum and Nuclear Fuel	23	Coke, refined petroleum products and nuclear fuels
c9	Chemicals and Chemical Products	24	Chemicals, chemical products and man-made fibres
c10	Rubber and Plastics	25	Rubber and plastic products
c11	Other Non-Metallic Mineral	26	Other non-metallic mineral products
c12	Basic Metals and Fabricated Metal	27	Basic metals
		28	Fabricated metal products, except machinery and equipment
c13	Machinery n.e.c.	29	Machinery and equipment n.e.c.
c14	Electrical and Optical Equipment	30	Office machinery and computers
		31	Electrical machinery and apparatus n.e.c.
		32	Radio, television and communication equipment and apparatus
		33	Medical, precision and optical instruments, watches and clocks
c15	Transport Equipment	34	Motor vehicles, trailers and semi-trailers
		35	Other transport equipment
c16	Manufacturing, n.e.c.; Recycling	36	Furniture; other manufactured goods n.e.c.
		37	Secondary raw materials
c17	Electricity, Gas and Water Supply	40	Electrical energy, gas, steam and hot water
		41	Collected and purified water, distribution services of water
c18	Construction	45	Construction work
c19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	50	Trade, maintenance and repair services of motor vehicles and motorcycles; retail sale of automotive fuel
c20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	51	Wholesale trade and commission trade services, except of motor vehicles and motorcycles

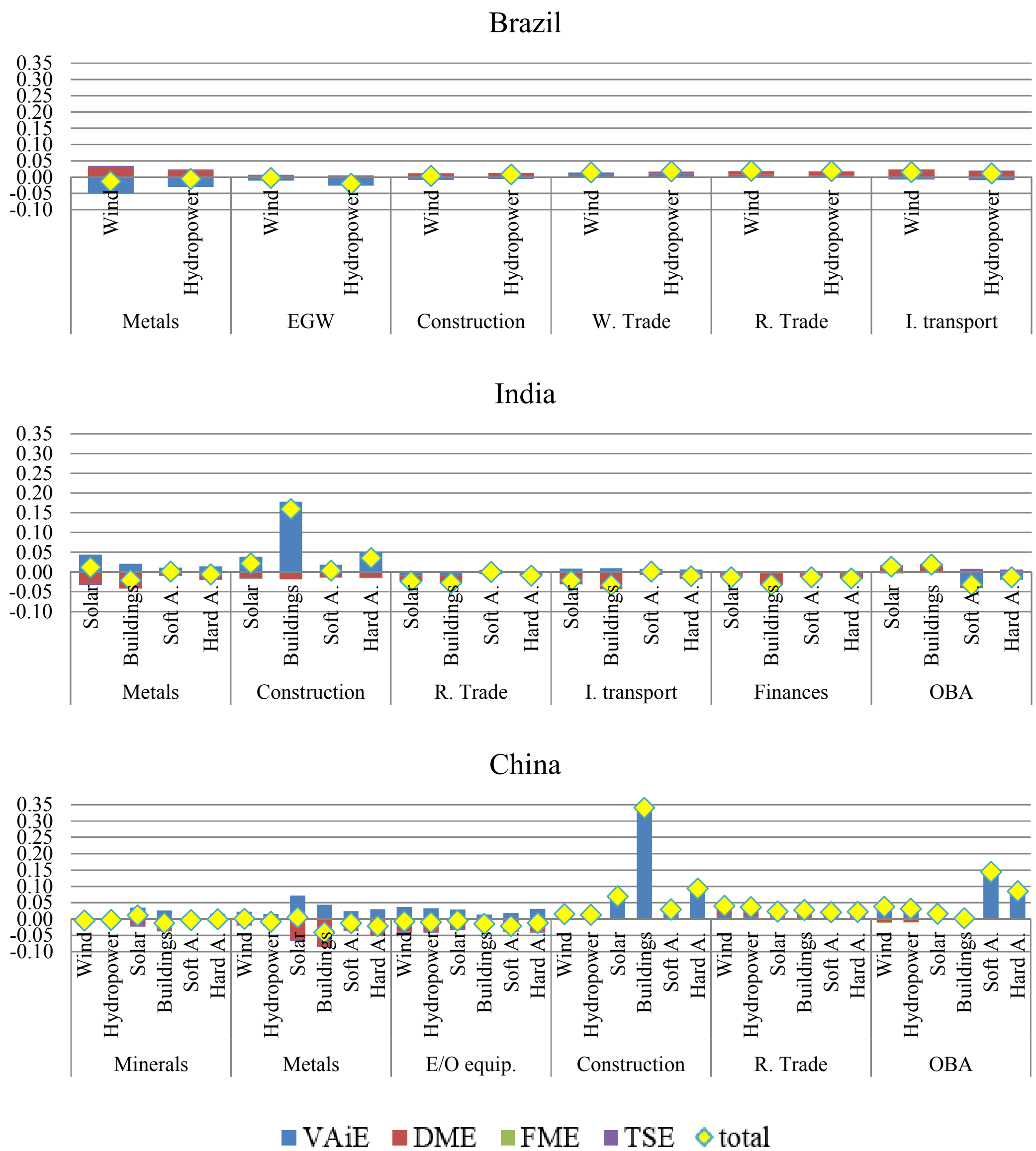
Source: Own work.

Table 10. Correspondence between industry and commodity codes (cont.)

Industry NACE classification	Description	Commodity CPA classification	Description
c21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	52	Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods
c22	Hotels and Restaurants	55	Hotel and restaurant services
c23	Inland Transport	60	Land transport; transport via pipeline services
c24	Water Transport	61	Water transport services
c25	Air Transport	62	Air transport services
c26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	63	Supporting and auxiliary transport services; travel agency services
c27	Post and Telecommunications	64	Post and telecommunication services
c28	Financial Intermediation	65	Financial intermediation services, except insurance and pension funding services
		66	Insurance and pension funding services, except compulsory social security services
		67	Services auxiliary to financial intermediation
c29	Real Estate Activities	70	Real estate services
c30	Renting of M&Eq and Other Business Activities	71	Renting services of machinery and equipment without operator and of personal and household goods
		72	Computer and related services
		73	Research and development services
		74	Other business services
c31	Public Admin and Defence; Compulsory Social Security	75	Public administration and defence services; compulsory social security services
c32	Education	80	Education services
c33	Health and Social Work	85	Health and social work services
c34	Other Community, Social and Personal Services	90	Sewage and refuse disposal services, sanitation and similar services
		91	Membership organisation services n.e.c.
		92	Recreational, cultural and sporting services
		93	Other services
c35	Private Households with Employed Persons	95	Private households with employed persons

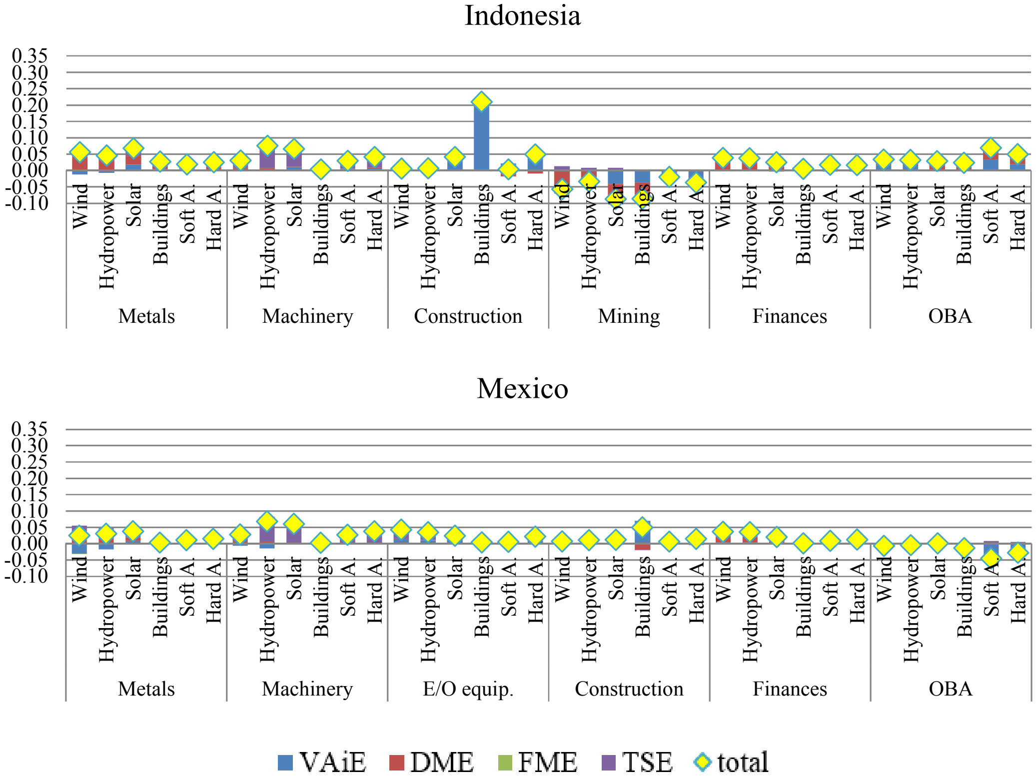
Source: Own work.

Figure 10. Top five sectors by recipient country and climate action



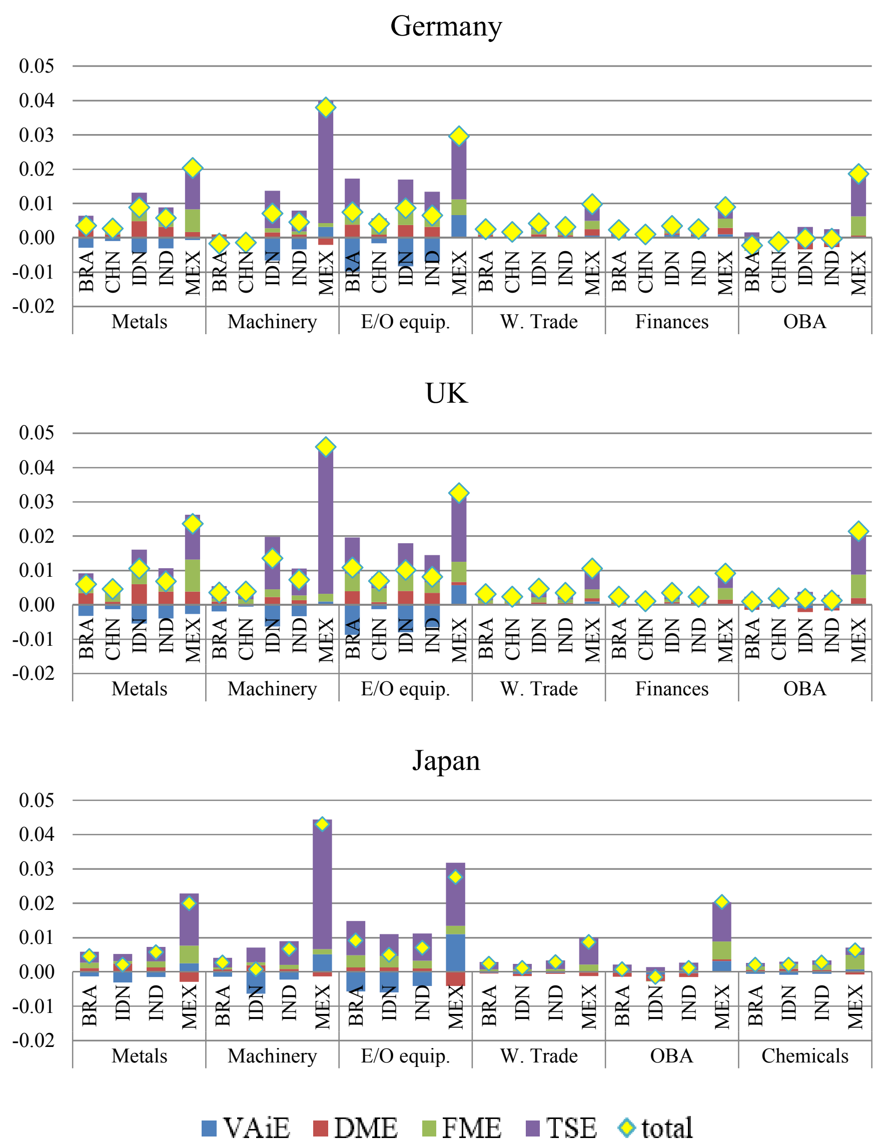
Source: Own work. Abbreviations: VAiE (value-added intensity effect), DME (domestic multiplier effect), FME (foreign multiplier effect), TSE (trade structure effect), B. insul (building insulation), Soft A. (soft adaptation), Hard A. (hard adaptation), EGW (electricity, gas and water supply), W. trade (wholesale trade), R. trade (retail trade), I. transport (inland transport), OBA (other business activities), E/O equip. (electric and optical equipment).

Figure 10. Top five sectors by recipient country and climate action (cont.)



