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1. Introduction

The notion that countries should bear global climate costs in proportion to their income level and historical responsibility has been a key subject of discussion since the beginning of climate negotiations. In 1992 high-income regions agreed to cover the 'full incremental costs' faced by developing countries, although no clear definition of the concept exists (UNFCCC 1992). In 2009 the Copenhagen Accord set a goal for high-income countries to mobilise jointly US$ 100 billion a year by 2020 'to address the needs of developing countries' (UNFCCC 2009). However, the success of this initiative is still uncertain.

Two major issues preventing a coordinated commitment to climate finance are, first, the absence of a well-defined rule for how to calculate the amount of economic support that would have to flow from high-income to developing countries and, second, what exactly these flows should be used for. A common procedure in the academic literature is to estimate the 'incremental investment' that developing countries would have to undertake (for example, in the energy supply sector) because of climate-change mitigation and adaptation (Gupta et al. 2014). However, there is no compelling reason why North-South climate finance flows should be equal to incremental investment. In many instances, efficiency-focused climate policies might lead to a decline of total energy supply investment – i.e. *negative* incremental investment – because of reduced energy demand. Additionally, the overall climate-related macroeconomic costs suffered by emerging economies are in any case likely to be much higher than the incremental investment needed, comprising not only extra consumption foregone to make way for investment but also changes in welfare brought about by changes in relative prices, including in some countries adverse changes in the terms of trade (Bowen et al. 2014).

In this paper we thus employ an original approach that involves the thought experiment of equalising overall climate mitigation costs – measured as a share of regional GDP – through a global carbon market. This is done using the results of the

Integrated Assessment Models (IAMs) participating to the LIMITS project[1] (Kriegler et al. 2014; Tavoni et al. 2015). We consider the resulting financial flows to be the lower bound of the international transfers required to make the allocation of mitigation costs 'equitable'.

The projected flows of finance from permit trading are then compared with estimates of current North-South climate financial flows from a variety of sources. We find the former to be larger than both current and planned international climate finance flows, and discuss the most effective strategies to fill this gap. Expanding private finance, either in the form of Foreign Direct Investment or through the issuance of 'green bonds', appears to be a particularly promising direction.

The paper is structured as follows. Section 2 introduces the LIMITS models and scenarios. Section 3 presents the international climate-related financial flows resulting from the implementation of an 'equal effort' allocation rule. Section 4 discusses the likelihood of a global carbon market capable of delivering such flows. Section 5 briefly describes the state of other channels of North-South climate finance. Section 6 draws some policy implications for filling the climate-change mitigation finance gap and argues in favour of private finance. Section 7 concludes.

2. The modelling framework

This study involves six Integrated Assessment Models[2] from the LIMITS project; GCAM (Kim et al. 2006), IMAGE (Bouwman et al. 2006), MESSAGE (Riahi et al. 2011), REMIND (Leimbach et al. 2010) , TIAM-ECN (Keppo and van der Zwaan 2012) and WITCH (Bosetti et al. 2009). The models use a harmonised group of ten geographical regions (Africa, China+, Europe, India+, Latin America, Middle East, North America,

[1] 'LIMITS' stands for 'Low climate IMpact scenarios and the Implications of required Tight emission control Strategies.'

[2] Integrated Assessment Models are large-scale numerical models that simulate the dynamic interconnections among the economy, climate and the energy system; details of the ones participating to LIMITS can be found in Kriegler et al. (2014).

Pacific OECD, Reforming Economies and Rest of Asia)[3]. All models cover the time period from 2020 until 2100.

IAMs are subject to a number of critiques. For instance, their high level of aggregation and long-term perspective prevent them from distinguishing among different economic agents and sectors or studying the effect of macroeconomic fluctuations. They also abstract from a number of market imperfections, most notably in fossil-fuel markets, when determining the optimal path for an economy. A systemic critique of the use of IAMs has been recently developed by Stern (2013) and Pindyck (2015) among others. Despite their shortcomings, IAMs are nonetheless powerful analytical tools widely used by the scientific community and often employed to inform policy-making. Furthermore, the diverse range of modelling techniques and assumptions represented by the LIMITS models makes the comparison exercise reflect features of the uncertainty around future physical and economic trajectories.

