The Climate Rent Curse: New Challenges for Burden Sharing

Ulrike Kornek*, [a] Jan Steckel[a, b, c] Kai Lessmann[a]
Ottmar Edenhofer[a, b, c]

October 25, 2013

Abstract

The literature on the "resource curse" has made a strong point (in theory as well as empirically) that large incomes from resource endowments may have adverse effects on the growth prospect of a country. Conceivably the income generated from emission permit allocations, as suggested in the context of international climate policy, could have a comparable impact. Such a "climate rent curse" has so far not been considered in the design of permit allocation schemes. In this study, we first determine when to expect a climate rent curse conceptually by analyzing its potential channels. Then we use a numerical model to explore to what extend a climate rent curse would take effect, and investigate its consequences. Two of the underlying objectives for the design of permit allocation schemes are (a) fairness in burden sharing and (b) overcoming the free-ride incentives to participation in a climate agreement. We show that given a curse, permit allocation schemes may fail to address these objectives. This conclusion therefore poses a new trade-off within fighting global climate change: benefiting from the revenues induced by the new climate rent and in turn suffering from its adverse effects on the

*Corresponding author at: Potsdam Institute for Climate Impact Research, PO Box 60 12 03, D-14412 Potsdam, Germany. Tel.: +49 331 288 2562. E-mail: kornek@pik-potsdam.de

[a]Potsdam Institute for Climate Impact Research, PO Box 60 12 03, D-14412 Potsdam, Germany

[b]Technische Universität Berlin, Department 'Economics of Climate Change', Strasse des 17. Juni 135, 10623 Berlin, Germany

[c]Mercator Research Institute on Global Commons and Climate Change (MCC) gGmbH, Torgauer Str. 12 - 15, 10829 Berlin, Germany

respective economy.

Keywords: International Environmental Agreements, Resource Curse, Climate Finance
JEL Classifications: C61, C72, O11, Q54, Q56

1 Introduction

In the past, resource rents have often caused more harm than good. There is empirical evidence that the inflow of revenues generated by natural resources is correlated with poor growth prospects. Since the seminal work of Sachs and Warner (1995), many have contributed to the literature (see Van der Ploeg, 2011, for a detailed review), partly challenging the initial finding that there is a general 'natural resource curse.' Rather, in the more recent literature it becomes apparent that whether resources have a negative or positive influence on long term growth depends largely on numerous circumstances.

While the available literature focuses on natural resources, rents induced by climate change mitigation policy might induce comparable negative effects on countries' growth prospects. This seems particularly likely when mitigation policy is enforced by an international emissions trading scheme: Committing to a particular abatement goal, a net seller of emission permits generates revenues. These revenues constitute a 'climate rent' whenever they are higher than the costs for abating emissions (Jakob et al., 2012).

How emission allowances are allocated among market participants, e.g. based on population, GDP or historical emissions, majorly determines the scale of this rent for a particular country (Luderer et al., 2012b). Against the efficient distribution of emission reductions (which is the purpose of emission trading schemes) as a point of reference, allocations implicitly define transfers among the market participants. Equity considerations often recommend a per-capita allocation of permits or an allocation based on historical responsibility of emissions (Edenhofer et al., 2010b), thus favoring developing countries as the receiving regions. As a consequence large scale climate rents occur in developing countries, which often lead to the fact that they are relatively well off in studies assessing mitigations costs, sometimes even showing gains rather than costs for mitigating emissions (Calvin et al., 2012; Edenhofer et al., 2010a; Luderer et al., 2012a). However, such analyses typically abstract from any adverse effects of climate rents.

Transfers are also prominent in the literature on climate coalitions and the incentives of countries to engage in international cooperation. Coalitions are groups of nations that cooperate such that climate change is addressed efficiently. When such a coalition forms, transfers enable its members to share the gains of cooperation, possibly making cooperation more attractive for all members and thus achieving higher degrees of participation (see e.g. Brechet et al. 2011, Altamirano-Cabrera and Finus 2006). To make a coalition *self-enforcing*, i.e. to make all members better off compared to free-riding, it is important to compensate countries with large abatement potentials in particular as they will carry a large burden for reasons of efficiency. Transfers to developing countries are therefore often introduced as a game changer also from a strategic point of view. Again, whether transfers include potentially adverse effects on the receiving economy has not yet been considered.

In our analysis we discuss how the implications of distributing the climate rent change when potentially adverse effects of permit allocations (and the corresponding implicit transfers) are taken into account. Without, permit allocations are simply a trade-off between who gives and who receives (usually the more the better), but including a 'climate rent curse' adds a new trade-off between enjoying the revenues from emission permit sales and suffering from its adverse effects on the economy. The desire for large permit allocations is reduced, but it is *a priori* not obvious by how much, nor if receiving transfers via permit allocation remains beneficial at all.

This paper combines insights from the resource curse literature with coalition theory by exploring the trade-off between additional revenues versus reduced growth and its implications for the success of self-enforcing climate agreements. The text is structured as follows: In the next section, we discuss whether and when to expect climate rents to cause adverse effects similar to a resource curse, addressing the three main channels of the resource curse: Dutch disease, rent-seeking and volatility. Based on these insights we evaluate the trade-off posed by the "climate rent curse" in an extended version of the numerical Model of International Climate Agreements (MICA) (Lessmann et al., 2009). We present model runs with and without the curse and discuss the implications on coalition formation. Doing so we assume governments to be benevolent who – under circumstances that will be discussed in the following sections – take a potential climate rent curse as given but consider it when taking their decisions.[1] Finally, we will conclude and discuss our results in the last section.

2 Resource Curse and the Climate Rent

There is a broad empirical literature on the "curse" of owning abundant resources summarized in Van der Ploeg (2011). The pioneering work of Sachs and Warner (1995) has shown empirically that the growth rate of a country is negatively affected by increasing shares of resource exports in its economic output. Sachs and Warner test a linear relationship of resource export shares and a reduction of the growth rate in a cross country regression analysis. The coefficient of proportionality, φ, is a measure of the strength of this adverse effect. Empirical findings that this strength is substantial has triggered an extensive body of research investigating its causation. Over time different channels of the adverse effects caused by the resource income could be identified (prominently the so-called Dutch Disease, but also the quality of institutions, rent seeking and, more recently, price volatility). It is challenging to disentangle these effects and their share in the magnitude of φ, especially since their specific importance may differ from case to case. Yet the general finding that resource wealth is – under certain conditions – associated with surprisingly low or even negative growth rates, has proven very robust.

In how far climate finance gives rise to comparable adverse effects depends (a) on the specific approach of financing emission mitigation, and (b) on the degree to which the channels of the resource curse apply to climate finance. The following section briefly explores the role of climate finance design for the susceptibility to adverse effects. In the main part of this section, we discuss whether the major channels of adverse effects applying for the "resource curse" are also relevant for a potential "climate rent curse." Finally, we will shortly discuss how these results are dealt with in the remainder of the paper.

[1] Relaxing this assumption might be a promising area of future research.

2.1 Characterizing the Emission-Permit

Whether climate finance may pose a threat to growth prospects depends largely on its institutional design, ranging from a carbon market (and all kinds of carbon market designs that are conceivable) to financing incremental mitigation costs, e.g. by a sovereign wealth fund (Jakob et al., 2012). Carbon markets are central to the design of the Kyoto Protocol, the prime example of international climate policy to date. They are also the default policy instrument in our numerical coalition model MICA, which we apply to evaluate the potential impact of the climate rent curse. Hence, this section focusses on the role of emission permits in the economy and their specific characteristics in order to relate its features to conventional resources. Taking into account other designs of climate finance, however, might change the results from our following analysis (see Jakob et al. 2012 for a detailed discussion).

When a carbon market with a stringent cap that limits the disposal space of the atmosphere is introduced, a CO_2-permit will have a positive price. This will induce firms to implement abatement measures. In this sense the carbon market functions just like a tax on emissions: both instruments place value on the environmental good of mitigation. However, because the cap in the market creates an artificial scarcity, there are crucial differences between these two instruments in their economic characteristics.

Different from a carbon tax, a carbon permit becomes a valuable asset in each economy because it will serve as the right to emit. As Benz and Trück (2009) argue in the context of the European market (EU-ETS), a CO_2-permit enters the tradable commodity market when a firm's emissions are already equal to its current permit holdings and production either needs be cut down or additional permits have to be purchased. Hence, permits are needed as a basic input factor to production (Benz and Trück, 2006): they can only be used once; they are substitutable by switching to a different, i.e. less carbon-intensive technology; arbitrary amounts can be traded, and the transport cost of permits is negligible.