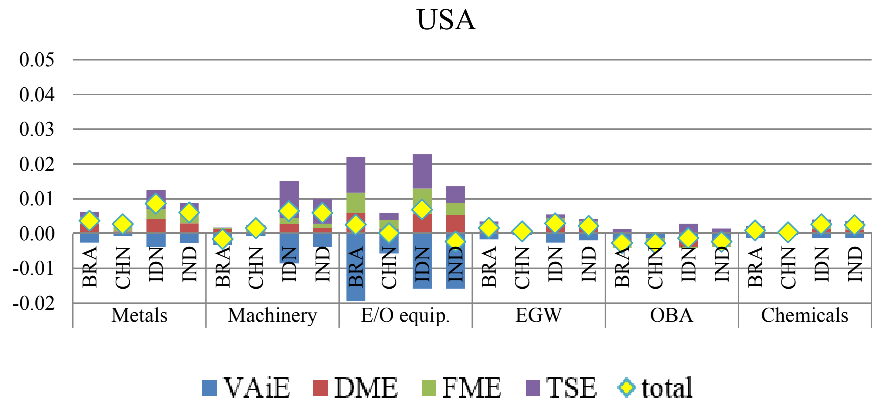
Source: Own work. Abbreviations: VAiE (value-added intensity effect), DME (domestic multiplier effect), FME (foreign multiplier effect), TSE (trade structure effect), B. insul (building insulation), Soft A. (soft adaptation), Hard A. (hard adaptation), EGW (electricity, gas and water supply), W. trade (wholesale trade), R. trade (retail trade), I. transport (inland transport), OBA (other business activities), E/O equip. (electric and optical equipment).

Figure 11. Top five sectors by donor and recipient country



Source: Own work. Abbreviations: VAiE (value-added intensity effect), DME (domestic multiplier effect), FME (foreign multiplier effect), TSE (trade structure effect), B. insul (building insulation), Soft A. (soft adaptation), Hard A. (hard adaptation), EGW (electricity, gas and water supply), W. trade (wholesale trade), R. trade (retail trade), I. transport (inland transport), OBA (other business activities), E/O equip. (electric and optical equipment), BRA (Brazil), CHN (China), IDN (Indonesia), IND (India) and MEX (Mexico).

Figure 11. Top five sectors by donor and recipient country (cont.)



Source: Own work. Abbreviations: VAiE (value-added intensity effect), DME (domestic multiplier effect), FME (foreign multiplier effect), TSE (trade structure effect), B. insul (building insulation), Soft A. (soft adaptation), Hard A. (hard adaptation), EGW (electricity, gas and water supply), W. trade (wholesale trade), R. trade (retail trade), I. transport (inland transport), OBA (other business activities), E/O equip. (electric and optical equipment), BRA (Brazil), CHN (China), IDN (Indonesia), IND (India) and MEX (Mexico).

4. Spill-over effects of climate finance: tied aid versus local content requirements

4.1. Introduction

Climate change, due to its global public good nature, requires an internationally coordinated response by the largest emitters of GHGs. Given the asymmetries in terms of responsibility, capability and vulnerability between countries, North-to-South financial transfers play a key role in the coordination of the global action for curbing GHG emissions and facilitating adaptation by the most vulnerable countries to unavoidable changes in the atmospheric conditions. In the climate summits of Copenhagen (UNFCCC, 2009) and Cancun (UNFCCC, 2010) developed countries committed to jointly mobilize USD 100 billion per year from 2020 onwards to support mitigation and adaptation policies in developing countries. In this respect, two quantitative goals were set: USD 30 billion for the period 2010 – 2012 (i.e. the FSF) and USD 100 billion per year by 2020 (i.e. the Long-term Finance) (ibid). Besides, the so-called Paris Agreement points at raising ambition in terms of climate finance mobilization after 2025 (UNFCCC, 2015).

With the objective of reaching the collective goals pledged in Copenhagen, developed countries have already started to mobilize funds from a variety of sources, which are disbursed through different channels to different countries for the implementation of climate actions with mitigation and/or adaptation purposes. The Climate Policy Initiative (CPI), an independent organization that, since 2011, tracks the flow of financial resources aimed at climate action, has reported USD 391 billion of climate finance in 2014 (Buchner et al., 2015). Most of this finance comes from private (62%) and domestic sources (74%). The OECD and the CPI have also estimated that in 2013-2014 the North-to-South transfers reached USD 57 billion on average, 74% of which came from public sources (OECD and CPI, 2015)[32].

It can be expected that international climate finance flows will continue to grow in the near future as the deadline of 2020 approaches. Thus, it is very important that we understand the economic consequences of these international transfers of

[32] This report does not reflect the pledges to the GCF, an entity created in 2010 (at the 16th COP in Cancun) with the aim to channel most of the international funding, and that became operational in 2014 (UNFCCC, 2010). Pledges to the GCF reached USD 10.3 billion on May 2016, something that makes the GCF the largest public climate fund.

financial resources. In Chapter 2, we have quantified the size of the impact associated to climate finance, differentiating between the domestic impact in value-added creation and the value-added that spills over to other countries (i.e. the so-called spill-over effect or spill-overs). Departing from the quantification of the spill-overs captured by different climate finance donors, in this chapter we focus on the influence of spending conditions such as tied aid and LCR on the size of spill-over effects, answering the following research questions: What is the effect of tied aid and LCR on the value-added captured by donor countries? What locations and industries are more sensitive to these practices? The scope of this exercise is, thus, limited to the economic consequences of the phase of climate finance disbursement. The economic implications of the previous phase of mobilization of climate finance is beyond the scope of this chapter[33].We focus on a group of donor and recipient countries and on a set of 26 climate actions including most relevant mitigation options and adaptation solutions.

The chapter is structured in six sections. After this brief introduction, Section 4.2 provides an overview of the evidence on the use of tied aid and LCRs. Next, Section 4.3 describes the methodology used to quantify the differences in spill-over effects arising from spending conditions. Section 4.4 presents the results, and these are subsequently discussed in Section 4.5. Finally, Section 4.6 concludes.

4.2.Tied aid and LCR

A quite established result in the development aid literature is that donors tend to provide more support to trade partners[34] (Hoeffler and Outram, 2011; Schraeder et al., 1998). Thus, Younas (2008) finds that OECD countries allocate more aid to recipient nations who import goods in which donor nations have a comparative advantage in production. However, this may not only be a consequence of comparative advantage in production but also the consequence of the practice of "tying" aid to the explicit obligation of buying products (or contracting services) from the donor's industries[35]. Theoretical

[33] Several previous analysis study the economic consequences of alternative instruments for mobilizing climate finance (Basu et al., 2011; IMF, 2011; Jones et al., 2013; Keen et al., 2012; Parker et al., 2010).

[34] Dollar and Levin (2006) find that in the case of France, Japan and Portugal aid is highly correlated with their bilateral trade, but the trade variable is not relevant for other donors.

[35] This practice might respond to several factors such as the demand of donor country's constituencies for a percentage of "domestic return" from the resources devoted to international aid, to a national strategy for expanding exports, or to the activity of a domestic lobby that, through its advocacy and influence,

studies suggest that the use of tied aid can be explained through rent-seeking behaviour, since such aid largely repatriates the transfer, giving rise to profits in the donor country (Brakman and van Marrewijk, 1995; Schweinberger, 1990). Wagner (2003) shows that approximately 50% of foreign aid in the 1990s was tied with exports and that the induced exports accounted for 133% of the resources transferred. However, this way of giving aid may be considered inefficient as it increases the costs of actions and negatively affects effectiveness of the intervention (Osei, 2005). Besides, it also creates trade distortions. Consequently, the Helsinki Package of discipline for tied aid, and the subsequent OECD Development Assistance Committee (DAC) agreements, set limitations for tied credits in the early 1990s (OECD, 2008). In 2001, the DAC made a recommendation for untying aid, which was reaffirmed in the Paris Declaration for Aid Effectiveness[36] (OECD, 2005; OECD/DAC, 2014). The argued benefits of untied aid were the promotion of local businesses and the creation of capacities locally as well as a more effective transfer of knowledge (Clay et al., 2009).

Since 2001, significant progress has been made in the elimination of legal and regulatory restrictions on the geographic origin of purchased goods and services. Martinez-Zarzoso et al. (2014) find that the average positive effect of bilateral aid on exports decreases substantially over the period 1989-2007, which could suggest that the recommendations given by the OECD/DAC concerning the untying of aid have been followed by the donors and led to declining impacts on their exports. Thus, in 2007 tied aid was 24% of the total foreign aid[37]. However, the portion of actual tied aid is estimated to be much bigger, since technical cooperation and management components of most projects have been found to be, if not formally, *de facto* tied (Clay et al., 2009).

In general, bilateral aid has a larger portion of tied aid. According to de Sépibus (2014), donors of climate finance are increasingly using "multi-bi-financing" channels at the expense of multilateral channels, because the former enable like-minded donors to earmark their contributions to particular objectives. Approximately 80% of

shapes aid policy in a way that is of primarily benefit to itself (Brakman and van Marrewijk, 1995; Martínez-Zarzoso et al., 2009; Selbervik and Nygaard, 2006).

[36] For the OECD agencies, this position has meant the loss of support from the business sector, who critically looks the Paris Declaration and the recommendation for untying aid (de Sépibus, 2014).

[37] Excluding technical cooperation and food support, with portions of tied aid of 30% and 50%, respectively.

FSF, and 56% of the public finance in 2013-2014 was channelled through bilateral aid institutions (OECD and CPI, 2015). Private-oriented finance, which includes developed country public flows to the private sector, is normally channelled through bilateral institutions. Buchner et al. (2015) estimate that 21% of public finance went to private entities, and 41% to public or public-private entities.

Some evidence exists about the use of tied aid by the donor countries that will be considered in this article, namely Japan, USA, Germany and UK. Umeda (2011) claims that Japan has untied foreign aid beyond the requirements of the recommendations by the OECD/DAC. Thus, in 2007, 95% of Japanese aid was untied. However, Whitley (2012) shows that in the case of Japanese private-oriented climate finance, all beneficiaries were private entities using Japanese expertise or technology, or co-financed by Japanese banks. He concludes that Japanese private climate finance support has been guided by the objective of enhancing Japanese competitive advantages through the promotion of products with high value-added, including low carbon technologies.

With regard to the USA, approximately half of its bilateral support to the private sector for climate action benefited directly or indirectly American companies. The main agencies involved require that beneficiaries are to some extent American, and have as mission creating jobs in the USA by financing exports to international buyers (Whitley and Mohanty, 2012).

In the case of German foreign aid, Palmer (2011) concludes that *"Germany has not entirely lived up to the recommendations on untying aid that were made by the OECD/DAC and the Accra Action Plan"* since the federal budget often specifies that technical assistance is to be provided directly by German services. It reports that, in 2008, 41% of German technical assistance was provided in the form of tied aid. Regarding private-oriented climate finance, Whitley and Mohanty (2013) report that 19% of Germany's private climate finance support identified for the period 2010 –2012 involved German technology.

With regard to the UK, Feikert-Ahalt (2011) reports that the UK is one of the first countries to completely "untie" aid. However, Whitley et al. (2012) point that UK's expertise in low carbon development is being promoted in emerging countries, and the Export Credits Guarantee Department offers support to exporters of low carbon technologies and renewable energies.

On the other hand, LCR constitute a protectionist tool that restricts and distorts trade flows. LCR are provisions that regulate the extent to which certain projects must use local products. These provisions can be enacted at the state, sub-state or regional level and are usually tied to government concessions and public support schemes (Johnson, 2013; Kuntze and Moerenhout, 2012). The main objective of LCR in the short term is to maximize the positive impact of the influx of foreign financing and technology in terms of job creation and development of the local private sector. A more strategic objective is to protect local infant industries while they develop the capabilities necessary to compete internationally and to participate in GVC. Particularly interesting for capturing greater shares of the value-added is to focus on industries participating in the stages of the production chain that have a higher technological content (Johnson, 2013; Pérez, 2013).

Elms & Low (2013) provide an overview of industrial policies showing that LCR have significant importance in emerging economies. LCR are also increasingly being used by countries with different levels of economic development to make green growth strategies politically acceptable. For example, many countries have used LCR as part of renewable energy support schemes: China, Brazil, Quebec (Canada) and Chubut (Argentina) for wind power; India, Brazil, Italy and France for solar power; Ontario (Canada), Montana and Louisiana (USA) for biofuels; Croatia, South Africa, Turkey and several areas of Spain (Galicia, Navarra, Castilla y León and Valencia) and of the USA (California, Massachusetts, New Jersey, Ohio and Washington) for renewable energy in general (Johnson, 2013; Kuntze and Moerenhout, 2012).

LCR are explicitly prohibited under the WTO, which considers them inconsistent with a free and fair international trade regime. However, many WTO member states use LCR, something that has given rise to numerous disputes in the last decades. Some examples related to climate policy are the complaint by Japan against Ontario's LCR provisions in the feed-in tariff scheme, and the dispute by China against certain EU member states regarding LCR in renewable energy policies (Johnson, 2013; Kuntze and Moerenhout, 2012).