All the models are used to run the same set of scenarios. The three scenarios most relevant for the purposes of this paper are presented in Table 1: a reference scenario with 'weak' climate policies (*RefPol*); a stringent climate policy scenario (*RefPol-450*); and a stringent climate policy scenario with emissions permits and permit trading (*RefPol-450-EE*). None of the model scenarios explicitly take into account any benefits of avoided climate change or any costs of adaptation; hence the LIMITS projections do not reflect a cost-benefit analysis, but rather focus on a cost-effectiveness assessment of policies to keep below the 2°C ceiling.

The *RefPol* scenario assumes that for the rest of the century individual regions implement only the commitments included in the Copenhagen agreement. These

[3] For the purposes of this paper, high-income economies include North America, Europe and Pacific OECD (plus Rest of the World for WITCH and REMIND). Emerging Economies include Africa, China+, India+, Latin America, Middle East, Reforming Economies and Rest of Asia. For more details, see Tavoni et al. (2014).

commitments are low and fragmented across the regions and lead by 2100 to an increase in global temperatures of 3-4°C (Kriegler et al. 2014)[4].

The *RefPol-450* scenario, by contrast, is LIMITS main mitigation scenario. It assumes that the Copenhagen Commitments are applied until 2020 but then a globally uniform carbon price is introduced so as to achieve a concentration target of 450 parts per million of CO_2 equivalent (CO_2e) by 2100.[5] This can be thought as a carbon tax applied in all regions, and on all GHGs covered by the Kyoto Protocol. This scenario delivers efficient climate-change mitigation, in the sense that suitably discounted consumption is maximised or the discounted costs of decarbonising the energy system are minimised (depending on the model).

In the *RefPol-450-EE* scenario, where EE stands for 'Equal Effort', each region is allocated a certain amount of emissions allowances, which can then be used or sold to other regions in a global carbon market. The allocation of allowances is designed to equalise mitigation effort across regions, in the sense that, from 2025/2030 onwards, all regions incur the same mitigation costs as proportion of GDP. A more detailed description of the scenario can be found in Tavoni et al. (2014).

Despite implementing a mechanism that aligns current and future proportional mitigation costs across all regions, the burden-sharing rule proposed by the 'Equal Effort' scenario does not necessarily achieve an 'equitable' allocation or warrant universal acceptance of its fairness, as it contains no elements of progressivity and is likely to disappoint those countries arguing to include historical responsibility as a criterion for burden-sharing in climate negotiations[6]. Additionally, it is debatable whether the equalisation should include costs related to changing patterns of international energy trade - i.e. whether the export revenue losses due to the

[4] Beyond 2020, regions are assumed to maintain a rate of emission intensity improvement broadly consistent with the one achieved through their pre-2020 action. See the Supplementary Material of Kriegler et al. (2014).

[5] A concentration of 450ppm CO_2e is consistent with a probability of greater than 67% of remaining below the 2°C ceiling. Temporary overshooting of targets is allowed.

[6] More generally, an extensive literature exists on climate burden-sharing mechanisms and equity in the distribution of abatement costs (Höhne et al. 2014; Rose et al. 1998) and a number of rules have been suggested to find a cost allocation agreement that could be perceived as fair by both high-income and developing regions, based on convergence of per capita emissions, carbon intensity, historical responsibility, grandfathering, or a combination thereof.

implementation of climate policies in fossil fuel exporting countries should be compensated (Clarke et al. 2014).

However, we believe the 'Equal Effort' scenario capable of providing an extremely useful benchmark case, to be interpreted as the *minimum standard* that would have to be satisfied in order to consider the allocation mechanism 'fair'. The international financial flows resulting from *RefPol-450-EE* are therefore the lower bound of what would be necessary: anything below them is highly unlikely to be acceptable to developing regions.