In this sense, permits exhibit considerable similarities to traditional resources. In addition to the aforementioned features, the scarcity of emission allowances creates new rents in the economies participating in the market. These new rents are substantial: Bauer et al. (2013) indicate that the carbon rent induced by stringent global climate policy even exceeds the rents from fossil fuels over the next century. The design of the carbon market determines how these rents will be allocated: under free allocation of permits the entire rent is obtained by the producers. However, if permits are auctioned large parts will accrue to the government, raising public revenues like a tax, but at variable prices. Nevertheless, even in this case Kepper and Cruciani (2010) showed for the EU-ETS that there are still large rents remaining in the power sector.

In order to determine the scale of the climate rent that accrues to a country (either to its producers or its government) in an international emissions trading scheme, it is crucial to determine the initial allocation of permits among the market participants. If the carbon market is integrated in space (Flachsland et al., 2009; Fankhauser and Hepburn, 2010b) and permits can be traded on the international level, the distribution of allowances may induce financial flows. If the allocation of emission permits exceeds a country's Business-as-Usual level, the surplus can be sold. This is a crucial difference of using the quantity approach as compared to the price one: while for the implementation of a tax on emissions financial support could be implemented through direct transfers of money, in an emissions trading scheme the sale of surplus emissions induces financial flows indirectly. Much of our subsequent analysis will build on this feature: new rents can be realized through exporting permits in an international carbon market.

There are crucial differences of carbon allowances and conventional resources as well. As the permit creates an artificial scarcity, political decisions will have a substantial influence on supply – and demand dynamics in a carbon market and thus on the comparability of a climate rent to other resource rents. Owners of conventional resources can decide independently when to sell their assets. In a carbon market, by contrast, permits could lose their value by governmental decision when a commitment period ends. However, the literature on carbon markets generally recommends to allow for banking of permits between commitment periods as efficiency would be increased in meeting the environmental target (Fankhauser and Hepburn, 2010a). As – from a natural sciences perspective – there is considerable flexibility when to emit greenhouse gases and still meeting temperature targets (Meinshausen et al., 2009) one could also think of negotiating the total amount of carbon that should be allowed to be emitted until a particular time, e.g. 2050, and then allocating budgets to different countries (WBGU, 2009). In both cases permits would be tradable over a long time horizon and could be sold by their holders whenever it seems appropriate to them in analogy to conventional resources.

In conclusion, the introduction of an international carbon market has two important implications inducing its comparability to conventional resources: it creates a scarcity that is connected to additional rents and the distribution of initial allowances defines the scale of trade between market participants and therefore induces financial flows indirectly.

2.2 Channels of the "Resource Curse" and Emission Permits

A number of channels have been identified that can explain the effects of the resource curse in more detail. In the following we will highlight three of the most important ones – Dutch Disease, rent seeking and the role of institutions, and volatility – and discuss their severity assuming that a country would need to manage a climate rent.

2.2.1 Dutch Disease

An international carbon market will induce trade of permits until all market participants converge to the same marginal cost of abatement. The initial endowment of permits together with the efficient allocation determine who will be a net importer of the good, while an overallocation of allowances generates exports and constitutes a 'foreign exchange gift' (Torvik, 2001) as permits are traded internationally.

These additional exports can be provided at conceivably low costs and constitute a new source of income that enters the budget constraint for the exporters. However, such additional revenues have caused an appreciation of the real exchange rate of resource exporting countries in the past and thus caused negative effects on the manufacturing sector (Corden and Neary, 1982; Corden, 1984), an effect that is often called Dutch Disease.

The fundamental mechanism of this phenomenon is the so called 'spending effect' (Corden, 1984). Resource-, or carbon-, incomes will – if passed through to the population – lead to higher general wage levels, which would induce higher demand for traded and non-traded goods. As the latter cannot be imported, it would lead to higher demand for labor in the non-traded goods sector, thus crowding out this production factor from the traded sector and causing its contraction. If productivity spillovers between firms in the exportable manufacturing sector, e.g. through R&D or learning by doing, are the core driver of endogenous growth, the resource exporting country's industrial structure can suffer a long-lasting effect of lower growth rates (Wijnbergen, 1984).

However, the exact effects of Dutch Disease on the long term growth prospects of a country critically hinge on how labor and capital are allocated to an economy's resource-, traded- and non-traded sectors and whether the exported resource is an input in the non-resource sectors by itself. The so called 'resource movement effect' (Corden and Neary, 1982) describes how factor inputs and output change with additional exports, which will determine the growth prospects along with long term adjustment effects due to changed productivities of all sectors. While empirical studies generally offer support for a contraction of the traded sector within a country after additional international revenue (see Van der Ploeg 2011 for a review), the exact long term consequences of an initial appriciation of the real exchange are country specific (Torvik, 2001).

Summing it up, Dutch Disease effects are triggered by additional international revenues which will result from an inefficient initial allocation of permits in a carbon market. Spending effects will lead to a contraction of the traded sector while resource movement effects will induce country-specific consequences. Hence, the net result of the permit on growth rates can in this respect be ambiguous, with a tendency toward a negative influence.[2]

2.2.2 Institutions, Rent Seeking and Governance

Institutions play an important role whether resource inflows are beneficial for an economy or become a curse. Generally spoken, a resource bonanza gives incentives for productive entrepreneurs to involve in rent-seeking. Weak institutions encourage rent-seeking activities and corruption, in turn leading to even worse institutions (Murphy et al., 1993). Given an aggregated demand externality income is lowered by more than the extra income from resources (Murphy et al., 1989). Additionally, Murphy et al. (1993) highlight that rent seeking hurts innovative activities, which are a main driver of growth in the long run.

[2]The implementation of an international carbon tax would per se not lead to such adverse effects. However, direct transfers of money in order to compensate certain countries would lead to similar effects (Younger, 1992).

In contrast to that, good institutions, e.g. characterized by a highly developed legal system and transparency, increase the likelihood that more people engage in productive activities rather than rent-seeking, now benefiting from the aggregated demand externality. It can also be shown empirically (Mehlum et al., 2006a,b) that countries with sufficiently good institutional quality have not experienced a curse.

To assess the impacts of the climate rent, we look at data on institutional quality from WorldBank (2012) considering the various dimensions of institutional quality, voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption. Data range from 2.5 for very good institutional quality to -2.5 for very bad institutional quality. For countries that have managed to absorb resource incomes relatively well, as for example Botswana, Norway, Canada or the United States, governance indicators are positive for all categories, with the lowest value being 0.3 for political stability in the US, and mean values for the different categories ranging from 0.91 to 1.84 (table 1).

Table 2 analyzes global data of institutional quality aggregated to 11 world regions also used in model analyzes presented in later chapters.[3] We find that developing and transitional regions, i.e. AFR, IND, LAM, MEA, OAS, RUS and CHN score negatively on almost all indicators.[4] From an institutional point of view, this might be a strong indication that those regions will not have the necessary institutional quality to deal with the expectable inflows and thus can be expected to be prone to rent-seeking and related negative effects for the economy when receiving large permit revenues.

The resource curse literature emphasizes that negative effects of resource incomes, in particular rent-seeking, are inversely related to technological complexity of extracting, selling and transporting a particular resource at a given low level of institutional quality (Boschini et al., 2007). It can be shown empirically that natural point-sources as for example diamonds, but also coffee and cacao retard democratic and institutional development (Mavrotas et al., 2011). One major reason can be attributed to the fact that they fuel distributional conflicts (Wick and Bulte, 2006; Schollaert and Van de Gaer, 2009). One could

[3]For a detailed description of regions see table 7 in the Appendix.

[4]To aggregate the country level indicators to the regions used in our model, we take the average weighted by population numbers.