Kuntze & Moerenhout (2012) explain that, although LCR may increase costs to the industry and consumers in the short term, in the medium term and under certain conditions, LCR may facilitate the creation of competitive and innovative industries domestically, decreasing the global costs of technology. Experiences in emerging countries evidence the potential of LCR to successfully promote green industries and build new clean-technology value chains (Mathews, 2015). Given this medium term benefits, it seems plausible that LCR are imposed as a precondition to the receipt of financial support for climate change mitigation and adaptation.

In the case of the recipient countries considered in this article, namely China, Brazil, India, Indonesia and Mexico, there are evidences of the use of LCR for the development of several industries, including some clean energy technologies. In Brazil, LCR have reduced the propensity to import from foreign companies and successfully facilitated the development of competitive industries (Pérez, 2013). The strategy consisted in attaching LCR to development bank financing for project developers, introducing LCR in public support programmes (e.g. in the automotive industry and in the electronics sector), tying them to fiscal benefits, and using the influence of powerful public companies to introduce LCR (Elms and Low, 2013; Pérez, 2013). This way, Brazil has also been able to build up competitive solar and wind power industries (Johnson, 2013; Kuntze and Moerenhout, 2012; Mathews, 2015).

In China, the use of LCR since 1996 has also been the key to the creation of a powerful wind industry. In 2009, after the complaints at the WTO by the USA, LCR were abolished at the introduction of countrywide feed-in tariffs. However, the period 1996-2009 was enough for the building of a globally competitive renewable energy industry (ibid).

In India the use of LCR as a tool for domestic industry development in the automotive industry has improved the bargaining power of local firms and influenced the value distribution in these GVC. India aims to achieve the same result for the renewable energy local industry, despite the attempts to obstruct this ambition by trade actions brought to the WTO by the USA. The Solar National Solar Mission of 2009 and the Indian Jawaharlal Nehru National Solar Mission of 2010 contain LCR for solar projects. India was also using LCR in the manufacturing of electric vehicles until 2012 (Elms and Low, 2013; Johnson, 2013; Kuntze and Moerenhout, 2012; Mathews, 2015).

Mexico and Indonesia have also used LCR mainly in the extractive and automotive sectors (Elms and Low, 2013; Kuntze and Moerenhout, 2012).

4.3.Methods and data

The Leontief IO model is a much extended tool for the assessment of the economic impact of policy interventions, concrete projects and events. Its interest for our purpose lies in its ability to capture direct and indirect impacts, and differentiate the part of the impact happening in a different place from where interventions take place (i.e. spill-over effects). Using this methodology, Beutel (2002) found that spill-over effects of European Structural Funds represented 20-30% of the total impact. However, the single-country IO framework used in this study did not enable to distinguish the countries benefitting from these spill-overs.

For that purpose a GMRIO framework is required. GMRIO databases contain, for a number of industries in different countries, the monetary value of transactions with other (national and foreign) industries, sales to (national or foreign) final users, remuneration of primary inputs and total output (Miller and Blair, 2009). GMRIO models are being increasingly used in the literature on GVC (Johnson and Noguera, 2012; Koopman et al., 2014, 2012; Los et al., 2015). Spill-overs, in particular, have been previously tackled in the study of the cross-border effects of trade (Arto et al., 2015). In the field of climate policy, the recent paper by Markandya et al. (2016) tracks the domestic and cross-border employment effects associated to the energy transition in the EU. The GMRIO framework also enables to quantify the contribution of each industry and country to the value-added embodied in goods and services. In Chapter 2, we used this method to provide a clear picture of the final destination of the financial resources transferred as climate finance, by tracing the value-added creation associated to climate investments.

The objective of this chapter is to calculate the spill-over effects in terms of value-added generated by climate finance on donor countries, depending on the conditions imposed on the use of the transferred resources and, in doing so, we will use the so-called WIOD. The WIOD provides multiregional IO tables (i.e. the WIOT) containing 35 sectors of 41 regions for the period 1995-2011 (Dietzenbacher et al., 2013b; Timmer et al., 2012). As we have already mentioned in the introduction, due to data availability we will not consider every single donor and recipient country, but we will focus on a particular set of countries. As donor countries we will consider Germany, UK, Japan and USA. These are the climate finance donors from which previous studies exist about the practice of tying climate aid (Whitley, 2012; Whitley et al., 2012; Whitley and Mohanty, 2013, 2012), and together represent 62% of the climate finance pledged as for October 2016 (Climate Funds Update, 2016). As climate finance recipient countries, we will focus on Brazil, China, Indonesia, India and Mexico. These countries are the five main climate finance recipient countries (accounting for 16% of the total funding approved as for October 2016) (ibid). The year of study is the most recent one available in the database (i.e. 2011).

Along with GMRIO tables, data on climate finance disbursements is also required to characterize the demand shocks produced by climate finance in the recipient economy. Different types of climate actions entail different demand shocks in terms of the goods and services required for their implementation and their associated costs. We combine different classifications of mitigation and adaptation measures from the literature (Blazejczak et al., 2014; Buchner et al., 2013; OECD/IEA, 2014; Prowse and Snilstveit, 2010; REN21, 2014, p. 21; UNFCCC, 2014b) and obtain a set of measures representing the whole spectrum of climate action. **Table 12** in the Appendix (Section 4.7.1) contains a list with the 26 climate action types considered, including 14 renewable energy technologies, three energy efficiency measures and nine adaptation alternatives. For each of these types of climate action, the typical cost breakdown is estimated using different sources of information, which are also detailed in **Table 12**. The information used for the characterization of the demand shocks of renewable energy technologies is based on empirical data from a comprehensive survey undertaken in Germany in 2011 by the *Deutsches Institut für Wirtschaftsforschung* (DIW Berlin), and has been used in previous studies (Lehr et al., 2012, 2008). There are also other studies that provide information about the typical cost breakdown of ocean energy and other mitigation actions (Allan et al., 2008; Markaki et al., 2013). Finally, the demand shocks of the different types of climate change adaptation are estimated with information contained in Priority Project Profile documents of NAPA (UNFCCC, 2014b). In order to connect this information with the GMRIO framework, demand shocks are expressed in terms of industries following the NACE classification. This is done following the correspondence between commodities and industries detailed in **Table 10** of Chapter 3 for the cases where the source of information refers to commodities in the budget allocation.

The demand shocks obtained represent the new requirements of production for different industries that a particular climate action entails. The next step is to allocate the new demands to specific countries. In order to reflect conditions on the spending of climate finance (i.e. tied aid or LCR), three scenarios are considered.

- First, a baseline scenario, representing a situation without conditions, is used as reference for comparison with the other two scenarios. In this case, trade structure vectors are computed with information from the WIOT, reflecting the actual flows of international trade as for 2011. This scenario reflects the *status quo* of tied aid and LCR practices. Trade structure vectors contain the share of final demand for one industry in one country that is satisfied with domestic production, along with the share satisfied with production from each of the rest of the countries.

- Second, the tied aid scenario is based on the baseline scenario but substituting imports from third countries by imports from the donor country (and the share of the demand satisfied with domestic production remains as in the baseline). This way, this scenario represents a hypothetical situation in which each donor imposes as condition for its support to be the supplier of the goods and services required for the financed climate actions that recipient countries need to import.

- Finally, the LCR scenario consists in substituting all imports with domestic products. This would represent the hypothetical and extreme case in which climate finance recipient countries impose a 100% LCR as condition for hosting internationally funded climate actions[38].

Having allocated the new demand to producing countries, the next step is to quantify total output requirements associated to this new demand. The production of additional demand, in turn, generates new requirements of intermediate goods/services, giving rise to a sequence of additional requirements amongst industries (or production multiplier effect). The total output requirements are condensed in the Leontief inverse matrix, which is calculated with information from the WIOT. Next, in order to determine the contribution of each industry and country to the value-added embedded in these total output requirements, we used information from the WIOT to calculate value-added coefficients, which express the value-added per unit of output in each sector and country.

At this point, we have all the elements to compute the impact in terms of value-added in each donor country associated to the implementation of each climate action in each host country, and depending on the scenario. The Appendix (Section 4.7.2) provides formal details of the calculations.

Finally, in order to facilitate the interpretation and exposition of the results, we group the 26 climate actions into five groups, and use group averages in the presentation of results. Groups are formed using a cluster analysis based on the k-means method (Tan et al., 2013). This non-hierarchic method allocates each element (in this case, each climate action) to one of the k groups (in this case, five groups). The optimization procedure consists in minimizing the aggregation of Euclidean distances between the elements and the group centroids. This equates to minimizing the aggregation of intra-group variances of all variables (in our case, the industries of the economy). Each of the resulting groups contains climate actions with similar cost structures, and represents a particular way to impact the economy with additional demands of goods and services.

Table 11 shows the clustering of the 26 climate actions into five groups, and **Figure 12** illustrates the average cost structure (i.e. distribution of the budget between

[38] In the practice, LCR range from 15% to 100%, according to Qiu and Tao (2001). We choose the more extreme case in order to offer an upper bound estimate of the effects of LCR.

the different economic sectors) of each group. **Figure 20** in the Appendix (Section 4.7.1) completes this information with the cost structures of all 26 climate actions.

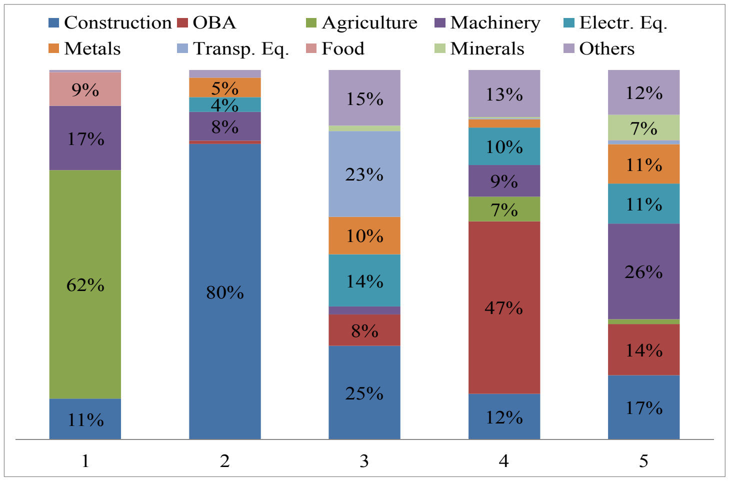
Table 11. Grouping of climate actions

Group 1	Renewable energy in transport (biofuels)	Group 5	Onshore wind power
Group 2	Building insulation		Solar thermal energy
	Biomass energy large scale		Hydropower
Group 3	Offshore wind power		Biomass energy small scale
	Photovoltaics		Biogas power
	Infrastructures for transport		Deep geothermal energy
Group 4	Concentrated solar power		Surface geothermal power
	Coastal protection		Ocean power
	Disaster risk reduction		Energy efficiency in industry
	Social protection		Renewable energy and energy efficiency in buildings
	Forestry and land use/ Terrestrial Ecosystems		Water supply and management
	Capacity building		Human settlements, infrastructure and spatial planning
	Agriculture; fishing and livestock		Waste and wastewater

Source: Own work.

Group 1 comprises only one climate action: renewable energy in transport (biofuels). This action forms a group by itself given the large share (60%) of expenses in agricultural products, something that substantially differs from the rest of climate actions. Another singularity is that another portion of the cost (9%) consists of products of the food industry. Group 2 comprises two actions: building insulation and biomass energy at large scale, which entail expenses in construction accounting for 80% of the total costs. This high content of construction is the main singularity of this group. Group 3 comprises three actions (two renewable energy technologies and one for transport) requiring expenses mainly in construction and transport equipment. The portion represented by transport equipment (23%) may be the distinctive feature of this group. Group 4 comprises seven climate actions, mainly related to adaptation (with the exception of one renewable energy technology: CSP) and with the common characteristic of requiring important expenses in OBA (47% of the total costs). Finally, group 5 comprises the most numerous and varied set of climate actions, including most renewable energy technologies but also some energy efficiency and adaptation actions. Consequently, the average cost structure is characterized by a rather equilibrated distribution of the budget between different industries (constructions, OBA, electrical and optical equipment, metals…), amongst which, the one with the largest share is machinery (26%).

Figure 12. Average cost structure by climate action groups



Source: Own work. Abbreviations: OBA (Other business activities), Electr. Eq. (Electrical and Optical equipment), Transp. Eq. (Transport equipment).