[Table 1 ABOUT HERE; LIMITS scenarios summary]

3. Results: North-South climate finance

3.1. The unequal distribution of costs under efficient mitigation

The models project that emissions in *RefPol-450* peak in 2020 and start declining rapidly immediately thereafter, reaching negative values by the end of the century. This causes a loss in income with respect to the baseline *RefPol* scenario, but growth rates remain positive in all regions.

Although total mitigation costs in this scenario are minimised, they are strongly unequally distributed across regions. Figure 1 reports the regional costs[7] associated with climate-change policies in *RefPol-450* as a proportion of global average mitigation costs[8]. The Figure shows how high-income regions (Europe, Pacific OECD and North America) bear a small proportion of overall mitigation costs, while low-income regions (Africa, India and others) and energy-exporting countries (Reforming Economies and Middle East) suffer mitigation costs well above the global average. These results – roughly consistent across models – are due to a variety of reasons, including different abatement potentials, the amount of baseline emissions, energy

[7] As in Tavoni et al. (2014), we compute regional mitigation costs using: consumption losses for models with a macro-economic component (MESSAGE, REMIND and WITCH); abatement costs for IMAGE and GCAM; and energy system costs for TIAM-ECN.

[8] Comparing regional mitigation costs with global mitigation costs helps to control for the differences in projected global mitigation costs (cumulated over 2020-2050) across models, which are pronounced; projections range from 0.51% of global GDP (IMAGE and GCAM) to 5.84% (WITCH).

intensities and the importance of energy exports (Gupta et al. 2014; Tavoni et al. 2014).

[Figure 1 ABOUT HERE; Regional mitigation costs per unit of GDP relative to World in *RefPol-450* (2020-50 cum. values, NPV 5%)]

This unbalanced distribution of costs presents a serious obstacle to international climate negotiations. Given the historical responsibility of high-income countries for bringing about climate change so far (MATCH 2008), it is hard to imagine low-income developing regions agreeing to an arrangement in which climate-change mitigation costs (relative to GDP) are placed mainly on their shoulders.

In order to examine the conflict between efficiency and equity along mitigation paths, the *RefPol-450-EE* scenario is assessed in the next section.

3.2. Financial transfers under the 'Equal Effort' scenario

Despite the allocation of emissions allowances according to the 'equal effort' rule, in the LIMITS models projected emissions still take place where it is most cost-effective to emit. The regions for which allowances are larger than their projected emissions sell the excess permits to those regions for which projected emissions are higher than the allowances initially allocated. The size of the resulting carbon market range from 1 to 6 $GtCO_2e$ per year, depending on the model. This corresponds to an economic value of US$ 400-2,000 billion around 2050.

Figure 2 shows the direction of the carbon market financial flows, cumulated over the 2020-2050 period and as a percentage of regional GDP. The total economic value of the carbon market never exceeds 1% of GDP for a region, except in WITCH and REMIND projections, in which it reaches 3-4% in certain regions. High-income regions (Europe, Pacific OECD and North America) are projected to be net buyers of emissions allowances across all models. In some models, the outflow represents only a small fraction of a percentage point of regional GDP, in others (mainly WITCH and REMIND) the cost of buying additional emissions allowances reaches 1-2% of GDP. The remaining regions show a higher degree of variability across models, but they broadly appear to be net sellers of allowances. These are particularly large in the

case of Reforming Economies and the Middle East. This is due to the high mitigation costs that these regions, as energy exporters, suffer in the mitigation scenario without carbon trade: the equalisation of efforts required by the *RefPol-450-EE* scenario creates large financial inflows for them. The African continent also seems to benefit from the 'equal effort' allocation, although to a lesser extent.

[Figure 2 ABOUT HERE; Climate-related financial transfers in *RefPol-450-EE* (2020-2050 cum. values, NPV 5%)]

Figure 3 shows the evolution of financial transfers from high-income to emerging economies over the 2020-2100 period. Despite a few exceptions, the general trend of these flows seems to be upwards throughout the century. By 2050, four out of six models report a North-South financial transfer of around US$ 400 billion, while in REMIND and WITCH this is higher (US$ 1 trillion and US$ 2 trillion respectively). By 2100, North-South climate finance flows have surpassed the US$ 1 trillion mark in four of the models, and WITCH reports again a higher value (around US$ 6 trillion). However, these aggregate amounts hide a large variability across regions. China, for instance, is projected to have strong financial outflows during the second half of the century according to REMIND; the same happens with Africa and India for WITCH, Latin America for MESSAGE and Rest of Asia for GCAM and REMIND.