Table 1: Governance indicators in countries that have not experienced negative growth effects from large resource inflows for the year 2010. Source: WorldBank (2012)

Country	Voice and Accountability	Political Stability	Government Effectiveness	Regulatory Quality	Rule of Law	Control of Corruption
Australia	1.43	0.81	1.82	1.66	1.77	2.06
Botswana	0.43	0.91	0.51	0.47	0.66	0.97
Canada	1.38	0.94	1.87	1.69	1.79	2.06
Netherlands	1.49	0.93	1.73	1.79	1.81	2.15
Norway	1.62	1.29	1.79	1.48	1.93	2.07
United States	1.16	0.31	1.44	1.42	1.58	1.23
Mean	1.29	0.91	1.58	1.47	1.63	1.84
Median	1.43	0.93	1.79	1.66	1.79	2.06
Min	0.43	0.31	0.51	0.47	0.66	0.97
Max	1.62	1.29	1.87	1.79	1.93	2.36

Table 2: Data on institutional quality based on the World Governance Indicators (WGI, 2012) in different categories: Voice and accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption. Note that national data from WGI are aggregated and weighted by population to match with aggregated regions used in MICA

Indicator	AFR	CHN	EUR	IND	JPN	LAM	MEA	OAS	ROW	RUS	USA
Political Stability/No Violence 2010	-1.14	-0.76	0.62	-1.31	0.87	-0.41	-1.44	-0.96	-0.01	-0.89	0.31
Voice and Accountability	-0.74	-1.64	1.19	0.42	1.05	0.13	-1.15	-0.51	0.11	-0.94	1.16
Government Effectiveness	-0.84	0.13	1.21	-0.01	1.4	-0.08	-0.55	-0.36	0.14	-0.39	1.44
Regulatory Quality	-0.69	-0.22	1.31	-0.39	0.98	-0.01	-0.64	-0.52	0.15	-0.39	1.42
Rule of Law	-0.88	-0.34	1.26	-0.06	1.31	-0.4	-0.64	-0.58	0.1	-0.78	1.58
Control of Corruption	-0.79	-0.59	1.09	-0.52	1.54	-0.23	-0.79	-0.73	0.11	-1.07	1.23

argue that permits fulfill characteristics that seem to facilitate rent seeking, being presumably easy to extract as well as a point resource, at least when issued to governments (as for example done in the Kyoto Protocol). However, their exact nature depends on the institutional environment that is induced by a future carbon market design. Expert knowledge on the government level would be required in order to deal with administrating carbon accounts or international Measurement, Reporting and Verification (MRV) requirements. Due to international control, selling permits would probably be difficult on informal markets, diffusing one key argument for resources with a low complexity of extracting, selling and transporting facilitating rent-seeking activities. Also, permits do not necessarily fulfill the negative characteristics of point-resources. For instance, it is debatable whether permits administrated by a central government induce grievance by parts of the population that might not have access to the resource in the same way as it has been observed for other natural resources.

The literature also identifies conflicts as an extreme form of rent seeking to become more likely with high resource incomes as the increased availability of finance makes rebellion feasible (Collier and Hoeffler, 2004). Risk of conflict increases initially along with resource income, but a high level of natural resource income decreases the risk of war as governments are increasingly able to defend themselves, e.g. by increased military spending (Collier and Hoeffler, 1998). The likelihood of conflict does not seem to be obviously increased by the climate rent itself. If we assume that governments are exclusively eligible to sell permits internationally, it would be difficult to sell permits on informal markets, thus potential warlords might not be rewarded. However, the probability of conflicts might be increased by a wider availability of funds in countries experiencing a climate finance bonanza. Also, it should be noted that permits in general as well as the international carbon market infrastructure are not safe from fraud, as experiences from the EU ETS have shown (Guardian, 2011; Bloomberg, 2013).

Finally, the quality of institutions is also related to the governance dimension of resource incomes. Governments might be tempted (even when having good institutions with functioning checks and balances) to raise public expenditure to a degree that is unsustainable once resource incomes decrease or vanish. Hence, this might lead to a political lock-in into granted benefits, which is hard to overcome.

2.2.3 Volatility

Prices of commodities have been shown to be more volatile than those of manufactures over the past centuries (Jacks et al., 2011). According to Van der Ploeg and Poelhekke (2009) and Van der Ploeg and Poelhekke (2010), an economy that largely depends on volatile revenues from these resources exhibits increased macroeconomic variability. The induced instability of economic output in turn is responsible for reduced long term growth prospects: many studies (see e.g. the fundamental study by Ramey and Ramey, 1995) have concluded that macroeconomic volatility induces strong negative effects on the affected economies.

This raises the question whether the volatility of permits might potentially be harmful for an economy. As for any other traded good, prices in a carbon market will be subject to fluctuations and therefore their sales will induce macroeconomic variability. The literature identifies two main sources of volatility: regular causes from demand and supply, as well as political decisions. Benz and Trück (2006) as well as Feng et al. (2011) investigate the EU-ETS and identify temperature, variable fuel prices and fluctuations in economic growth as the main drivers of volatility. Additionally, governmental intervention like renewable subsidies, nuclear phase-outs and the initial permit allocation influence the variability as well as the trend of prices.

In order to assess the magnitude of these fluctuations, it is worthwhile to compare the volatility of European Union Allowances (EUAs) – exemplary for carbon markets – with those of other internationally traded commodities. The comparison has to be taken with caution as the time range of the data is short for EUAs and the results are only valid for the European market. Building on the methodology of Jacks et al. (2011) table 3 shows that the volatility of EU-ETS prices is comparable to that of crude oil and minerals while being almost double that of steel. This first look at the data suggests permits to exhibit a variability comparable to typical resources having caused negative effects in the past.

When considering an international agreement and the setup of an integrated carbon market, the nature and design of the market will influence the extend of volatility. Combining heterogeneous countries into one carbon market would

Table 3: Volatilities of specific goods

Good	Volatility
EUAs[a,b]	0.099[c]
Crude oil[a]	0.102[d]
Steel[a]	0.042[d]
All Commodities	0.080[e]
Food	0.084[e]
Agricultural raw materials	0.061[e]
Minerals ores and metals	0.099[e]

a Volatilities are calculated as in Jacks et al. (2011) as the standard deviation of logged monthly price ratios, that is, the standard deviation of the percentage changes in price over a given period
b December 12
c ECX, 2012; 51 observations, 2008–2012
d Index Mundi, 2012; 51 observations, 2008–2012
e Jacks et al. 2011; 2005–2008

likely decrease the volatility of the price.[5] Shocks from changes in the initial supply of permits will probably be moderate once an international agreement is in place, but still possible. Thus, market integration would probably lead to decreasing volatility, while the regular causes of instability (business cycles, technology shocks, fuel prices) remain.

In addition, the intertemporal design of the market will also be crucial in determining prices: Experiences from the first phase of the EU-ETS have shown that the absence of banking at the end of the commitment period can have significant influences on the price level leading to a highly increased volatility.[6] Therefore, taking advantage of the freedom in when to emit, variability of the carbon price could be greatly reduced by increasing the duration of the commitment periods or allowing for banking between them (see also Fankhauser and Hepburn 2010a).

Next to the volatility of prices implied to an economy it is also important to take the overall volatility of an economy into account. Van der Ploeg and Poelhekke (2010) find that the magnitude of the negative impact of resource revenues is

[5] Jacks et al. (2011) show that world market integration has a positive impact on the stability of commodity prices.

[6] In the case of the EU ETS a remarkable decrease of the permit price was observed towards the end of the first commitment period.

dependent on the general level of economic variability and the respective institutions in place. If financial markets are less developed, the instability of the growth rate leads to an inefficient increase in the interest rate and also to restrictions in borrowing. As a consequence, innovation and therefore growth become hampered for these countries causing the adverse effects shown empirically.

In order to identify which regions are vulnerable to volatile permit prices, table 4 considers two indicators for financial development, as in Van der Ploeg and Poelhekke (2009) and Van der Ploeg (2011): first domestic credit to the private sector as a share of GDP and second money and quasi money as a share of GDP. Using the regional aggregation that was introduced in the previous section, both indicators show that AFR, IND, LAM, MEA, OAS, and RUS are least developed financially, which largely coincides with their volatility. Adding additional fluctuations by exportable permits will – based on historic experiences – likely cause AFR, MEA, ROW and RUS to exhibit significantly lower growth. Since IND and LAM currently exhibit fairly low volatility, the influence of additional varying climate rents would arguably be less severe in their cases. For ROW the indicators do not lead to a sharp conclusion, which can be explained by the regional aggregation combining countries that are structurally very different. CHN, EUR, JPN, and USA are most developed financially and will thus likely be able to absorb volatile climate rents relatively well.

2.3 Vulnerable Players

The discussion so far has emphasized that the adverse effects from conventional resources strongly depend on the characteristics of the individual countries. For two out of the three channels, institutions/governance and volatility, their likelihood to take effect can be specified along the characteristics from tables 2 and 4. This would leave some players only to be affected by Dutch Disease, a channel with its net effect in specific cases possibly also positive.