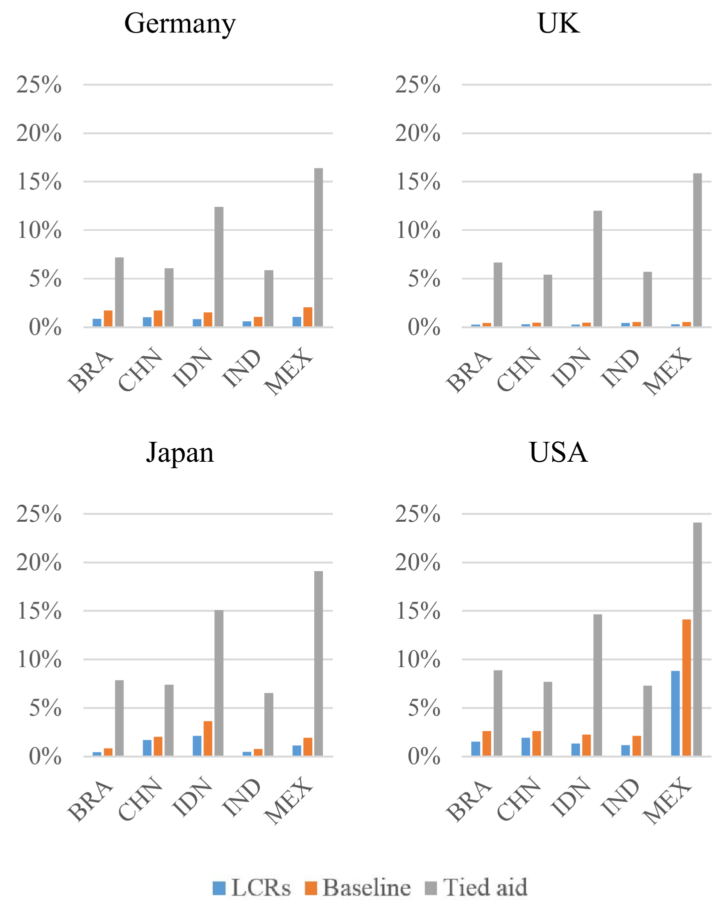
4.4.Results

In this section we will summarize the main results of the scenario analysis regarding the size of the spill-overs in terms of value-added of climate finance on donor countries, which depends on three factors: 1) the action in which climate finance is employed; 2) the country hosting the climate action; and 3) the scenario. The exposition is firstly centred on the impact at country level. These overall results are then linked to the most influential industries in each case, using the results disaggregated at sectoral level.

4.4.1. Country level

Figure 13 shows the spill-overs captured by each donor country depending on the host country for the three scenarios. It shows that, for example, out of every USD 100 spent on climate actions in Mexico, assuming that international trade was as in 2011 (i.e. baseline scenario), USD 14 would end up in the USA, as a result of requirements of goods and services produced in the USA for undertaking the climate actions. If the USA were the donor, and the aid was granted with the condition that required imports would come from the USA (i.e. tied aid scenario), then the USA would capture USD 24, instead of USD 14. If, contrarily, Mexico imposed as precondition for the receipt of aid, that all suppliers would be Mexican, then the USA would capture only nine dollars through the imports of intermediate inputs by Mexican industries.

Figure 13. Spill-overs by recipient country and scenario



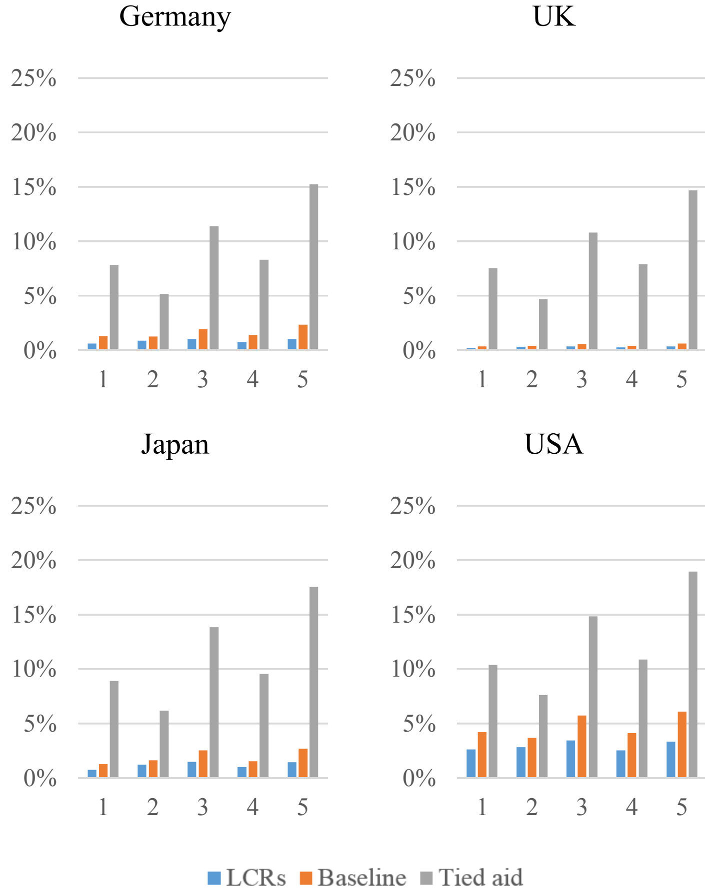
Source: Own work. Abbreviations: BRA (Brazil), CHN (China), IDN Indonesia), IND (India), MEX (Mexico).

As expected, the lowest spill-overs correspond to the LCR scenario, and the highest ones to the tied aid scenario, while spill-overs of the baseline scenario lie between these two extremes. Note that the USA is the donor capturing the largest spill-overs in all scenarios (an average of 7%), followed by Japan (5%) and Germany (4%). The UK is the donor with the smallest spill-overs independently of the scenario (3%). In some cases spill-overs differ depending on the host country. In the baseline and LCR scenarios, Germany and the UK capture similar spill-overs from all host countries (between 0% - 2%). Japan captures relatively large spill-overs from Indonesia (2% - 4%) and the USA captures large spill-overs from Mexico (9% - 14%).

On the one hand, the tied aid scenario leads to higher levels of spill-overs captured by donors than those of the baseline scenario. The increase of spill-overs captured by donor countries ranges from 4 to 17 pp, with an average increase of 8.4 pp. The tied aid especially increases spill-overs produced by climate finance disbursed in Mexico and Indonesia. These two countries become the host countries producing largest spill-overs for all donors in this scenario. Thus, Japan would capture 17 pp more from Mexico, the UK and Germany 15 pp and 14 pp more (respectively) also from Mexico, and the USA 12 pp more from Indonesia. On the other hand, the LCR scenario would produce relatively unimportant differences for all donors (less than 0.9 pp) except in the case of the USA, where spill-overs from Mexico are reduced 5 pp. The LCR scenario reduces the differences in the spill-overs obtained with different countries (standard deviations are reduced an average of 0.6 pp), whereas the tied aid scenario accentuates these differences (an average increase of standard deviations of 3.4 pp).

Figure 14 contains the spill-overs captured by each donor country depending on the climate action group for the three scenarios. It shows that the tied aid scenario produces a large increase in spill-overs for all donors independently of the climate actions implemented. Certain types of climate actions generate larger spill-overs than others. Groups 5 and 3, including climate actions that intensively use machinery and equipment, stand out as the ones generating the largest spill-over effects. The tied aid scenario increases especially spill-overs from group 5, producing an increase of 14 pp on average. Japan is the country experiencing the largest increase (15 pp), then the UK (14 pp), and finally Germany and the USA (13 pp, each). Groups 1 and 2, representing actions that intensively use goods from the agriculture and construction sectors, are the groups that produce the lowest spill-overs in the baseline scenario. Again, the LCR scenario reduces the differences in the spill-overs obtained with different climate actions groups, whereas the tied aid scenario accentuates them (standard deviations changes are -0.3 and +3.2 pp, respectively). The largest decrease produced by the LCR scenario is in spill-overs to the USA in climate actions of group 5 (3 pp).

Figure 14. Spill-overs by climate action groups and scenario



Source: Own work.

The best combinations of host country and climate action, in terms of the size of the spill-overs captured by donors, vary depending on the scenario. **Table 13** in the Appendix (Section 4.7.1) contains the five combinations producing the largest spill-overs for each donor and scenario.

In the case of Germany, the best options in the baseline scenario include actions of groups 3 and 5 in different host countries (Mexico, China, Indonesia and Brazil), producing an average spill-over of 2.6%. In the tied aid scenario the best options consist on a larger set of climate actions (from groups 1, 3, 4 and 5) especially in Mexico (but also in Indonesia), with an average spill-over of 19%. In the LCR scenario, the best five combinations are actions of groups 3 and 5 in Mexico, China or Indonesia (Brazil disappears from the best options) with an average spill-over of 1.2%.

The case of the UK is similar to that of Germany. In the baseline, actions of groups 3 and 5 in a wide set of host countries (China, Indonesia, Mexico and India) are the best combinations, with spill-overs of 0.7% in average. In the tied aid scenario, the largest spill-overs (18.6% in average) come from a wide range of actions (from groups 1, 3, 4 and 5) in Mexico and Indonesia. In the LCR scenario the best options, with spill-overs of 0.4% in average, involve actions of groups 3 and 5 especially in India, but also in Mexico and Indonesia (China disappears from the best options).

For Japan, combinations producing the highest spill-overs in the baseline scenario (3.9% in average) are concentrated in two countries (Indonesia and China) and mainly in two groups of actions (3 and 5, although group 2 also appears). In the tied aid scenario, Mexico replaces China, and a wider set of actions (from groups 1, 2, 4 and 5) in Indonesia and Mexico are the best combinations (generating spill-overs of 22.4% on average). The set of best combinations for Japan for the LCR scenario remains the same as in the baseline.

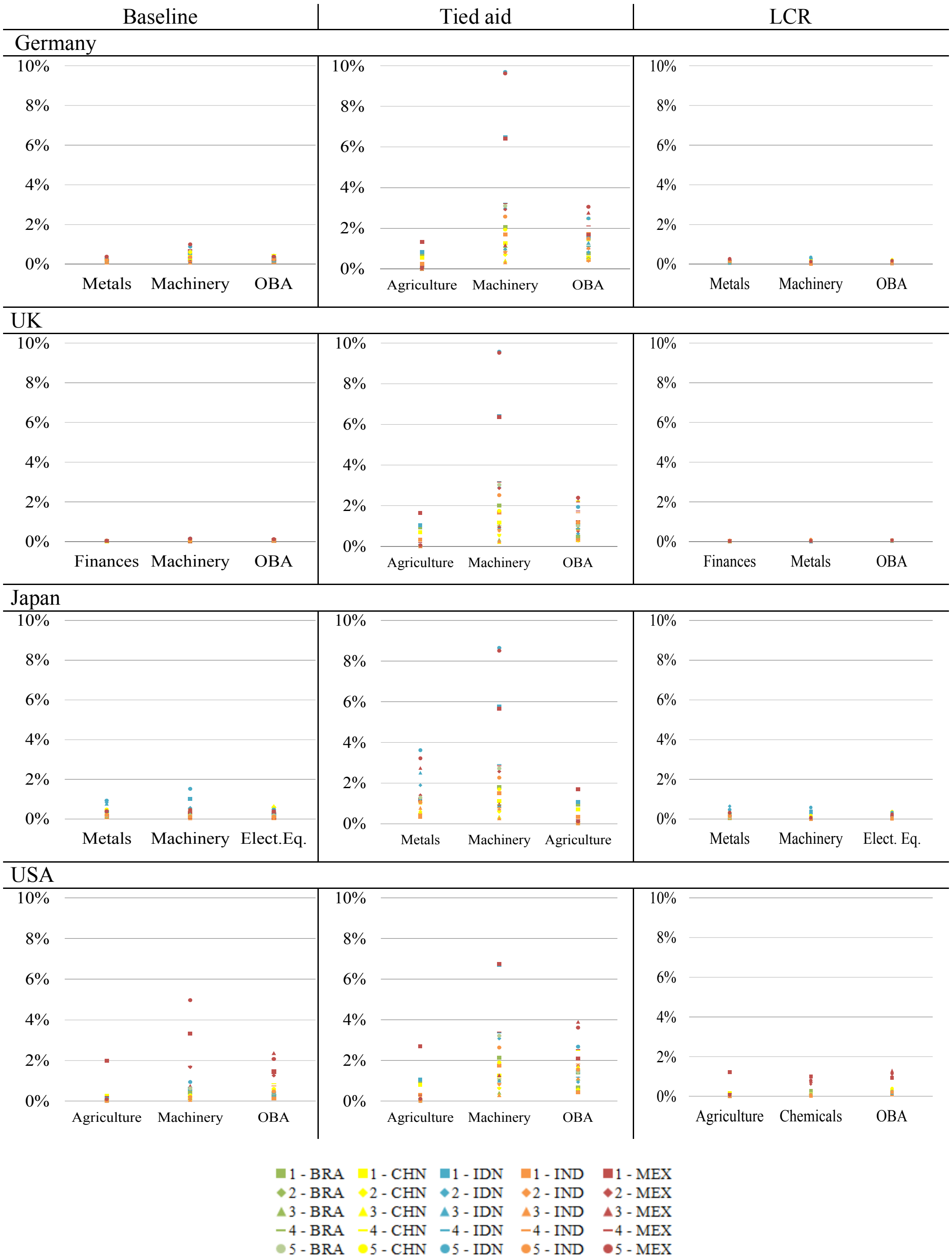
In the case of the USA the set of best options does not change qualitatively with different scenarios. The best options involve any type of action in Mexico. Nevertheless, the size of the spill-overs produced by this set of combinations changes from an average of 14% in the baseline scenario to 26% in the scenario with tied aid, and to 8.8% with LCR.