[Figure 3 ABOUT HERE; Total annual financial flows to emerging economies in *RefPol-450-EE*]

The resulting financial flows are pure 'compensatory' budget transfers. They result from the equalisation of mitigation effort but they are not necessarily earmarked to finance climate-friendly activities in developing countries. In other words, there is nothing in the models that requires international carbon market flows and energy investment expenditure to be linked. However, it is possible to draw a comparison between the two variables to have a sense of their relative size. The curves in Figure 4 represent the average across models[9], and give an indication of how adequate potential carbon finance inflows are in terms of supporting the required energy

[9] With the exception of GCAM, the results of which are not comparable with those of the other models.

transition. A value beyond 100% means that the financial flows resulting from carbon trade will be higher than the optimal energy supply investment, which could therefore be indirectly financed by those regions that need to purchase allowances. The results show that inflows for both Middle East and Reforming Economies will be more than enough to finance the overall amount of their energy investment[10]. The proportion of investment financed by external resources in China will hover around 20-30% until 2070, and will then increase above 100% by the end of the century. Africa will manage to cover a relevant proportion of its energy investment during the next few decades, with a peak around 55% in 2030, but will then become a net purchaser of allowances in the second half of the century. A similar trajectory is followed by Latin America, India and Rest of Asia.

[Figure 4 ABOUT HERE; Carbon financial flows as % of optimal energy supply investment]

4. The outlook for global carbon markets

The previous section has presented projections of the financial transfers that would be necessary to equalise mitigation efforts across regions while keeping below the 2°C ceiling. How realistic is it to expect a global market in emissions allowances, such as the one assumed in the *RefPol-450-EE* scenario, to deliver such flows? Unfortunately, the outlook is not encouraging at the moment.

The only current market-based instrument capable of generating climate-related finance flows from high-income to developing economies is the Clean Development Mechanism (CDM). The CDM was set up by the Kyoto Protocol to provide countries with quantitative mitigation obligations (Annex I countries) the option to acquire emissions reductions from mitigation projects implemented in non-Annex I countries. Given that developing regions often offer cheaper mitigation options, the

[10] This result confirms the relevance of trade-of-terms effects. However, the issue of whether exporters of fossil fuels should be compensated for the loss incurred because of changes in trade patterns is not likely to affect our results on North-South flows. A calculation looking at the difference between climate finance inflows and fossil fuel exports suggests that, while their regional distribution would be affected, the overall flows to developing regions would only marginally change.

CDM allows high-income countries to meet their emission reduction targets at a lower cost, while promoting sustainable development in emerging economies.

From 2005 to 2014 around 7,500 projects were registered to the CDM, leading to a reduction of 1.5 billion tonnes of CO_2e and an investment of US$ 410 billion in climate-friendly activities (UNEP DTU 2015). Flows of funds to emerging economies of around US$ 2.2-2.3 billion were generated from sales of Certified Emission Reductions (CERs) in 2009-10 (Clapp et al. 2012). Unfortunately, due to the European economic crisis and problems with the design of the EU Emissions Trading System, the price of CERs has fallen sharply. As a result, the incentives for potential project developers to invest have been reduced. From 2012 to 2013, investment in CDM-supported activities dropped from its peak of almost US$ 200 billion to just above US$ 20 billion (UNEP DTU 2015).

Although the CDM market has substantially weakened, it has helped prepare the ground for other carbon markets to arise. At the international level, the UNFCCC is coordinating the effort to create a 'New Market-based Mechanism', which, together with a 'Framework for Various Approaches', should help 'to enhance the cost-effectiveness of, and to promote, mitigation actions, bearing in mind different circumstances of developed and developing countries' (UNFCCC 2012, 2014b). Additionally, governments around the world have incorporated lessons learnt from the CDM in the design of new emissions trading schemes. There are currently 19 regional, national or and subnational ETS operating. Around 7% of global emissions are now covered by these carbon markets (World Bank and Ecofys 2014).