We thus summarize the findings from above to specify a "vulnerability to a climate finance curse". Only for these vulnerable players the value of φ, the strenth of the curse, will be greater than zero in our numerical model. The conclusion is straightforward for EUR, JPN, and USA as the individual findings for institutions and volatility indicate that a curse is unlikely to take place in these regions. For AFR, MEA, OAS, and RUS both channels are likely to

Table 4: Standard deviation of growth rate as well as a two financial development indicators for the eleven world regions of MICA. Means and standard deviations are cross-country averages over the period 1990-2010

	AFR	CHN	EUR	IND	JPN	LAM	MEA	OAS	ROW	RUS	USA
Standard Deviation (Penn World 7.1)	6.75	5.24	3.84	3.53	2.48	4.29	7.29	5.11	6.63	7.75	2.31
Domestic credit to private sector as share of GDP (%) (World Bank)	15.89	112.28	104.79	32.48	193.16	34.1	37.73	64.96	101.45	23.84	167.57
Money and quasi money (M2) as % of GDP (World Bank)	28.53	162.3	108.13	52.99	209.41	49.33	50.51	52.93	48.95	27.19	71.86
Resource share in GDP in 2004 (%) (GTAP 7)	25.6	1	1.2	1.6	0	6.1	23.7	2.9	5.2	10.7	0.5

cause negative effects. The characteristics of IND and LAM only suggest a tendency toward adverse effects of receiving a climate rent as especially the macroeconomic volatility is low. Nevertheless, we presume that overall a curse is more likely to take place . ROW, and CHN are ambiguous when summarizing both channels and we will proceed with assuming no curse to take effect for these two regions.

3 The Climate Rent Curse in a Coalition Formation Model

In order to derive a quantitative estimate for the trade off between receiving additional revenues through the climate rent and experiencing its adverse effects on the economy as discussed in the previous section, we use the Model of International Climate Agreements (MICA).[7] MICA is a simple dynamic model of the world's major economies and the global climate system that can be solved for different degrees of cooperation on climate change mitigation. This section summarizes the essentials of the model; the technical details of model equations and solution techniques are found in the appendix.

3.1 Model Regions and Equilibrium

MICA differentiates eleven world regions, which are set up to include the major global players in climate policy. Table 7 gives details on the aggregation. We assume free market economies in all regions, modeled by the maximization of a social welfare function by a representative agent.[8] Climate change damages are an international externality, which is not internalized when the regions maximize just their welfare (non-cooperatively). The outcome of the global economy is then inefficient. This is prevented when regions cooperate in an international climate agreement (coalition), and consequently climate change damages of the signatories are internalized by a maximization of their aggregate social welfare. Cooperation may be full, comprising all regions in a grand

[7] MICA has been introduced and used in Lessmann et al. (2009); in this paper we present an updated version with heterogeneous players calibrated to real world regions.

[8] We can interpret the solution of this optimization as a market equilibrium because there are no market imperfections on the regional level, and therefore the market equilibrium will be the same efficient allocation as this social planner optimization.

coalition, or partial, in which case the aggregate welfare of the coalition is maximized while non-signatories maximize their individual welfare.

We are particularly interested in climate agreements that are *self-enforcing* in the sense that its signatories form a stable coalition, where no member would be better off if she left the treaty (internal stability) and no non-member would rather join (external stability). As external stability has been identified not to be the main bottleneck of coalition formation (Dellink, 2011), we will focus on internal stability in the following analysis.

Technically, this implies that the *stability function*, measuring the difference of a regions welfare as a member of the coalition minus her welfare as a free-rider to the remaining coalition after she defects, is positive for all members. Formally, the agreement is the first stage in a two stage game: a game of membership in the agreement followed by the decision of economic strategies in the second stage. The equilibrium is solved by a Nash equilibrium in economic strategies in the second (termed a partial agreement Nash equilibrium, cf. Chander and Tulkens, 1995), and by coalition stability in the first stage.

Economic Strategies

A region's social welfare aggregates the discounted utility of its population over time, where utility is a function of per capita consumption. Regions produce and consume a single good using capital and labor as input factors. Therefore, the central decision is how much to consume at a given point in time. The remainder of the domestic product is then either reinvested in capital for future production, exported internationally, or used to finance emission mitigation. Net exports must balance over the modeled time horizon, all other expenditures are subject to budget constraints at every point in time.

Global warming is driven by carbon-dioxide emissions, which are modeled as a side effect of production. A climate module computes the increase in global mean temperature that arises from aggregate emissions. The loop with the economy is closed by a climate change damage function which translates temperature rise into a fraction of domestic product that is lost. Climate change mitigation takes the form of an aggregate mitigation option that allows reducing emissions at increasing marginal costs.

In addition, MICA allows for permit trading within a given coalition: emissions for each player have to be covered by the initial allowance net of exports. When an exogenous distribution of emission rights, efficient for the coalition, is given, players trade until their marginal abatement costs are equalized. Therefore, those regions that are over-allocated with permits are able to sell the excess to those that demand them, thus inducing a financial flow proportional to the endogenous carbon price. The specification of the formulas for the initial distributions is given in section 4.1.

3.2 Climate Rent Curse

As discussed in detail in Section 2, economic performance is adversely affected by the revenues from exporting permits. Following Sachs and Warner (1995), a high share of revenues π relative to the gross domestic product GDP reduces the growth rate in region i from the counterfactual g_0 to g^* according to

$$g^*(i,t) = g_0(i,t) - \varphi \cdot \frac{\pi(i,t)}{GDP(i,t)}. \tag{1}$$

Growth rates g_0 and g^* at time t are averaged over the next twenty years, and the parameter φ determines the severity of the 'curse' effect. Within MICA, the counterfactual economic product $GDP(i,t)$ is known and taken from a model run assuming no climate rent curse over that period. This also defines the associated growth rates $g_0(i,t)$. Together with the revenues from permit-trade $\pi(i,t)$, defined through the different allocation schemes within the model, $g^*(i,t)$ can directly be calculated. Since the growth rate is endogenous in the model and can therefore not be set directly, we adjust the total factor productivity resulting in the reduced growth rate g^*. This interpretation is in line with the most prominent channels inducing the curse: unproductive rent-seeking as well as inefficient rises in the interest rate hampering innovation. In addition, ingenuine investment decisions can also be attributed to less total factor productivity. Other modeling approaches, as for example inefficient saving, are less capable to cover the phenomena discussed in the previous sections.

After the adjusted values for the total factor productivity are found, the model is re-run to produce results that include the climate rent curse. Evaluating their payoffs under this setting, regions take the adverse effect into account when deciding about their participation without preventing its cause.

The total factor productivity ($\alpha(i,t)$ in (5)) is adjusted in the following procedure for every time step t beginning at the initial period: For time period t, we adjust the total factor productivity twenty years ahead $\alpha(i,t+20)$ to reduce $GDP(i,t+20)$ such that the growth rate drops to $g^*(i,t)$. The growth rates $g_0(i,t'>t)$ are updated to take this new value into account. We find that adjusting $\alpha(i,t)$ has only a small influence on the growth rate of the previous steps, and we can therefore apply this algorithm successively for all times t.

The specified way implicitly assumes that the reduction in total factor productivity is not permanent but that countries recover from it fully within a decade after the revenue from resources vanishes. This view is optimistic and represents a lower bound to the negative effects of the climate rent curse.

The estimates of φ in Sachs and Warner (1995) depend on the number of variables controlled for and takes statistically significant values between 6.96 and 10.57. As we do not include any other variables considered by Sachs and Warner (1995) φ will take the value of 9.43, which follows from their basic regression with only the initial *GDP* and the resource income controlled for in the empirical analysis.

In section 4.2 we relax the strength of the climate rent curse. This acknowledges the fact that permits are not totally congruent to conventional resources (see section 2) and also the possibility of countries taking measures in order to prevent the curse partially.

4 Implications of the Climate Rent Curse in the Climate Game

In this section, we discuss the influence of four transfer schemes on internal stability in the model MICA. In the basic setting, discussed first, we present the results without any adverse effects from trading permits. The second part demonstrates the implications of a climate rent curse, which crucially influences the conclusions of the first part. The basic results will mainly be drawn from statistics of the entire ensemble of coalitions (amounting to 2037 distinct ones). Specific examples concerning the grand coalition (GC), comprising all players, will demonstrate the effects in more detail.

4.1 Stability Analysis without the Climate Rent Curse

Evaluating the whole payoff-matrix in the absence of transfers, 54 internally stable coalitions emerge. Out of these, one consists of four players, 17 of three players while the others are two-player coalitions. The one with the best performance in environmental terms is: {CHN, OAS}. This coalition achieves 17.2% (188 GtC over 200 years) of the abatement undergone in the GC, while the other internally stable coalitions on average reach only 5.0% of the abatement in the social optimum.

In order to enhance participation and reach better performance in environmental effectiveness, additional measures can be implemented. Since the regions within MICA are very heterogeneous in their characteristics on costs and benefits from mitigation, transfers proof to be a good tool to share surpluses between low-costs and high-damage players. We study the influence of four transfer schemes, three conventional and one optimal one:

1. Per-Capita-Convergence (PCC): starting with the permits being allocated by grandfathering in the first period, it gradually (with a weighted sum) converges to the equal-per-capita permit scheme; transition is completed after 50 years (based on Leimbach et al., 2010).