4.4.2. Industry level

Figure 15 shows the three industries capturing the largest shares of spill-over effects in each donor country and scenario. It also informs about the type of climate action and the host country producing the spill-overs in each case.

In the baseline scenario, the German industries that receive the largest spill-overs (around 1%) are machinery (especially due to actions of groups 5), OBA (especially due to actions implemented in China) and metals (especially due to actions undertaken in Mexico). In the tied aid scenario, the machinery and OBA industries continue being amongst the most benefitted by spill-overs, which this time are close to 10%.

Figure 15. Spill-overs by donor, scenario, action group and recipient country



Source: Own work. Abbreviations: BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico), OBA (other business activities), Electr. Eq. (electrical and optical equipment);

The German machinery industry benefits from actions of groups 1 and 5, especially in Mexico and Indonesia. OBA's spill-overs are originated in actions of groups 3, 4 and 5 implemented in Indonesia, China and Mexico. In this scenario, the German agriculture sector is the third most benefitted (instead of the metals industry), due to actions of group 1 in Mexico, Indonesia and Brazil. The results of the LCR scenario are very similar to those obtained in the baseline scenario.

The results for British industries resemble those obtained for German ones, with slight differences. In the baseline scenario, the largest spill-over effects are around 0.2% and take place, along with the machinery and OBA sectors, in the sector of financial intermediation (especially due to actions implemented in India). In the LCR scenario, the main beneficiaries of the rather small spill-over effects (0.1%) are the metals industry (from India), OBA (from Mexico and China) and the financial intermediation (from India).

The Japanese industries that benefit most from spill-overs (around 1.5%) in the baseline scenario are the machinery and metals sectors (due to actions in Indonesia) and the industry of electronic equipment (especially from actions in China). In the tied aid scenario, the largest spill-overs (8.7%) are captured by the machinery and metals sector (this time due to actions in Mexico and China), and also by the agriculture sector (associated to actions of group 1). The results of the LCR scenario are very similar to those obtained in the baseline scenario.

American industries capturing the largest spill-overs (approx. 5%) in the baseline scenario are machinery, OBA and agriculture (especially due to actions undertaken in Mexico). In the tied aid scenario the largest spill-overs are captured by the same set of industries, although the size of the spill-over effects doubles and it involves actions not only in Mexico but also in Indonesia. In the LCR scenario, the largest spill-overs (1.3%) are captured by OBA, agriculture and the chemical industry from actions in Mexico.

We have observed that in all cases (for all donors) the most affected industry, both by tied aid and LCR, is machinery. Tied aid increases spill-overs captured by donors' machinery industry 2.19 pp on average, while LCR reduce them 0.3 pp on average.

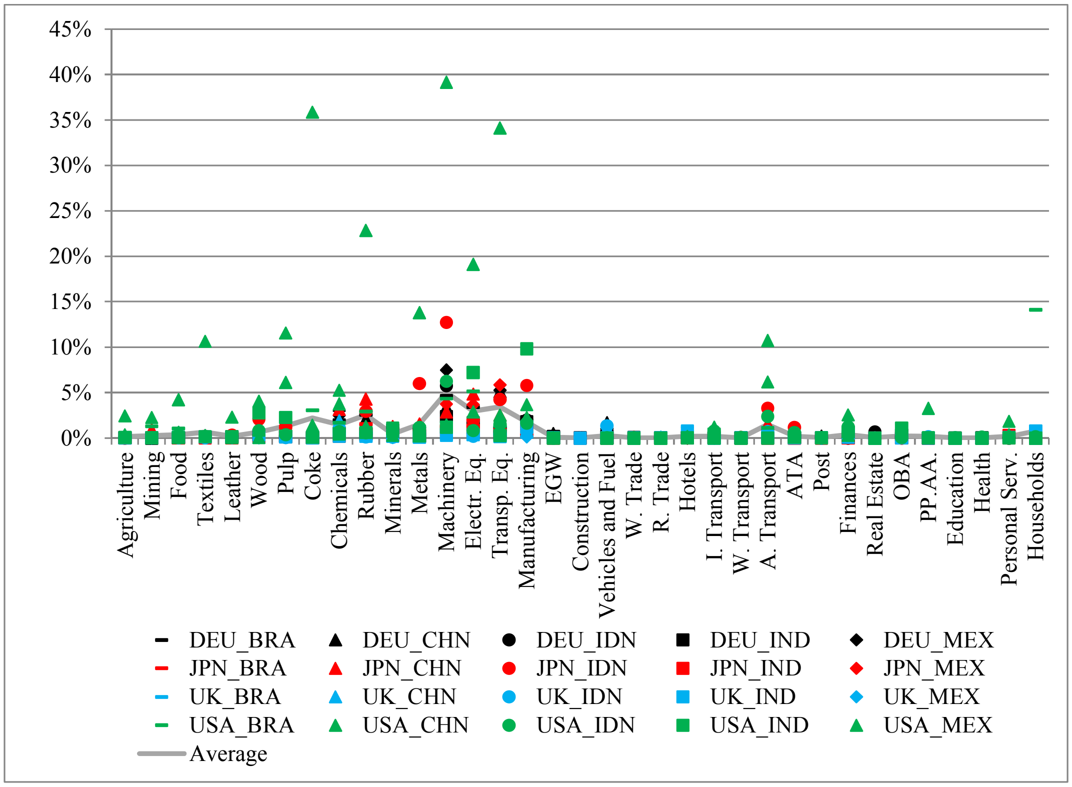
4.5.Discussion

According to the results presented in the previous section, the spill-overs resulting from the baseline scenario differ between donors. **Figure 16**, illustrating the trade shares of each donor in each recipient country for the different sectors of the economy, clearly shows that the USA is a prominent provider in many sectors for recipient countries, compared with other donors. In most manufacturing sectors, Japan and Germany also produce significant shares of the recipient countries' imports. In the light of this information, it is easy to see that if the UK is the donor with the smallest spill-overs this is, in part, due to the limited share that the UK final goods and services represent on these countries' purchases. It is also worth noting that in the case of the USA, the largest trade shares are in Mexico, and in the case of Japan, in Indonesia and China. This suggests that the geographic proximity is relevant for trade linkages between countries.

Besides, the average of trade shares (grey line in **Figure 16**) shows that the industries where donors have the largest portions of sales of final products to recipient countries are the machinery and electrical and transport equipment industries. This explains why groups 3 and 5 are those producing the largest spill-overs. These groups comprise climate actions related to the deployment of renewable energy and the construction of infrastructures for energy efficiency, water and waste management, with substantial requirements of machinery and equipment. The high dependence of recipient countries on international trade for these types of products would also explain that spill-overs from these industries are especially sensitive to both tied aid and LCR conditions.

Figure 16 also shows that agriculture, food and construction are among the economic activities with the lowest penetration of donors' exports. **Figure 17**, representing the share of the final demand that is domestically produced in each recipient country by industry, confirms the relevance of local production in these sectors. This would also explain that spill-overs resulting from climate actions with intensive use of agricultural products and construction services, like those clustered in the first two groups, are small.

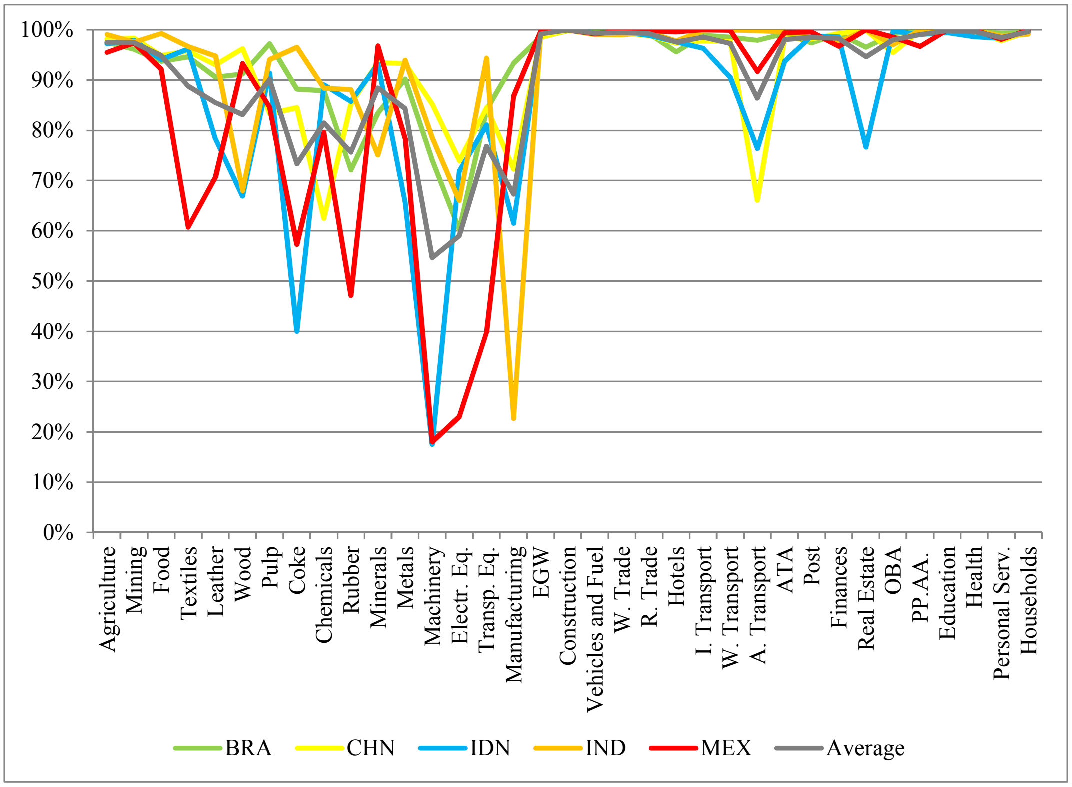
Figure 16. Trade shares in recipient countries by donors' industries



Source: Own work based on WIOD. Abbreviations: DEU (Germany), UK (United Kingdom), JPN (Japan), USA (United States of America), BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico), Electr. Eq. (electrical and optical equipment), Transp. Eq. (transport equipment), EGW (electricity, gas and water supply), W. Trade (wholesale trade), R. Trade (retail trade), I. Transport (inland transport), W. Transport (water transport), A. Transport (air transport), ATA (auxiliary transport activities), OBA (other business activities), PP.AA. (Public Administrations), Personal Serv. (personal services).

According to sectoral results of the baseline scenario, donors' industries with the lowest penetration rates in the recipient countries (like metals, financial intermediation, OBA and agriculture) also capture spill-overs. We might find an explanation for this in **Figure 18**, which contains production multipliers. These multipliers reflect the magnitude of indirect effects on donors' industries via the purchases of intermediate inputs by host countries' industries. Indirect effects enable industries not directly involved in the supply of final goods and services for the funded actions to participate in the associated economic benefits through their contribution to the value chain of industries directly involved. Moreover, financial intermediation, OBA and agriculture in donor countries are also characterized by high value-added intensity (see **Figure 19**), something that contributes to explain spill-overs captured by these sectors.

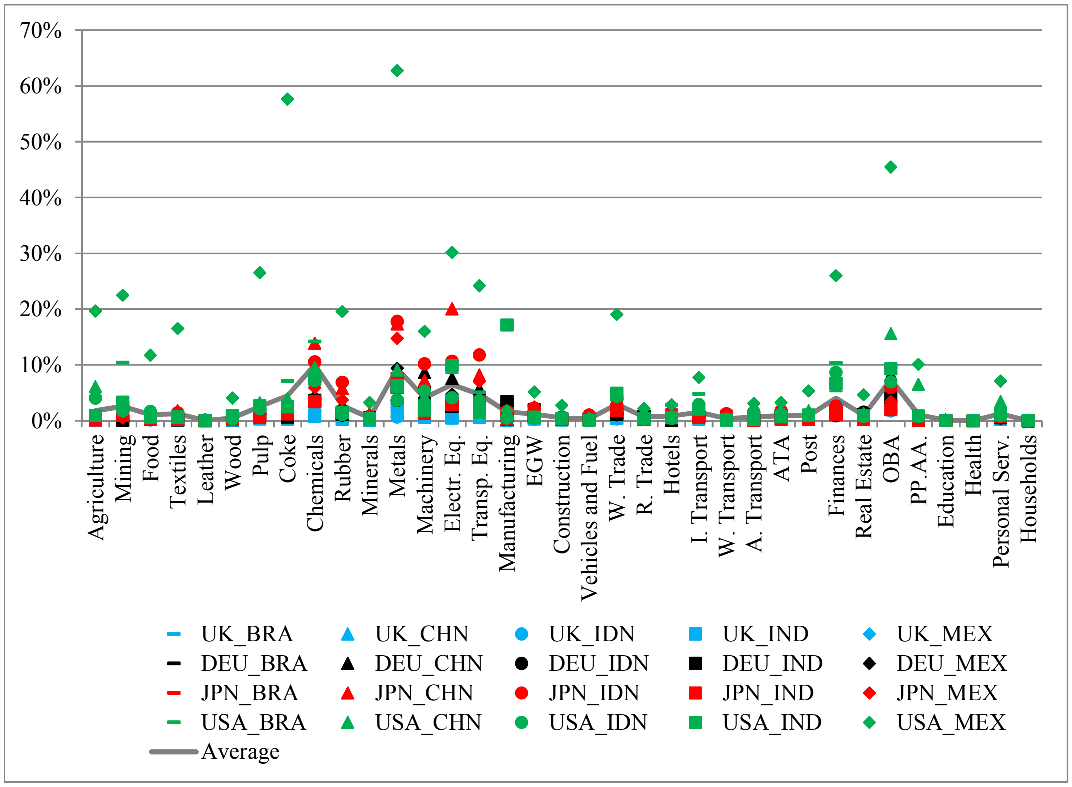
Figure 17. Share of domestic production in recipient countries by industry



Source: Own work based on WIOD. Abbreviations: BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico), Electr. Eq. (electrical and optical equipment), Transp. Eq. (transport equipment), EGW (electricity, gas and water supply), W. Trade (wholesale trade), R. Trade (retail trade), I. Transport (inland transport), W. Transport (water transport), A. Transport (air transport), ATA (auxiliary transport activities), OBA (other business activities), PP.AA. (Public Administrations), Personal Serv. (personal services).