These markets could be the precursors of a global carbon market yet to come, to be achieved by gradually linking up the sub-global ones (Flachsland et al. 2009; Ranson and Stavins 2014). A link between the California and the Quebec cap-and-trade programmes was set up successfully in January 2014. However, other plans to link carbon markets are currently frozen. Furthermore, discussions regarding linking have until now concerned only high-income countries (USA, Canada, European Union, Australia, Switzerland) so that, even if implemented, they would not contribute to making finance flow towards emerging economies.

5. The current state of North-South climate finance

If a global carbon market is unlikely to be implemented in the near future, how feasible is the achievement of this 'efficient and equitable' level of North-South climate finance? The rest of the section will address this question by discussing a number of sources and channels of finance that might be used to fill the gap between the current state of climate finance and the LIMITS results[11].

Estimating climate-related financial flows – and in particular the ones flowing from high-income to developing economies – is not an easy task. Data tend to be of low quality, fragmented and unverified (Clapp et al. 2012; CPI 2014; Stadelmann and Michaelowa 2013). Despite these caveats, some estimates have been provided in the recent literature on climate finance. CPI (2014) calculates the financial resources flowing from OECD to non-OECD countries in 2013 in the range of US$ 30-55 billion, depending on the method used. Most of this finance originates in development institutions, either bilateral or multilateral. Private investment and bilateral aid also play a role, while climate funds contribute only a very small proportion. UNFCCC (2014a) estimates North-South climate finance is in the range of $40-175 billion per year in 2011-2012, with the private sector accounting for a relevant portion of total flows.

Public climate finance can be of two main kinds[12]. First, high-income countries can decide to transfer financial resources directly to an emerging country to help its low-carbon development. In recent years, the climate component of bilateral Official Development Assistance (ODA) has become increasingly relevant, reaching US$ 21.9 billion in 2013 (74% of which had mitigation objectives), equal to 17% of total ODA flows (OECD DAC 2014). Second, high-income countries can support multilateral

[11] A precise comparison between sources of climate finance and LIMITS results is not possible. While the carbon market in LIMITS model can be thought of as providing budget support to regions with projected financial inflows, with no explicit requirement to use them for low-carbon investment, the sources and channels we discuss in this section are unequivocally directed to investment. Additionally, the highly aggregate nature of LIMITS models prevents us from distinguishing between different types of flows (public and private, for instance). Finally, in the LIMITS models, financial flows take place only from 2025/2030 onwards, while current commitments and projections of climate finance seldom go beyond 2020.

[12] For a more detailed discussion of source and channels of public climate finance, see Gupta et al. (2014) and Bowen (2011).

institutions, which in turn supply finance for climate-friendly activities in developing countries. There are, for example, a growing number of 'climate funds', initiatives designed to help developing countries address the challenges of climate change. In 2013, climate funds spent around US$ 2.2 billion (CPI 2014), a very low proportion of overall North-South climate finance, and an even smaller proportion of the flows needed in the future. The establishment of the Green Climate Fund (GCF) in 2010 was the centrepiece of the UNFCCC strategy of raising US$ 100 billion per year for climate-friendly investment in developing countries (UNFCCC 2009).

Private finance is potentially the most important source of funds for climate mitigation investment. Nelson and Pierpont (2013) estimate that as much as US$ 45 trillion are currently managed by OECD institutional investors holding long-term assets. Private investment flows can be divided between Foreign Direct Investment (FDI) – which lead to a controlling stake of the activity (>10%) – and portfolio investment (<10%). Stadelmann and Michaelowa (2013) estimate North-South climate FDI to have been in the range of US$ 10-40 billion per year, and portfolio investment around US$ 4-5 billion, in the period 2008-2011.