2. Equal-Per-Capita (PC): permits are handed out proportional to the population (based on Altamirano-Cabrera and Finus, 2006).

3. Historic Responsibility (HR): permits are handed out inversely proportional to the emission-population ratio of the players in the starting year weighted with the current population (based on Altamirano-Cabrera and Finus, 2006).

4. Optimal Transfers (OT): We follow the algorithm proposed in Kornek et al. (2013) and identify the transfers-schemes which achieve internal stability in our model if feasible. The left-over surplus, free to be allocated inside the coalition, is equally shared among the members so as to leave everyone of them with a positive incentive to remain a signatory.

Whereas PC and HR have been termed equitable by Altamirano-Cabrera and Finus (2006) because they are based solely on normative criteria, the PCC-scheme takes a more pragmatic view and starts out with a grandfathering mechanism, therefore decreasing the burden of the currently large emitters. It induces the least magnitude of financial flows among the conventional schemes, which is displayed in table 5 where the average and maximum amount of monetary flows received in all coalitional structures are displayed. HR requires particularly large transfers of up to 13.6 % of the current GDP.

Table 5: Characteristics of the four transfer schemes: a) Basic setting without adverse effects from exporting and b) with taking the climate rent curse into account

	No-transfer	HR	PC	PCC	OT
a)Without climate rent curse					
Avg.[b] total flow (Tr USD)[a]	-	0.73	0.37	0.15	0.02
Max. total transfer (Tr USD)[c]	-	6.26	1.87	0.68	0.08
Max.[b] transfer (% of current GDP)	-	13.6	5.0	2.1	1.2
Internally stable coalitions:					
Number	65	33	35	47	480
Max. participation	4	3	3	3	6
Max. Abatement (% of GC)	17.2	9.6	9.6	16.4	31.8
Players stabilized by transfer:					
Number	-	1958	2702	2576	897
Avg.[b] total transfer received (Tr USD) [a]	-	0.76	0.41	0.17	0.02
Max[b] transfer (% of current GDP)	-	13.6	5.0	2.1	1.2
b)With climate rent curse, players stabilized by transfer					
Destabilized players, number:	-	1887	2662	2395	578
Remaining positive					
Vulnerable players	-	25	12	22	3
Non-vulnerable players	-	46	28	159	316

a Discounted sum of transfers over entire time horizon

b Over whole ensemble

c Discounted sum of transfers over entire time horizon, maximum of whole ensemble

As is evident from table 5, many coalitions that are internally stable without transfers are destabilized under the conventional transfer schemes. This is due to the fact that these transfers are not designed along the incentives of the regions. Rather, they are perceived to be fair in distributing the burden of abatement costs and therefore target the incentives of the developing world only. For these players, the conventional transfer schemes induce higher consumption and therefore a higher payoff inside the coalition. Considering the effect of the transfer schemes on individual players rather than whole coalitions, table 5 therefore displays the number of players that are internally stabilized through the redistribution, i.e. where the membership of certain players was encouraged through transfers from other signatories inside all possible coalitions.

The table shows that the number of internally stabilized players is substantial, especially for the PC-transfer scheme. Notably, 99.9 % (99.6 %, 93.2 %) of these are developing regions in the case of HR (PC, PCC)[9] thus showing that the design of the conventional transfer schemes is attractive primarily to the developing regions. Of course, as only few coalitions are internally stable, there are other members that have an incentive to leave them. In order to see this, figure 1 shows the financial flows required for all transfer schemes inside the grand coalition. Especially AFR and IND benefit from the equitable schemes. In AFR (IND) permits account for 2.9 % (13.1 %) of its initial GDP for HR, while it is 3.3 % (AFR) and 4.8 % (IND) for PC. To see the diminishing influence to the paying players, compare the incentives to stay inside the grand coalition in the case of 'No tranfers' to 'PC $\varphi = 0$' in figure 2: the incentives of AFR, IND, LAM and OAS are positive but this comes at the disadvantage of developed countries.

As opposed to the examples given so far, transfers can have a tremendous effect on internal stability if designed properly. Optimal transfers (OT), as proposed e.g. by Weikard et al. (2006), induce increased participation. We apply the framework developed in Kornek et al. (2013) and find 480 coalitions in MICA internally stabilized using the OT mechanism, among which the largest include six players. With reference to table 5, the maximum environmental effectiveness and participation improve compared to the internally stable coalitions in the no-transfer case. Financial flows are significantly reduced compared to the two equitable schemes, with the maximum share accounting for 1.2 % of

[9]Developing regions are identified according to the list given by ISI (2012). A region in MICA counts as 'developing' if more than 50 % of its GDP is made up of developing countries.

GDP.[10]

As we have seen in the discussion so far, proposed conventional transfer schemes from the literature imply large monetary flows between regions, not always to the benefit of stabilizing whole coalitions but targeting the developing world at the expense of rich players. This induces them to remain a member to an agreement that distributes the climate rent well from a normative perspective because a large burden of abatement costs is shifted from the poor to the rich. Overall, cooperation is however not enhanced because the conventional transfer schemes are not designed in accordance to the incentives of the players. On the contrary, transfers are able to enhance cooperation greatly if designed properly in the form of optimal transfers, which foster a large increase in participation to an internally stable climate agreement.

Looking at the magnitude of required transfers in table 5, however, it is questionable if one could expect these large financial flows to solely induce higher consumption, which they are designed for. As we have argued in section 2, the permit as a scarce resource may show adverse effects comparable to the resource curse. We therefore proceed with analyzing the performance of the four transfer schemes when this effect is taken into account.

4.2 The Influence of the Climate Rent Curse

Building on the analyses in section 2 as well as in the previous section, this section studies the magnitude of the adverse effects of a climate rent curse. The adverse effect is known to each player and taken into account when deciding about her membership without being able to influence it. Players are in this respect understood as benevolent governments aiming to maximize their region's intertemporal welfare during the climate negotiations.

Expecting a climate rent curse to materialize essentially destabilizes all internally stable coalitions for the conventional transfer schemes that involve vulnerable players (for the identity of these players see section 2.3). In order to see the influences in a distinct example, figure 2 shows the consequences of a curse for the grand coalition (that is not stable) under the PC transfer scheme.

[10]Flows under the OT-mechanism are significantly decreased as signatory and non-signatory solutions exhibit only small variations from each other compared to the magnitude of the climate rent.

Looking at the influence of a climate rent curse, the bars '$\varphi = 9.43$' show, as expected, that the stability function of the affected players that receive positive transfers inside the coalition is reduced in value; the magnitude of the decrease is substantial.

In order to track the reasons for this in more detail, it is worthwhile to consider the optimal division of output among the expenditure options (see equation (17) in the Appendix) – consumption, saving, mitigation costs, damage costs and net exports – with and without a curse. Figure 3 displays the change in the budget-decisions when the climate rent curse is introduced inside the grand coalition and with the PC-scheme in place: the discounted sum (over the entire time horizon) of the difference in each expenditure option with a climate rent curse and without any adverse effects. For players that are not directly affected by the curse only minor changes occur due to general equilibrium effects. Each expenditure option is negatively influenced for players affected by the climate rent curse, i.e. AFR, IND, LAM, and OAS, which reflects the fact that the over-all production without the curse is, as expected, higher. Interestingly, the figure depicts that this change in production is over-proportionally transformed into a cut in consumption. The allocation in efficient saving is changing compara-bly less. This is due to the fact that the interest rate, governing the investment decision, is determined by the production of all players and is therefore only marginally affected by the decrease in total factor productivity of the vulner-able players. Saving therefore has to decrease for them when introducing the climate rent curse, which in turn leads to even less production in later periods and therefore to sharp decreases in consumption.[11]

The preceding analysis explains why the entire surpluses of the developing re-gions AFR and IND are canceled by the climate rent curse inside the grand coalition and all players are left with a negative incentive to stay inside the agreement. The overall welfare of the coalition is below the 'No Transfer' case and the seemingly attractive attributes of the equitable transfer scheme, the rich paying the poor for their abatement, is lost.

Looking at the stability across all coalitions, table 5 displays the basic statistics about the internal stability of players the transfer mechanisms originally en-

[11] The negative contributions from damages are due to the fact that without a climate rent curse, production in affected regions is higher. This is turn leads to higher damages as these are proportional to the output, see equation (5).

couraged to participate. For HR (PC, PCC) out of 1912 (2674, 2417) players, which are vulnerable to the climate rent curse, only 25 (12, 22) still remain with a positive incentive after taking the climate rent curse into account showing the severe negative influence of a climate rent curse in the case of the equitable transfer schemes.