Coming back to **Figure 17**, we see that Indonesia and Mexico are the countries where, being the local production more limited, imports represent a large share of the total demand. This explains why, in a scenario with tied aid (i.e. donors supplying all imports), spill-overs from these countries increase specially (something that puts them in the first positions amongst donors' best options in the tied aid scenario).

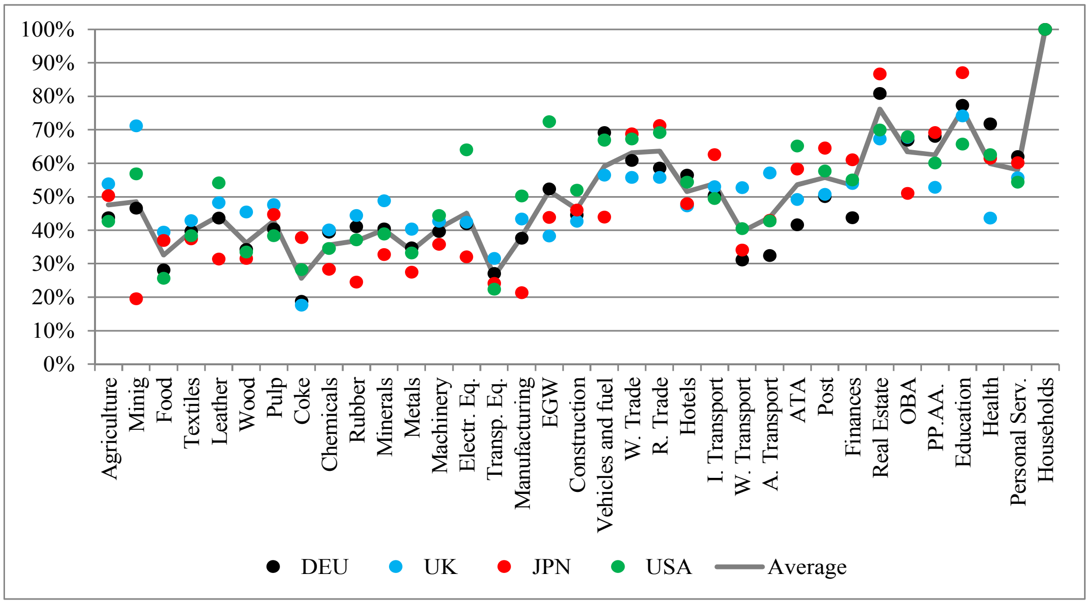
Figure 18. Indirect effects in donors' industries by recipient country



Source: Own work based on WIOD. Abbreviations: DEU (Germany), UK (United Kingdom), JPN (Japan), USA (United States of America), BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico), Electr. Eq. (electrical and optical equipment), Transp. Eq. (transport equipment), EGW (electricity, gas and water supply), W. Trade (wholesale trade), R. Trade (retail trade), I. Transport (inland transport), W. Transport (water transport), A. Transport (air transport), ATA (auxiliary transport activities), OBA (other business activities), PP.AA. (Public Administrations), Personal Serv. (personal services).

Similarly, the machinery and equipment (electrical and transport) industries have on average low shares of domestic production. Again, this might explain why the tied aid scenario produces especially large spill-overs in the case of climate actions of groups 3 and 5 (where these industries represent a relevant share of the expenses). However, the fact that tied aid increases particularly spill-overs for the USA and Japan cannot be explained by trade shares on final products since, by definition, all donors would have the same trade shares in the tied aid scenario. We find an explanation in **Figure 18**: the high multiplier effects on Japanese and USA industries, compared with other donor countries. The fact that tying aid increases spill-overs captured by the agricultural sector in all the donors seems to be related to the high value-added intensity of this sector in donor countries (see **Figure 19**).

Figure 19. Value-added intensity in donors' industries



Source: Own work based on WIOD. Abbreviations: DEU (Germany), UK (United Kingdom), JPN (Japan), USA (United States of America), Electr. Eq. (electrical and optical equipment), Transp. Eq. (transport equipment), EGW (electricity, gas and water supply), W. Trade (wholesale trade), R. Trade (retail trade), I. Transport (inland transport), W. Transport (water transport), A. Transport (air transport), ATA (auxiliary transport activities), OBA (other business activities), PP.AA. (Public Administrations), Personal Serv. (Personal services).

With 100% of LCR, spill-overs are limited to impacts produced indirectly, in the second and subsequent rounds of purchases between industries. They are, therefore, related to international trade of intermediate inputs. As already mentioned, **Figure 18** depicts the indirect effects triggered by expenditure in recipient countries. The average values show that some sectors producing intermediate goods and services for other industries (like chemicals, metals, electrical equipment, financial intermediation and OBA) are those that receive the largest indirect impacts via the imports of recipient countries' industries. This is in line with the sectoral results of the LCR scenario. This scenario results detrimental for the machinery industry of donor countries, being its impacts reduced from the current large direct impacts (via exports of final products) to more limited indirect impacts (via purchases of intermediate inputs by local industries). However, spill-overs in this scenario are not negligible for some combinations of donors and recipient countries, like the USA-Mexico (9%), USA-China (2%), Japan-Indonesia and Japan-China (both 2%). All these combinations are associated to high indirect effects (as depicted in **Figure 18**).

4.6.Conclusion

According to our estimates, tied aid would substantially increase donors' share of spill-overs: from 4 to 17 pp, with an average increase of 8.4 pp. The industry of machinery, very relevant for the deployment of renewable energy technologies, is especially sensitive to the tied aid scenario with spill-overs going from around 1% to close to 10%. Thus, with tied aid, the penetration of products from donor countries would augment specially in sectors related to mitigation. Also, those destinations more dependent on international supplies to satisfy their final demand are especially sensitive to the tied aid scenario (spill-overs from Mexico and Indonesia increase around 10 pp with tied aid). Tied aid accentuates the differences between alternative locations and climate actions regarding their potential to generate spill-overs for donors, something that increases the incentives to maintain the current concentration of disbursements (on mitigation projects in few countries) reported by OECD (OECD and CPI, 2015).

Given the incentives to tie aid, and since bilateral channels facilitate this practice, the type of channel chosen to deliver the funds becomes thus an important factor in the discussion. Multilateral funds are less susceptible to be used by donors to promote their exports. Some multilateral agencies, like the World Bank's Climate Investment Funds, enable donors to earmark their contributions to objectives aligned with their interests, but not to tie aid directly. In the case of the GCF, donors cannot even earmark their contributions. Having GCF financing decisions to be agreed by representatives of developing and developed countries (equal in number and by consensus) is a good safeguard to avoid temptation of tying aid. Thus, as far as contributions towards the USD 100 billion goal are channelled through the GCF or similar multilateral funds, tied aid becomes less probable. Ultimately this means that the magnitude of spill-overs would be limited, and a larger share of the aid's positive economic impact will remain in recipient countries. This becomes more important given the increasing relevance of new donors which have openly adopted the practice of tying aid.

In this study emerging countries are considered as net recipients of climate aid, when in fact, they are also becoming relevant donors. These new donors are also adopting the practice of tying aid. China provides concessional loans to states aligned with the purpose of stimulating exports of Chinese mechanical and electrical products. These loans are tied to the requirement that at least 50% of the total amount of the loan is spent in Chinese materials, techniques and services. India refuses to accept tied aid but much of the development aid India offers to other countries is tied, with a substantial part spent in India. Its aid policy is motivated not only by altruism but also by economic benefits (Ahmad, 2011). Thus, it would be interesting to analyse the implications of the three analysed scenarios in the case of South-to-South climate cooperation.

On the other hand, LCR do not seem to have a relevant impact on donors' spill-overs. These would decrease less than 0.9 pp on average. LCR affect especially the machinery industry of donor countries. Nevertheless, donor countries participating in GVC are still able to capture a share of the economic benefits of climate action in developing countries via international trade of intermediate inputs. This suggests that, in the absence of other issues, the chances that donors would avoid recipient countries that impose LCR are relatively low. Besides, LCR would reduce the incentive to concentrate finance on mitigation as a way to increase sales of export-oriented sectors, since with LCR spill-overs are rather indirectly captured and also from sectors contributing to tackle adaptation needs.

This type of policy may contribute to increase the impact of climate finance in the short run and to generate (green) industrial activity in the recipient country, but it might not suffice to developing globally competitive industries. LCR cannot avoid spill-overs from indirect effects via trade in intermediate inputs and tasks. Thus, industrial development policies have to put attention on intermediate goods producers, and focus in a specialization on high value-added tasks.

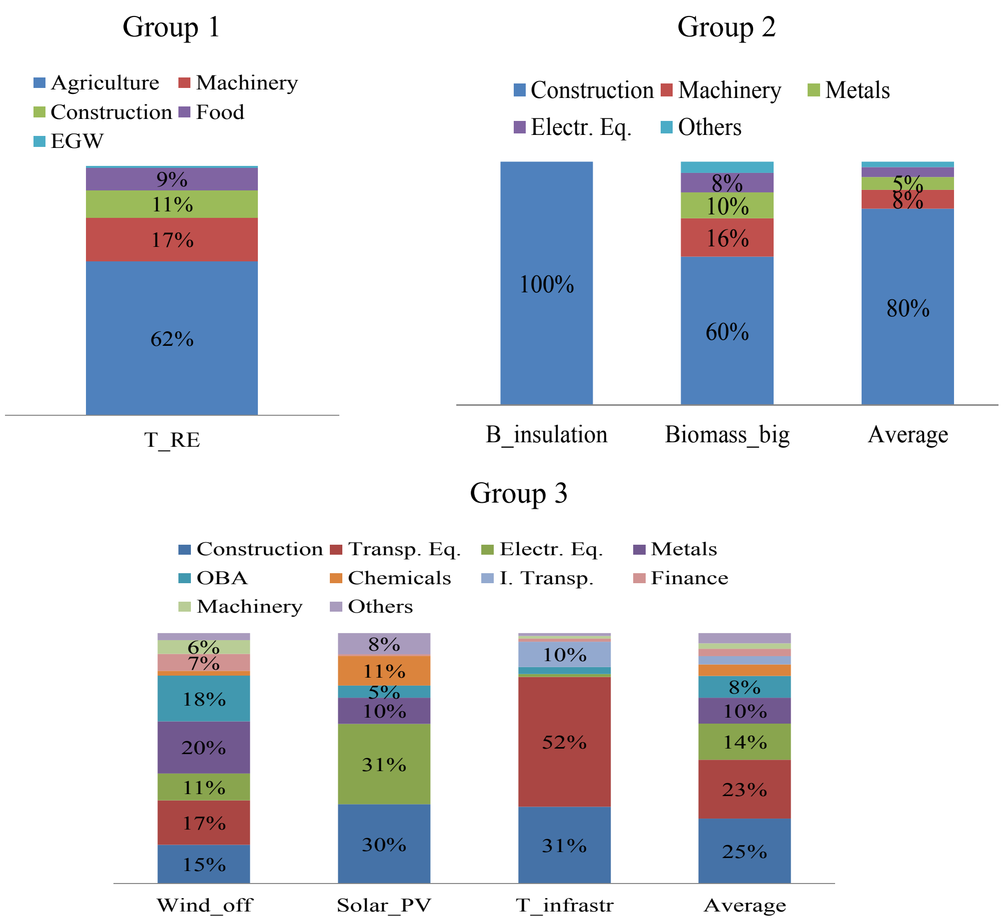
Note that the employed methodology entails several limitations. First of all, the limitations derived from the IO model assumptions: constant returns to scale, linear production function, lack of substitution possibilities, homogeneity of input factors, underutilization of the economy and constancy of input coefficients over time. These assumptions imply that the economies can expand without putting pressure on prices and wages, that technology does not change and that the different activities within a certain sector are equal (Madlener and Koller, 2007). Hence, this methodology is only appropriate to assess interventions in the medium term that, because of their limited dimension relative to the economy size, would not affect factors availability and prices (as it is our case). Second, the WIOD has its own weaknesses related to measurement issues regarding imports by use category, trade in services and intangibles, exports and imports for processing, among others (Timmer et al., 2015).