A third type of North-South climate finance source is represented by Development Financial Institutions (DFIs), including national development banks (e.g. Germany's KfW), multilateral development banks (MDBs) (e.g. the World Bank) and bilateral financial institutions, (BFIs) (e.g. the Japan International Cooperation Agency - JICA). All these types of development financial institutions have a prominent role in providing climate finance. In 2012, DFIs committed US$ 121 billion while during 2007-12 at least US$ 425 billion were provided to projects for renewable energy production, energy efficiency and other environment-related activities (BNEF 2013). However, most of the US$ 121 billion were invested domestically, with only US$ 15-22 billion taking the form of international North-South flows. MDBs and BFIs have nonetheless become increasingly important in managing the international financial flows between OECD and non-OECD countries, delivering the majority of total North-South climate finance, according to CPI (2014).

6. How to fill the climate-change mitigation finance gap

Comparing the estimates provided in the previous section with our model-based projections of required North-South climate finance, there is likely to be a large mitigation finance gap from 2020 unless actual flows are ramped up rapidly. However, a number of obstacles prevent this gap being filled.

6.1. The only way is private?

The shortcomings of public climate finance appear particularly hard to overcome. Despite the recent increase of climate-related ODA, the economic crisis reduced the already low aid commitments of high-income countries. In 2013, the long-standing objective of OECD countries to deliver the equivalent of 0.7% of their Gross National Product (GNP) as ODA had been achieved by only five countries out of 28[13], and it is not clear whether high-income countries will agree to increase their contributions to climate finance, and, if they do, without diverting resources from other development objectives.

The multilateral climate finance goals to which high-income countries have committed are also rather unambitious. By the end of 2014, commitments of capital to the Green Climate Fund reached only just over US$ 10 billion - only a very small proportion of what models show will be needed - and disbursements were not expected to start until late 2015 (Fenton et al. 2014; Schalatek et al. 2014). Even so, pledges can later be easily neglected[14]. Moreover, the recent emphasis in many high-income economies on reducing budget deficits does not favour helping countries that will soon be direct competitors and that will be able to finance climate-change mitigation on their own if necessary (Bowen et al. 2014).

It is therefore probably safe to say that it is not from the fluctuating goodwill of policy-makers that we should expect the financial resources required to fill the North-South climate finance gap. Private, profit-driven investment motivated purely

[13] Data source: OECD DAC; available at http://www.oecd.org/dac/stats/.

[14] According to Climate Funds Update, out of a total of US$ 34 billion pledged for climate funds by February 2015, only US$ 15.7 billion (46.2%) have been deposited so far, and only US$ 1 billion (3%) disbursed. See climatefundsupdate.org/data.

by financial returns may underpin international climate finance more effectively than the reluctant commitments of debt-burdened governments. This can originate from both high-income economies' firms investing directly in developing countries or development banks, among others, redirecting the resources raised on private capital markets through the issuance of 'green' financial instruments. These two channels of finance already represent the source of the overwhelming majority of global climate investment (CPI 2014).

6.2. The outlook for climate investment

At the moment, climate-friendly investment opportunities are not sufficiently attractive from an economic perspective at either the domestic and international level. This is due to typical features of many low-carbon assets such as long-term time horizons, high initial capital costs, high financing costs and, more importantly, strong perceived risks related to technology evolution, market development and policy support (Frisari et al. 2013). Additionally, many developing countries may encounter difficulties in attracting low-carbon FDI because of legal and institutional obstacles (e.g. insufficient incentives and regulation, legal protection and lack of transparency) and socioeconomic challenges (e.g. lack of skills, expertise or training) (UNCTAD 2013). Some of the key factors in attracting FDI, such as market size, potential and availability of natural resources, cannot easily be influenced by public policy interventions (Hornberger et al. 2011).

Various public policies can be designed and implemented to modify the risk/return profile of abatement activities, the most important of which is the introduction of a price on carbon: changing the system of price incentives should make green activities more attractive to firms and households. To complement carbon pricing, or to substitute for it when it would be politically infeasible or economically detrimental to introduce it, there is a wide variety of other policy instruments that can be employed, including de-risking government instruments, 'green' industrial policies and financial regulation (Campiglio 2015; Fay et al. 2013; Hourcade et al. 2012; WEF 2013). Additionally, it is essential for governments of low-income countries to develop robust investment promotion strategies by improving their

institutional and regulatory framework, as BRICS countries have been doing in recent years (Bayraktar 2013; UNCTAD 2013).