One may suspect that this negative outcome is due to the rather high payments involved in the conventional transfer schemes. On the contrary, almost all coalitions, internally stabilized by the OT-scheme, are destabilized under the influence of a climate rent curse as well:[12] Only 30 affected coalitions remain internally stable. Looking at internally stabilized players that are affected by the curse, just 3 out of 581 remain with a positive incentive to stay. However, this result crucially depends on the fact that in the OT-scheme, due to the small amount of surplus shifted, each player also has a significantly decreased value of the stability function. Although the negative effects caused by the climate rent curse are much decreased in magnitude compared to the conventional transfer schemes, these small changes already influence internal stability in the negative direction.

As the analysis has shown so far, the adverse effects of the proposed climate rent curse are so large that internal stability is greatly reduced irrespective of the design of the transfer scheme. Especially, decreased magnitude of the transfers involved could not improve upon this result. We therefore conclude the analysis with a parameter study of the strength of the climate finance curse.

Varying the Strength of the Climate Rent Curse

In order to examine how the assumed strength of the climate rent curse affects the results from above, we study the influence of decreasing values for the parameter φ in a sensitivity analysis. This generally takes into account that the permit is not exactly congruent to conventional resources and, additionally, it describes the ability of the players to apply measures to handle the large windfall revenues in a better way. As discussed in section 2, this would require to address the different channels of the conventional resource curse so as to decrease φ.[13] Before presenting the results from the model, we provide a rough

[12] The OT-transfers stay at their level without the climate rent curse.

[13] Rodrik (2007) discusses in great detail how policy reforms should be designed in order to enhance the growth prospects in the face of various economic and institutional constraints. In

estimate for when the value of φ is small enough so that a transfer induces an increase in payoff.

Consider a player with initial consumption c, growth rate of consumption over 20 years g and constant interest rate r. The payoff of this player is then approximately given by

$$U(c,g) \approx c + \frac{c \cdot \exp^{g \cdot 20}}{(1+r)^{20}}.$$

Increasing the initial consumption c_0 by Δc, we assume the growth rate g to be negatively affected: $g = g_0 - \varphi \frac{\Delta c}{\Delta c + c_0}$. The change in payoff, approximated for small φ, is:

$$\Delta U = U(c_0 + \Delta c, g_0 - \varphi \frac{\Delta c}{\Delta c + c_0}) - U(c_0, g_0) \approx \Delta c - \varphi \frac{c_0 \cdot \exp^{g_0 \cdot 20}}{(1+r)^{20}} \frac{\Delta c \cdot 20}{\Delta c + c_0}.$$

From this, we can give an upper bound to φ in order for the change ΔU to be positive:

$$\varphi < \frac{(1 + \frac{\Delta c}{c_0}) \frac{1}{20}}{\frac{\exp g_0 \cdot 20}{(1+r)^{20}}}.$$

The maximum strength of the curse is affected by three determinants: i) larger transfers Δc relax the upper bound, ii) lower interest rates r and iii) higher average growth rates g_0 reduce the upper bound. Using numbers from MICA for the period 2005 to 2025, the average growth rate in consumption is $g_0 = 4.1\%$ and the average interest rate is $r = 5.9\%$. For values of $\frac{\Delta c}{c_0} = 0.001...0.15$ the upper bound on φ is 7.0...8.1. Following this approximation, the strength of the curse would have to be in the order of $\varphi = 7$ in order for the transfer to still induce a higher payoff.

The presented estimate of the maximum φ neglects a number of important features that our model incorporates: the change in transfers, interest rate and growth rate of consumption over time, the savings dynamics and the connection of resource income to GDP-growth. In addition, this estimate is only valid

our model, an endogenous choice of the strength of the resource curse is not considered but an extension that includes the costs of reform would be an interesting future research topic.

for increases in the utility: for coalition formation, one needs to consider the stability function. We therefore investigate the impact of varying the strength of φ on the whole ensemble of our model for each transfer scheme separately. Figure 4 summarizes the results by showing the percentage of affected players that the respective transfer scheme encouraged to participate and that the climate rent curse destabilized at different strengths of $\varphi = (2,4,6,8,9.43)$. The points '$\varphi = 9.43$' represent the data from table 5.

The figure shows that for strengths of the curse $\varphi \geq 8$, the majority of internally stabilized players becomes destabilized. At first sight, this is in accordance to our estimate. When looking at the data in more detail, however, it becomes apparent that for all three conventional transfers a negative outcome is more likely with larger magnitudes of the transfer for $\varphi \geq 8$ (not shown). This can be attributed to the dynamics of the model: If a transfer is received during the first period, it will not solely influence consumption in the beginning but due to the investment dynamics, consumption at later periods is also reduced (see the discussion of figure 3). Therefore all conventional transfer schemes perform badly as they induce transfers especially in the first century.

Lowering φ further, the negative effect of the curse on internal stability is greatly reduced. Decreasing φ from 6 to 4 seems to induce the largest number of players to change to a positive incentive to stay inside the agreement for the conventional transfer schemes. The timing of transfers is now less important and larger financial flows are more likely to induce a positive effect. When φ decreases to a value of 4, the majority of affected players, which the conventional transfer scheme internally stabilized, remains with a positive incentive to stay inside the agreement even if the climate finance curse is taken into account.

The OT-scheme is different in this respect as the number of players destabilized remains high when reducing the strength. This is due to the fact that by design this mechanism leaves the players only with a slightly positive incentive to stay inside the coalition without a curse. Inducing only moderate negative effects can already reduce the value of the stability function to negative signs. However, the number of internally stable coalitions increases greatly when the strength of the curse is reduced. Table 6 shows the number of internally stable coalitions that are affected by a curse in the form of reduced growth and their performance in size and environmental effectiveness.[14] At a strength of $\varphi = 4$,

[14]The best performing internally stable coalition under the OT-scheme that is not affected by

174 internally stable coalitions exist with the best performing one reaching an abatement of 23.9 % of the social optimum and with maximum participation at 5 players. Due to the greatly stabilizing characteristics of this transfer scheme, cooperation remains significantly enhanced for moderate strengths of the curse.

Summing it up, this analysis suggests that the strength of the climate finance curse demands decreased values to around 4 compared to historically observed ones in order for the transfers to largely preserve their intended effects. Especially the OT-scheme performs well in terms of enhancing cooperation.

Table 6: Performance of internally stable coalitions under the OT-scheme that are affected by the climate rent curse under varying strengths φ

φ	0	2	4	6	8	9
Nb. of internally stable coalitions	430	269	174	96	46	30
Max. abatement (% of GC)	31.4	26.6	23.9	21.7	17.0	17.0
Max. participation	6	6	5	5	4	4

5 Discussion and Conclusion

Being confronted with global climate change, developing countries face a tragedy: While not having caused global emissions to rise, as their cumulated historic CO_2 emissions are comparably low, impacts from climate change seem to be most severe in developing regions of the tropics and sub-tropics. Luckily – one might think – costs of mitigation are comparably low or even negative, depending on the allocation scheme that is applied (Luderer et al., 2012a). In this respect, transfers are seen to be a crucial tool from an equity point of view (Edenhofer et al., 2010b), which manifests in developing countries calling for allocation schemes based on historical responsibilities or equal per capita emissions. Also, in game theoretical analyses transfers between players are found to be pivotal to increase the size and number of stable climate coalitions (Dellink, 2011).

In the light of our analysis we conclude that climate rents induced by international carbon markets show characteristics comparable to resource rents that have been harmful for long-term economic growth of countries in the past. Even

the curse achieves an abatement of 19.3 % of the social optimum at a strength of $\varphi = 9.43$.

though not totally congruent, all channels of the resource curse might be relevant for a potential climate rent curse. First, Dutch-Disease spending effects will also occur in the case of receiving climate rents. Second, volatility of permit prices observed today is comparable or even higher than volatility observed on resource markets. Third, institutional quality in countries potentially receiving the climate rent based on ethical considerations is at present significantly lower than in countries that managed to absorb resource rents relatively well in the past, and rent-seeking can be expected to be high. Thus, it is unlikely that negative effects of Dutch Disease, rent seeking and volatility can be countervailed by good institutions as it has been the case in countries that have so far performed well despite high resource exports.

In how far an emission permit bonanza is a blessing or a curse for countries susceptible to this 'climate rent curse' is a trade-off between the revenues from permit sales and the adverse effects associated with it. Given our assumptions on how vulnerable economies are affected, and how severe the effect on growth is, our numerical experiments suggest that for a range of equitable, pragmatic and incentive compatible allocation schemes, the influence of transfers in permits are almost exclusively negative.