Finally, there is uncertainty about how the different expenditures are allocated over the different sectors of the model, since the cost breakdown of climate actions can vary depending on the country and the specific purpose of the project. Despite these limitations, the approach used is a good and robust tool to calculate the spill-over effects associated to international trade.

4.7. Appendix

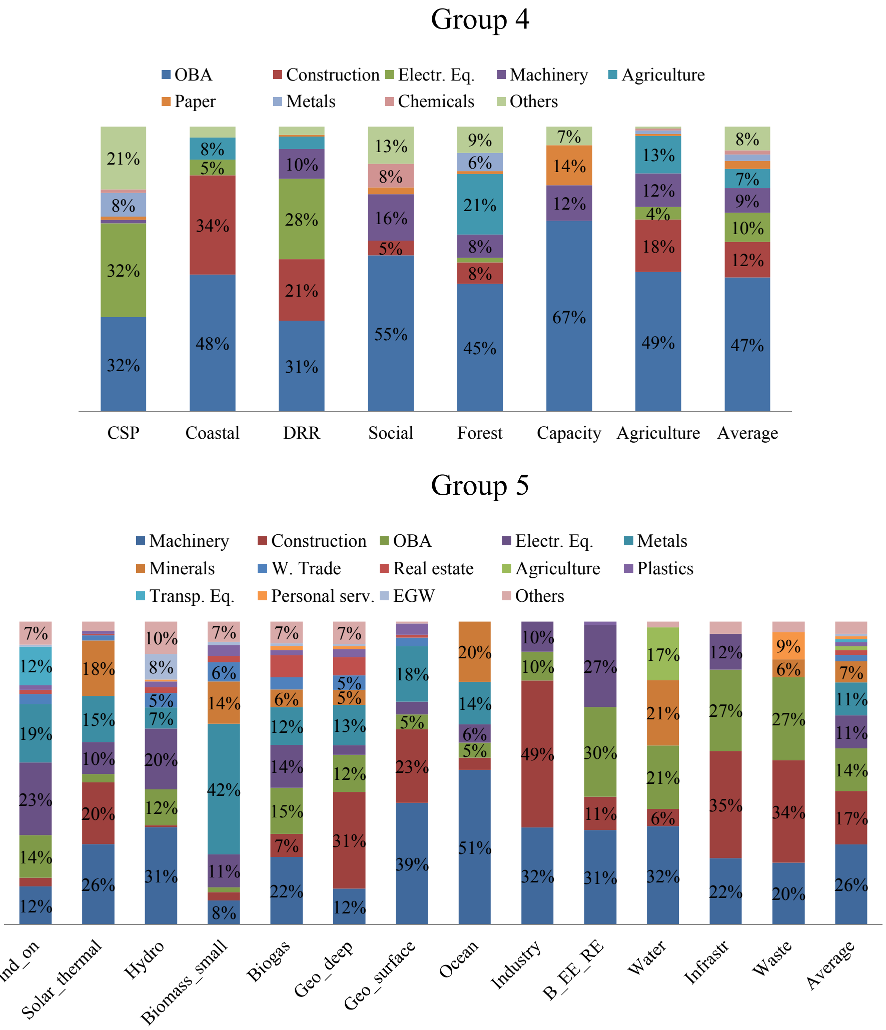
4.7.1. Additional figures and tables

Figure 20. Cost structure by group



Source: Own work. Abbreviations: EGW (electricity, gas and water supply), Electr. Eq. (electrical and optical equipment), Agriculture. (agriculture,fishing and livestock), B_insulation (building insulation), B_EE_RE (renewable energy and energy efficiency in buildings), Biogas (biogas power), Biomass_big (biomass energy large scale), Biomass_small (biomass energy small scale), Capacity (capacity building), Coastal (coastal protection), CSP (concentrated solar power), DRR (disaster risk reduction), Forest (forestry and land use/ terrestrial Ecosystems), Geo_deep (deep geothermal energy), Geo_surface (surface geothermal power), Hydro (hydropower), Industry (energy efficiency in industry), Infrastr (human settlements, infrastructure and spatial planning), Ocean (ocean power), Social P. (social protection), Solar PV (photovoltaics), Solar_thermal (solar thermal energy), T_infrastr (infrastructures for transport), T_RE (renewable energy in transport, biofuels), Waste (waste and wastewater), Water (water supply and management), Wind_off (offshore wind power), Wind_on (onshore wind power).

Figure 20. Cost structure by group (cont.)



Source: Own work. Abbreviations: EGW (electricity, gas and water supply), Electr. Eq. (electrical and optical equipment), Agriculture. (agriculture,fishing and livestock), B_insulation (building insulation), B_EE_RE (renewable energy and energy efficiency in buildings), Biogas (biogas power), Biomass_big (biomass energy large scale), Biomass_small (biomass energy small scale), Capacity (capacity building), Coastal (coastal protection), CSP (concentrated solar power), DRR (disaster risk reduction), Forest (forestry and land use/ terrestrial Ecosystems), Geo_deep (deep geothermal energy), Geo_surface (surface geothermal power), Hydro (hydropower), Industry (energy efficiency in industry), Infrastr (human settlements, infrastructure and spatial planning), Ocean (ocean power), Social P. (social protection), Solar PV (photovoltaics), Solar_thermal (solar thermal energy), T_infrastr (infrastructures for transport), T_RE (renewable energy in transport, biofuels), Waste (waste and wastewater), Water (water supply and management), Wind_off (offshore wind power), Wind_on (onshore wind power).

Table 12. Climate actions and sources of information

Type and abbreviation	Source
Onshore wind power (Wind_on); Offshore wind power (Wind_off); Photovoltaics (Solar PV); Solar thermal energy (Solar_thermal); Hydropower (Hydro); Biomass energy large scale (Biomass_big); Biomass energy small scale (Biomass_small); Biogas power (Biogas); Deep geothermal energy (Geo_deep); Surface geothermal power (Geo_surface); Concentrated solar power (CSP)	Lehr (2008,2012)
Ocean power (Ocean)	Allan et al., (2008)
Renewable energy in transport (T_RE); Energy efficiency and renewable energy in buildings (B_EE_RE); Insulation of buildings (B_insulation); Energy efficiency in industry (Industry); Infrastructures for transport (T_infrastr)	Markaki et al., (2013)
Coastal protection (Coastal)	NAPAs Gambia #9, Cape Verde #3, Sierre Leone #18
Disaster risk reduction (DRR)	NAPAs Gasmbia #1, Bhutan #5#7#9, Sierre Leone #2
Water supply and management (Water)	NAPAs Sudan #2, Sierre Leone #12, Tuvalu #3
Human settlements, infrastructure and spatial planning (Infrastr)	NAPAs Tanzania #5, Sierre Leone #8, Gambia #6, Maldives #10, Bhutan #6, Samoa #6, Maldives#8
Social protection (Social P.)	NAPAs Malawi #1, Lesotho #8, Sierre Leone #23
Waste and wastewater (Waste)	NAPAs Sierre Leone #22, Maldives #5
Forestry and land use/ Terrestrial Ecosystems (Forest)	NAPAs Eritrea #3, Lesotho #6, Tuvalu#5, Burundi #3, Bhutan #11
Capacity-building (Capacity)	NAPAs Burundi #11, Malawi #5, Sierre Leone #5
Agriculture, fishing and livestock (Agriculture)	NAPAs Sierre Leone #5#7, Eritrea #2, Maldives #9

Source: Own work based on literature (Blazejczak et al., 2014; Buchner et al., 2013; OECD/IEA, 2014; Prowse and Snilstveit, 2010; REN21, 2014, p. 21; UNFCCC, 2014b)

Table 13. Top five options for each donor by scenario

Baseline		Tied aid		LCRs	
Germany					
MEX5	2.94%	MEX5	25.15%	MEX3	1.36%
CHN3	2.64%	IDN5	22.15%	MEX5	1.24%
MEX3	2.59%	MEX3	21.50%	CHN3	1.23%
IDN5	2.47%	MEX1	13.64%	IDN5	1.17%
BRA5	2.44%	MEX4	13.21%	CHN5	1.15%
UK					
CHN3	0.72%	MEX5	24.50%	IND2	0.55%
IDN5	0.68%	IDN5	21.62%	IND3	0.49%
MEX5	0.67%	MEX3	20.64%	IND5	0.47%
IND5	0.65%	MEX1	13.35%	MEX3	0.35%
IND3	0.61%	MEX4	12.80%	IDN5	0.34%
Japan					
IDN5	5.48%	MEX5	29.00%	IDN5	2.82%
IDN3	3.96%	MEX3	26.11%	IDN2	2.32%
CHN3	3.41%	IDN5	26.08%	IDN3	2.28%
CHN5	3.24%	MEX1	15.44%	CHN3	2.11%
IDN2	3.20%	MEX4	15.17%	CHN5	1.93%
USA					
MEX5	17.83%	MEX5	33.52%	MEX3	10.37%
MEX3	17.00%	MEX3	30.18%	MEX5	9.60%
MEX1	14.06%	IDN5	25.86%	MEX1	8.63%
MEX2	10.84%	MEX1	21.37%	MEX2	8.28%
MEX4	10.82%	MEX4	19.60%	MEX4	7.14%

Source: Own work. Abbreviations: BRA (Brazil), CHN (China), IDN (Indonesia), IND (India), MEX (Mexico).

4.7.2. Methodology

This appendix provides details about the quantification with GMRIO tables of spill-over effects on donor countries in terms of value-added. Similar methods have been previously used, for example, in Markandya et al. (2016).

We start from the following information contained in GMRIO tables: $\mathbf{x}^r$ is the column vector of gross outputs in country r. The inverse of the diagonal matrix of this vector is denoted as $\left(\hat{\mathbf{x}}^r\right)^{-1}$. $\mathbf{w}^r$ 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. With those elements, we calculate the column vector of value-added coefficients as $\mathbf{v}^r = \left(\hat{\mathbf{x}}^r\right)^{-1} \mathbf{w}^r$.

Moreover, $\mathbf{Z}^{rs}$ 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. We calculate the matrix of input coefficients as $\mathbf{A}^{rs} = \mathbf{Z}^{rs}\left(\hat{\mathbf{x}}^s\right)^{-1}$ and the Leontief inverse matrix as $\mathbf{L} \equiv \left(\mathbf{I}\text{-}\mathbf{A}\right)^{-1}$, where $\mathbf{I}$ is an identity matrix of the appropriate dimension. $\mathbf{L}^{rs}$ contains production multipliers of country r associated with demand in country s.

Next, $\mathbf{f}^{st}$ 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 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 produced domestically (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 in the baseline scenario. For the construction of the other two scenarios, we substitute certain terms of this vector. We illustrate the procedure using an example with three countries, where 1 is the donor country, 2 is the recipient country and 3 is another country. Then, in the baseline scenario $\mathbf{t}_B^{s2} = \begin{pmatrix} t^{12} \\ t^{22} \\ t^{32} \end{pmatrix}$, in the tied aid scenario $\mathbf{t}_T^{s2} = \begin{pmatrix} t^{12} + t^{32} \\ t^{22} \\ 0 \end{pmatrix}$ and in the LCRs scenario $\mathbf{t}_L^{s2} = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$.

Finally, we define $\mathbf{e}^a$ as the column vector of the demand shock, with elements e_j^a indicating the proportion of expenditure on a specific climate action a spent in sector j. We assume that this expenditure by sector is expressed at basic prices, i.e. excluding taxes and transport and trade margins. With these elements we can calculate the value-added created in the donor country r as a consequence of the implementation of climate action a in the recipient country t as $\mathrm{w}^{rta} = \sum_s \mathbf{v}^{r}{}'\mathbf{L}^{rs}\mathbf{t}^{st} \otimes \mathbf{e}^a$, where $\otimes$ denotes the Hadamard product (i.e. the element by element multiplication).

5. Conclusions

5.1. Introduction

In 2016, shortly before the 22nd COP in Marrakech, developed countries released the USD 100 billion goal roadmap for 2020 (UK Government and Australian Government, 2016). According to this roadmap, the EU will transfer on average from 2014 to 2020 more than USD 2 billion per year to developing countries. Within the EU, Germany and the UK have decided to double international support in 2020 compared to 2014. Japan also expects to mobilize more than USD 11 billion to support developing countries' climate actions, including public and private sources of finance. The USA has promised to increase its annual transfers for adaptation projects in developing countries in more than USD 400 million. According to the OECD (2016), these commitments coupled with conservative estimates regarding private-public finance ratios, would be sufficient to meet the USD 100 billion goal.

In this context of increasing North-to-South climate finance flows, the objective of this thesis has been to study the economic impact of the climate finance disbursements associated to mitigation and adaptation actions, not only in the countries hosting the actions but also in the rest of the world. In other words, we have performed an economic impact assessment of climate finance disbursements at a global level. This chapter summarizes the main findings, policy implications and conclusions of this assessment and indicates possible extensions for future research.