Therefore, despite being driven by 'ethically neutral' market considerations, climate-friendly foreign direct investment still requires a number of facilitating public policies in order to take place, which are subject to the same issues as public finance – weak commitments and poor long-term planning.

6.3. Green bonds: a possible game changer

Even more promising, and not as dependent on public policy as FDIs, is the private finance flowing to developing regions through the issuance of 'green bonds' by companies, projects or development banks (BNEF 2014; CBI 2015; Clapp et al. 2015). Typically, the funds raised by the issuance of green bonds are ring-fenced for specific environmental objectives but benefit in the same way as traditional bonds from the financial standing of the issuer and offer similar risks and returns to financial investors. This is especially true for green bonds issued by multilateral development banks, which have been among the most active promoters of their diffusion. Despite the possible higher underlying risk, debt instruments issued by the likes of World Bank and European Investment Bank can benefit from high ratings and market-average yields, which make them attractive to institutional investors.

Green bonds thus have a substantial potential for driving financial resources towards low-carbon sectors, especially if issued in large amounts and in a standardised fashion. The market is already in a phase of rapid expansion, and the outstanding amount of green bonds in 2015 – both 'labelled' and 'unlabelled'[15]- is around US$ 598 billion, which represents a 16% increase from previous year (CBI 2015).

7. Conclusions

This study has employed a number of Integrated Assessment Models to determine what financial transfers between high-income and developing economies would

[15] 'Unlabelled' green bonds are bonds whose proceeds are employed for climate-related activities but are not formally categorised as 'green'. The outstanding amount of 'labelled' green bonds in 2015 was around US$ 66 billion.

have to be if climate mitigation effort, measured as mitigation costs as a share of GDP, were to be equalised across regions. This can be interpreted as the minimum standard of North-South financial flows to be satisfied to have a commonly agreed 'equitable' allocation of costs. Four out of six models imply that a North-South annual financial transfer of around US$ 400 billion is required by 2050, while the other two models imply larger sums. By 2100, the 'efficient and equitable' climate finance flows to developing countries will be well above US$ 1 billion according to four of the models.

We found the warranted transfers to be larger than both current and planned international climate finance flows. Additional resources will have to be employed to meet the models' projections of finance needs. However, a global carbon market as envisioned in LIMITS models seems unlikely to be created in the short to medium term. The only market that allows for significant international flows, the Clean Development Mechanism, is now moribund. The development of new carbon markets - most notably the prospect of a unified Chinese trading scheme - certainly represents good news, but will not help with generating international finance flows to help achieve mitigation commitments.

Among the other forms of North-South climate finance, we found private sources and channels more promising than public ones, despite the fact private investment is often crucially dependent on the implementation of public policies. Public finance will still be necessary for sectors in which financial returns are likely to be low even in presence of such policies (e.g. adaptation activities). The expansion of the market for 'green bonds' – debt financial instruments placed by companies, projects and development banks on private capital markets – is likely to be particularly helpful.

Finally, some consideration must be given to the appropriate governance arrangements for future North-South finance flows. In the event that climate finance does expand as rapidly as the projections in this paper suggest is desirable, several developing countries will have to manage financial inflows that are significant relative to GDP. Countries with immature financial intermediation systems and unstable public institutions may incur in a 'climate curse' triggering macroeconomic

difficulties through exchange rate appreciation, rent-seeking and the undermining of fiscal discipline (Jakob et al. 2015). Developing countries should therefore continue to improve the efficiency of domestic financial intermediation and ensure monitoring, transparency and debate about the use of the finance flows.

A sounder legal and financial system will also help to raise domestic finance in developing countries. Historical experience suggests that emerging-market economies will be able to finance the low-carbon transformation of their energy supply systems reasonably easily from domestic saving flows if necessary, particularly if they use revenues raised from carbon pricing to finance investment in capital embodying low-carbon technologies (Bowen et al. 2014).

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