As a consequence, based on our coalition model, we find the incentives to remain a signatory to decrease significantly as soon as we introduce the resource curse. This of course assumes rational behavior of agents and – maybe more important – benevolent behavior of negotiators and governments whose explicitly damaging – i.e. rent seeking – behavior is a major driver of the curse. Therefore, in a climate negotiation game, countries that are identified to be vulnerable to a curse might nevertheless join a climate coalition. However, we interpret our results from a different angle. Reasonably expecting a climate rent curse, how should climate policy be designed to avoid negative effects on developing countries' long term growth prospects? Nevertheless it remains an interesting area of new research how results would change if non-benevolent negotiators were explicitly modeled.

Based on our analysis we can derive different answers to this question. When assuming a carbon market involving transfers to developing countries it is crucial to bring down the severity of the curse in those countries. Trying to neutralize particular channels of the resource curse might be a way to achieve this goal.

The quality of institutions seems to be a pivotal prerequisite to control rent-seeking and to provide the necessary quality of financial markets to control for volatility. As it can be assumed that institutional quality increases with economic development it may be reasonable to postpone transfers in time until developing countries have reached a particular level of institutional quality. In this respect the design of a carbon market can have an impact on the severity of the resource curse. Integrating a maximum number of heterogeneous countries in combination with a flexible design regarding the freedom in when to emit (e.g. by allowing for banking) can bring down price volatility significantly. Choosing a different allocation scheme implying less rents, e.g. grand-fathering or optimal transfers, can be less problematic with respect to rent seeking, but is however difficult to justify from an equity perspective. This raises the general question whether developing countries can and should be integrated into an international carbon market or whether other instruments are preferable.

Observing that transfers have potentially damaging effects, a carbon tax regime might generally be preferable over a quantity instrument. Raising a carbon tax would give less room for rent seeking, as artificial scarcities, monopolies or rents are not created (Nordhaus, 2007). Spending effects implied by Dutch-Disease can probably be avoided and in addition volatility concerns raised in a carbon market can be eased. However, a carbon tax in developing countries implies that mitigation costs would need to be covered by themselves, which again raises questions of equity and justice and might even slow down poor countries' growth prospects (Jakob and Steckel, 2013).

It is also conceivable that transfers could be collected and managed internationally. For example, a fund could be used to provide necessary additional investments needed to finance low-carbon technologies (Jakob et al., 2012) or foster investments in infrastructure needed to avoid lock-ins (Mattauch et al., 2012). Also, revenues generated by an international carbon market could be used to buy down the costs of low carbon technologies.

In any case, simply integrating developing countries into a – Kyoto like – global carbon market in our perspective might add a third dimension to the tragedy mentioned above: Not only would countries in developing regions face high impacts, but designing climate policy in a way that would leave them with extraordinary climate rents might additionally corrupt their long term growth prospects.

Acknowledgements

Funding from the German Federal Ministry of Education and Research (BMBF) (funding code 01UV1008A, EntDekEn) is gratefully acknowledged. The authors want to thank Michael Jakob for helpful comments and suggestions.

A Model Equations

In this section, we present the details of our numerical model. The model builds on Lessmann et al. (2009) and Lessmann and Edenhofer (2011) but uses eleven world regions as players, instead of nine symmetric players in cited studies. In the following, we first describe the model equations, their calibration, and the numerical procedure to solve the model.

Preferences

We model the world economy as a set of $N = 11$ regions (or players), see table 7. Players decide in an intertemporal setting which share of income to consume today and which share to save and invest for future consumption. Intertemporal welfare W_i and instantaneous utility function U based on per capita consumption are given by:

$$W_i = \int_0^\infty l_{it}\, U(c_{it}/l_{it})\, e^{-\rho t}\, \mathrm{dt} \tag{2}$$

$$U(c_{it}/l_{it}) = \begin{cases} \dfrac{(c_{it}/l_{it})^{1-\eta}}{1-\eta} & \text{if } \eta \neq 1 \\ \log(c_{it}/l_{it}) & \text{if } \eta = 1. \end{cases} \tag{3}$$

Here, c_{it} and l_{it} denote consumption and labor in region i at time t, respectively. Parameter ρ is the pure rate of time preference, and parameter η denotes the elasticity of marginal utility.

Table 7: Regions as defined in MICA and corresponding world regions

Model region	Countries
AFR	Sub-Saharan Africa w/o South Africa
CHN	China
EUR	EU27 countries
IND	India
JPN	Japan
LAM	All American countries but Canada and the US
MEA	North Africa, Middle Eastern and Arab Gulf Countries, Resource exporting countries of FSU, Pakistan
OAS	South East Asia, both Koreas, Mongolia, Nepal, Afghanistan
ROW	Non-EU27 European states w/o Russia, Australia, Canada, New Zealand and South Africa
RUS	Russia
USA	USA

Technology

The economic output y_{it} in each region is produced with a constant elasticity of substitution (CES) production technology F with share parameter γ and elasticity of substitution ρ_F. The total factor productivity α_{it} is the one in the base setting. Climate change damages (defined below in Equation 16) destroy a fraction $1-\Omega_{it}$ of the production. Economic output is further reduced by abatement costs $1-\Lambda_{it}$ (defined in equation 9). F is calibrated using the initial values of output, labor productivity, labor, and capital (y_{i0}, λ_{i0}, l_{i0}, and k_{i0}).

$$y_{it} = (1-\Lambda_{it}-\Omega_{it})F(l_{it},k_{it}) \tag{4}$$

$$F(l_{it},k_{it}) = \alpha_{it}y_{i0}\left[(1-\gamma)\left(\frac{\lambda_{it}l_{it}}{\lambda_{i0}l_{i0}}\right)^{\rho_F}+\gamma\left(\frac{k_{it}}{k_{i0}}\right)^{\rho_F}\right]^{(1/\rho_F)} \tag{5}$$

Labor l_{it} is given exogenously, as is labor productivity λ_{it}. Capital k_{it} accumulates with investments i_{it} and is depreciated at rate δ_i.

$$\frac{d}{dt}k_{it} = i_{it} - \delta_i k_{it} \tag{6}$$

$$\tag{7}$$

Emissions and Emission Allowances

Greenhouse gas emissions e_{it} are a byproduct of economic activity y_{it}. We assume that the emission intensity σ_{it} falls exogenously due to technological progress: $\sigma_{it} = \sigma_0(i)\left[\cdot(1-\sigma_{min}(i))\exp^{v_1(i)\cdot t+v_2(i)\cdot t^2} + \sigma_{min}(i)\right]$. Beyond this, emissions may be reduced by abatement a_{it} at the cost of Λ_{it}, where the generic functional form is taken form Nordhaus and Yang (1996).

$$e_{it} = y_{it}\,\sigma_{it}\,(1-a_{it}) \tag{8}$$

$$\Lambda_{it} = b^1_{it}\cdot(a_{it})^{b^2_i} \tag{9}$$

Emission allowances may be traded internationally (z_{it} denotes net export of allowances by region i), but we exclude intertemporal banking and borrowing of allowances, i.e. total imported and exported allowances must be balanced in every period.

$$e_{it} \leq q_{it} - z_{it} \tag{10}$$

$$\sum_j z_{jt} = 0, \qquad \forall t \tag{11}$$

Climate Dynamics

Global warming is driven by total global emissions of CO_2 into the atmosphere, which are equal to cumulative total emission allowances Q_t.

$$\frac{d}{dt}C_t = \zeta Q_t - \kappa(C_t - C_0) + \psi E_t \tag{12}$$

$$\frac{d}{dt}E_t = Q_t \tag{13}$$

$$Q_t = \sum_i q_{it} \tag{14}$$

Equation 12 translates global emissions into carbon concentration in the atmosphere C. Concentration C rises with global allowances (same as emissions), where ζ converts emissions into a change in concentration, and it decreases due to the carbon uptake of the oceans proportional (κ) to the increase above the pre-industrial level C_0. The final term limits the ocean carbon uptake (to the fraction $1-\psi/\zeta\kappa$ in equilibrium). For more details on the climate equations see Petschel-Held et al. (1999).

$$\frac{d}{dt}T_t = \mu \log(C_t/C_0) - \phi(T_t - T_0) \quad (15)$$

Equation 15 transforms concentration levels into a global mean atmospheric temperature increase T. Here, parameter μ controls the strength of the temperature reaction to a change in concentration, whereas parameter ϕ is related to its timing. Together, they have an interpretation as the "climate sensitivity" ($\mu/\phi \cdot \log 2$), i.e. the equilibrium temperature increase for a doubling of the concentration. In view of the inertia of the climate system, we run the model for 250 years in steps of 10 years.