5.2. Summary of findings

5.2.1. International trade redistributes one share of the economic impact of climate finance away from recipient countries.

The analysis in this thesis has permitted to focus on the economic benefits associated to climate finance disbursements, showing that international trade determines the distribution of these benefits between the recipient country and the rest of the world. Results confirm that only one part of the total disbursement of climate finance remains in the recipient country as remuneration of domestic labour and capital directly or indirectly employed in the implementation of climate actions. The remaining share of the disbursement corresponds to the compensation of foreign production factors that also participate in the fabrication of the products needed for the deployment of climate actions. This share constitutes the spill-over effect of climate finance.

The three research questions that were posed in Chapter 2, were the following: *(i) How are the economic impacts of climate actions distributed between countries? (ii) How much of the impact spills over to non-recipient countries? And, (iii) how much impact is captured by each donor country?*

Regarding the first two questions, the analysis finds that on average 71% of the impact remains in the recipient country and 29% spills over to other countries. Nevertheless, the geographic distribution of the economic impact of climate finance and the volume of spill-overs varies depending on the country receiving the disbursement. Domestic impacts range from 61% to 80% and spill-overs from 20% to 39%. **Figure 3** in Chapter 2 illustrates the resulting distribution of the economic benefits for each recipient country considered. India and Brazil are the recipient countries with the largest shares of local impact, approaching 80%. Even for the same recipient country, the geographic distribution and the magnitude of spill-overs can be very different depending on the type of climate action implemented. Certain types of actions have greater local impact than others. In particular, adaptation and energy efficiency measures, which require significant services from the domestic construction sector, are those that result in the greatest local impact. Other actions such as the deployment of renewable energy sources are dependent on imported machinery and equipment and, consequently, generate large spill-overs.

With regard to the third question, the analysis shows that spill-overs captured by donor countries range from 10% to 28%, depending on the donor country, on the climate action implemented and on the country receiving the funds. On average, the EU is the donor that benefits most from international spill-overs (6.8%). These results can be used to rank the combinations of locations and climate actions based on their potential to generate spill-overs for each donor country.

5.2.2. The relevance of each of the factors determining the size of the economic impact of climate finance varies with the country.

Since both the magnitude of the local impact on developing countries and the volume of spill-overs captured by developed countries vary widely, depending on the specific country observed, Chapter 3 tries to bring to light the relative importance of the factors determining the observed differences by answering the following two questions: *(i) What is the contribution of each of these factors to the differences observed between countries? And (ii), what factors and industries offer the highest potential for increasing the economic impact of climate finance?*

According to our decomposition analysis, four are the key determinants of the impact of climate finance disbursements on a country: the value-added per unit of output (or value-added intensity), the level of economic integration between industries (or domestic multiplier), the participation in GVC (or foreign multiplier) and the trade of final goods with other countries (or trade structure).

Answering the first question, the relevance of each factor depends on the country. The factor productivity (measured as value-added per unit of output) and the reliance on imports of final products are especially relevant for explaining why some recipient countries retain larger proportions of the impact than others. And in the case of donor countries, trade of final goods and participation in GVC explain the main differences in their ability to attract spill-overs.

With regard to the second question, our analysis shows that margins for improvement are concentrated in few sectors such as construction, machinery, electrical equipment and other business services. The characteristics of the construction sector determine the size of the local impact of energy efficiency and adaptation projects involving relevant expenditures in this type of services. In particular, differences in the value-added intensity of this sector explain why the local impact of such types of projects is much larger in some recipient countries than in others. The local impact of renewable energy deployment is larger in those recipient countries whose machinery industry is well developed and less dependent on imports. Finally, the penetration of donors' machinery and electrical equipment in recipient countries' markets is one of the most important factors determining donors' ability to attract spill-overs.

5.2.3. Provisions on the use of transferred funds modify the volume of spill-overs captured by donor countries.

Finally, considering the prevalence of certain practices by national governments that might influence the purchases derived from climate finance disbursements, like tying aid and LCR, Chapter 4 deals with the following two research questions: *(i) What is the effect of tied aid and LCR on the value-added captured by donor countries? And (ii), what locations and industries are more sensitive to these practices?*

Regarding the first question, our analysis shows that if aid is tied and recipient countries are forced to buy the goods and services required for the implementation of climate actions from the donor country, then the spill-overs captured by this donor country increase substantially. In particular, spill-overs would increase 8.4 pp on average for the donors considered. And if recipient countries impose LCR associated to transfers of climate funds, then, donors' spill-overs would decrease only slightly (less than 0.9 pp on average).

With regard to the second question, the analysis in Chapter 4 suggests that the effect of these conditions is especially relevant for those recipient countries that largely depend on imported goods to satisfy their final demand. Regarding sectors, the analysis shows that spill-overs produced by climate actions where machinery industries play a key role (such as the deployment of renewable energy) are highly sensitive to these conditions. Thus, for all donors the machinery sector is especially sensitive to the tied aid scenario, with spill-overs going from around 1% to close to 10%. LCR have also an important (negative) effect on the machinery industry of donor countries, since spill-overs are reduced to the indirect effect of purchases of intermediate inputs by local industries.

5.3. Policy implications

Next, we will present the main policy implications that can be drawn from the findings of this thesis. In order to do so, we will first focus on those policy recommendations that stem from the analysis of the economic impact of climate finance on donors.

Results in Chapter 2 confirm that international trade contributes to distribute one part of the economic impact of climate finance from the recipient country towards other economies, including donor countries. In this sense, climate finance could be seen as an instrument to stimulate, indirectly, the economies of donor countries. Furthermore, our analysis has shown that, amongst the whole spectrum of climate-related interventions, mitigation projects involving the deployment of renewable energy sources are those that generate most value-added in donors' economies (i.e. spill-over effects). Also, we have found that each donor would experience different levels of spill-over effects depending on which country is the recipient. This means that, if spill-overs from climate finance were considered in donors' decisions about how to distribute disbursements (something that cannot be tested yet due to the lack of information but that would constitute an important area for future research), the current thematic and geographic unbalance would be accentuated. This also means that past unbalance is consistent with a hypothetical decision framework where donors would choose those recipient countries with the highest pay-back in terms of economic spill-overs.

In any case, given that developed countries see challenging but feasible meeting the USD 100 billion per year target by 2020 (as expressed in the mentioned roadmap[39]), we can expect that future North-to-South climate finance flows will continue to increase, and with them, the spill-over effects captured by donor countries. Findings in Chapter 3 imply that donor countries could improve the extent to which they benefit from spill-overs, regardless of where climate finance is disbursed and who mobilizes it, by augmenting their competitiveness and participation in GVC of those technologies, services and tasks related to climate change mitigation and adaptation.

Finally, Chapter 4 suggests that spill-overs create an incentive for donors to use bilateral channels (that facilitate tying aid), and to concentrate disbursements on mitigation actions in countries dependent on international supplies. It also advocates that those donor countries with globally competitive industries supplying intermediate goods and services along GVC of climate-related goods and services would still attract relevant spill-overs without need to tie aid and despite LCR. Besides, LCR would diminish the incentive to concentrate finance on mitigation as a way to increase sales of

[39] UK Government and Australian Government (2016)

export-oriented sectors, since spill-overs are rather indirectly captured and also from sectors contributing to tackle adaptation needs.

Results from this study also offer several insights with policy implications for recipients of climate finance. Since a major share of the economic impact of climate finance disbursements occurs within recipient countries, the foreseeable future flows of climate finance would constitute a sizeable impulse for the development of these economies. Nevertheless, Chapter 2 shows that the magnitude of this impulse might significantly vary. For example, adaptation measures have a larger potential for creating local impact than mitigation projects based on renewable energy. Thus, if climate change adaptation and development are usually considered as complementary objectives, our analysis reinforces this thesis by making visible the short-term economic co-benefits of adaptation interventions. According to our results, measures with benefits in terms of both adaptation and mitigation are those that create the largest local impacts. Hence, this type of interventions results in a win-win outcome, since donor countries would benefit from mitigation achievements (given its global good nature) while recipient countries would strengthen their resilience and development at the same time. Developed countries' recent announcement of increased funds for adaptation is, hence, a good news for recipient countries' economies (UK Government and Australian Government, 2016).

Developed countries have also recognized that it is more efficient and effective to integrate climate action in programmes that generate wider development results. They are committed to address the current barriers faced by developing countries to access finance by supporting them in the preparation of National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs) consistent with their national development plans. Each developing country can request up to USD 3 million to the GCF for the formulation of NAPs, and the Paris Committee on Capacity-building will start working in 2017 to address needs in capacity building for the implementation of NDCs (ibid).

This means that developing countries have access to resources for the design of climate action plans compatible with their development goals, which will make visible their financial needs to potential donors. Our findings provide some considerations to bear in mind when designing these plans in order to maximize the potential of finance disbursements to impulse the local economy in the short term. In particular, Chapter 3 identifies three areas of action where governments of developing countries can focus in order to exploit the complementarities between climate action and development: 1) to specialize in products that are intensive in high technology and skilled labour; 2) to increase the integration of the economy, by ensuring good intraregional communications and transport networks; and 3) to develop a competitive industrial base to reduce their dependence on imports. Finally, governments of these countries could maximize the economic co-benefits of climate finance disbursements by concentrating their development efforts towards industries related to climate action. Chapter 2 suggests that technology transfer programmes could also contribute to domestically build up competitive industries, multiplying the local impact of climate finance.

Finally, Chapter 4 suggests that the consolidation of the GCF as the main channel for climate finance would benefit recipient countries' economies by limiting the possibilities of including provisions to tie aid, and thus, avoiding larger spill-over effects. This consolidation becomes even more essential given the increasing importance of new donors[40], which have openly adopted the practice of tying aid. An additional advantage of the GCF for recipient countries is the guarantee of a balanced allocation between mitigation and adaptation. In any case, Chapter 4 suggests that the recipient countries could decrease the sensitivity to this practice by decreasing their dependence on foreign supplies of final goods. This chapter also shows that spill-overs result only slightly affected by LCR. They continue happening through trade of intermediate goods, given the increasing relevance of trade in tasks in international trade. This means that this type of policies alone would be insufficient to develop globally competitive industries. Thus, industrial development policies have to pay attention to intermediate goods producers, and focus on the specialization on high value-added tasks.

[40] South-to-South cooperation accounted for an average of USD 8.5 billion in 2013-2014, according to the Standing Committee of Finance (UNFCCC, 2016).

5.4. Concluding remarks

This thesis illustrates the relevance of adopting a global approach in the assessment of the economic impacts of climate finance disbursements, and provides new insights that might help both developed and developing countries to understand the implications of decisions about climate finance disbursements. For example, we show that correcting the current bias towards mitigation would also benefit recipient countries' economies, and that incentives to maintain this bias are accentuated when donors can tie aid.

This thesis also contributes with recommendations for the design of national strategies promoting the local economy and the fight against climate change at the same time. This reinforces the message of the "green economy" literature that climate action and economic development are compatible. Thus, we show that the transition towards a decarbonized and resilient economy offers opportunities for development and that, in order to benefit from these opportunities, countries should direct their development towards climate-related industries with high value-added content. This means that the search for short-term economic co-benefits of climate finance could result in the development of effective solutions for this global environmental problem.

This thesis also illustrates the potential of GMRIO models for analysing worldwide impacts of climate finance, contributing to relevant discussions on the global climate regime. This framework captures the consequences of the vertical specialization, making visible the role of "trade in tasks" in the distribution of the economic gains from climate action.

5.5. Future research directions

The work initiated in this thesis could be extended in a number of ways. Here, we detail three of the possible directions.

First, the geographic scope of the assessment could be widened including more recipient countries and the new emerging donors. The incorporation of the least developed countries would be especially interesting since, with enhanced accessibility to finance favoured by capacity building programmes, climate finance disbursements might rapidly increase in these countries. Moreover, this would also enable to study the implications of the increasing South-to-South cooperation. However, the use of another GMRIO database would be required to that end, since the WIOD does not contain information about these countries yet.

Second, the assessment of climate finance disbursements could be complemented with the calculation of emissions embedded in, and avoided by, financed climate actions. With this additional input about the net mitigation potential, alternative climate actions could be assessed in a multi-criteria framework that would take into account both the economic and environmental benefits. Such exercise would identify trade-offs between both objectives, as well as win-win options avoiding emissions and stimulating the economy at the same time.

Third, the economic impact generated by climate finance disbursements could be divided into labour and capital compensation. The WIOD provides the necessary data to make this distinction. It also provides data for the estimation of the job creation potential of climate actions, as well as for distinguishing the labour income generated for three different skill levels. In this regard, it is necessary to note that while employment and wages remain in the country where they are generated, this is not necessarily the case of capital compensation. This happens because GVC involve sizeable flows of foreign direct investment, and one part of the capital compensation generated in one country can accrue to firms headquartered in another country. The WIOD does not contain information about the nationality of income, so such extension would require additional sources of information about the ownership of capital.

6. References

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