The climate change damage function is taken from Dellink et al. (2004):

$$\Omega_{it} = 1 + \theta_{2i}(T_t)^2 \quad (16)$$

Two sets of "book keeping" equations complete the model: the budget constraints for consumption and investments for each region at every point in time, as well as the intertemporal budget constraint ensuring that over the entire time horizon, the import value must equal the export value in each region.

$$y_{it} + m_{it} = c_{it} + i_{it} + b_{it} + x_{it} \quad (17)$$

$$\int_0^\infty p_t\, m_{it}\, \mathrm{dt} = \int_0^\infty p_t\, x_{it} + p_t^z\, z_{it} \mathrm{dt} \quad (18)$$

Variables m_{it} and x_{it} are imports and exports of region i, respectively, and p_t and p_t^z are the prices of goods and allowances, respectively.

Model Calibration

The focus of this model is on the incentive of regions to participate in the international abatement effort. For the calibration of the model, two aspects are therefore of primary importance: the costs of emissions reductions and associated benefits, i.e. foregone damages.

For an estimate of mitigation costs, we calibrate our model to a large scale integrated assessment model, REMIND-R (Leimbach et al., 2010). MICA and REMIND-R share some important features, resulting in similar economic dynamics: both are multi-region optimal growth models driven by the maximization of intertemporal utility, and both allow for intertemporal trade. Thus, when using the same initial values (k_{i0}, l_{i0}, y_{i0}), exogenous population scenario (l_{it}), and parameter values where possible (i.e. in the utility function: ρ, η, in the production function: γ, ρ_F, and in capital dynamics: δ_i), and calibrating the labor productivity (λ_{it}), the economic dynamics in absence of climate policy or climate change damages are in "good agreement." We measure this agreement by computing the coefficient of determination R^2 for y_{it}, and c_{it} over the first 10 decades. With rare exceptions, the resulting R^2 are large (columns 1-2 of Table 8). The exogenous decline in emission intensity σ_{it} was chosen by calibrating the parameters ($\sigma_0(i)$, $\sigma_{min}(i)$, $\nu_1(i)$, $\nu_2(i)$) such that emissions over the century coincide. Here we report remaining difference as the deviation of cumulative emissions over the first century, with values around 5 % in all regions (see column 4 in table 8).

The actual costs of reducing emission by a_{it} percent versus these baseline dynamics are defined by the cost function Λ (equation 9). We calibrate its parameters, b^1_{it} and b^2_i, to reproduce the abatement costs in REMIND-R, such that both models reduce emissions by the same amount over the century under the two carbon tax scenarios (high tax and low tax). For this, the b^1_{it} follow the generic equation ($b^1_{it} = b^0_i \cdot e^{\vartheta_i \cdot t} + b^{\text{inf}}_i$), whose parameters ($b^0_i$, ϑ_i, b^{inf}_i)) are then found to best fit to the abatement of REMIND-R. The remaining difference is reported in columns 5-6 in table 8.

Information on climate change damages is available in the literature in form of damage functions. We use the damage function from Dellink et al. (2004), which we rescale to the spacial layout of our eleven regions (see (Nordhaus, 2002) for a discussion of spatial rescaling).

Table 8: Remaining errors in the calibration of MICA. We measure the goodness-of-fit by the R^2 value, except for emissions where the difference in their cumulative amount over the century is reported.

Region	BAU Product	Consumption	Emissions (%)	Tax Abatement low tax	Tax Abatement high tax
AFR	0.971	0.961	6.514	0.939	0.950
CHN	0.938	0.932	1.341	0.865	0.958
EUR	0.981	0.922	1.806	0.932	0.923
IND	0.998	0.957	1.723	0.954	0.973
JPN	0.988	0.852	-0.158	0.945	0.966
LAM	0.987	0.990	0.849	0.901	0.911
MEA	0.990	0.984	2.893	0.983	0.993
OAS	0.993	0.932	3.309	0.895	0.909
ROW	0.993	0.919	4.274	0.895	0.943
RUS	0.982	0.835	0.617	0.984	0.911
USA	0.991	0.954	2.341	0.980	0.992

Solving the Model for the Game's Equilibrium

We are considering a two stage game of, first, *membership* in an international environmental agreement (IEA), and second, an *emission game* where players choose their emission allowances.

The game is solved numerically by backward induction, i.e. first we compute partial agreement Nash equilibria (PANE, cf. Chander and Tulkens 1995) for all possible coalitions, then we test these coalitions for internal and external stability according to the following criteria:

$$W_i|_S \geq W_i|_{S\setminus\{i\}} \text{ for } i \in S \quad \text{(internal stability)} \tag{19}$$

$$W_j|_S > W_j|_{S\cup\{j\}} \text{ for } j \notin S \quad \text{(external stability)} \tag{20}$$

The computation of the PANE for the second stage is complicated by the fact that we are looking at an intertemporal optimization model featuring an environmental externality as well as international trade. To our knowledge, there are no out-of-the-box solvers available to solve such a model in primal form. Lessmann et al. (2009) suggest an iterative approach based on Negishi's approach

(Negishi, 1972). For this study, we use a modified version of the iterative algorithm, which works as follows:

Negishi's approach searches for the social planner solution that corresponds to a competitive equilibrium by varying the weights ω_i in the joint welfare maximization:[15]

$$\max_{\{i_{jt}, a_{jt}, m_{jt}, x_{jt}, z_{jt} \,:\, j=1 \ldots N\}} \sum_{i=1}^{N} \omega_i W_i \tag{21}$$

$$\text{subject to Equations 2–17} \tag{22}$$

Since this exploits the fundamental theorems of welfare economics, the approach cannot be applied for an economy with externalities. In principle, this problem is circumvented by making any external effect on other players exogenous to model (turning variables into parameters that are adjusted in an iteration).

Here, the externalities are climate change damages through aggregate global emissions. In Nash equilibrium, players will only anticipate the effect that their emissions have on their own economic output, not the effect onto other players' output. We can mimic this in a social planner solution by giving each player his own perception of the causal link between emissions and global warming. Instead of Equation 12, which describes one trajectory of concentration C_t, we introduce N equations for C_{it}:

$$\frac{d}{dt} C_{it} = \zeta \left(q_{it} + \sum_{j \neq i} \overline{q_{jt}} \right) - \kappa (C_t - C_0) + \psi E_t \qquad \forall_{i \notin S} \tag{23}$$

$$\frac{d}{dt} C_{it} = \zeta \left(\sum_{k \in S} q_{kt} + \sum_{j \notin S} \overline{q_{jt}} \right) - \kappa (C_t - C_0) + \psi E_t \qquad \forall_{i \in S} \tag{24}$$

Here, the allowance choices of other players enter as a fixed value (a parameter, indicated by the bar), set to the levels of the corresponding variables during the previous iteration (or some initial value). The sum of allowances in Equation 13 needs to be adjusted analogously, and the temperature Equation 15 will consequently have N instances for T_{it}, too. The temperature change T_{it}, anticipated by player i, will then enter in Equation 16 instead of T_t.

[15] Note that the intertemporal budget constraint Equation 18, which contains the (*a priori* unknown) market clearing prices is omitted from the model.

The thusly modified model is then solved in a nested iteration: In the inner iteration we solve the model for a given vector $\overline{q} = (\overline{q_{it}})$ of allowance choices repeatedly, updating $\overline{q_{it}} = q_{it}$ at the end of each iteration, i.e. we perform a fixed point iteration of the mapping $q = G(q)$ where G is the best response of players to the exogenously given strategy $\overline{q_{it}}$ of the other players. If the inner iteration converges, it converges to a Nash equilibrium in allowance choices. However, the international markets for allowances and private goods may not be a competitive equilibrium. This is what the outer iteration achieves.

The outer iteration follows the standard Negishi approach: we adjust the welfare weights ω_i in the joint welfare function (Equation 21) until the intertemporal budget constraint (Equation 18) is satisfied. The resulting equilibrium is the desired PANE.

Numerical Verification of the Equilibrium

We verify the resulting candidate PANE equilibrium strategies in emissions and trade numerically by comparing them to the results of the following maximization problems:

$$\begin{aligned} &\forall_i \max_{\{i_{it}, a_{it}, m_{it}, x_{it}, z_{it}\}} W_i \\ &\text{subject to Equations 2–18 and prices } p_t, p_t^z \end{aligned} \tag{25}$$

Deviations of this model from our solution should be within the order of magnitude of numerical accuracy only, which is what we find (not shown). In particular, simultaneous clearance of all international markets confirms the competitive equilibrium in international trade.

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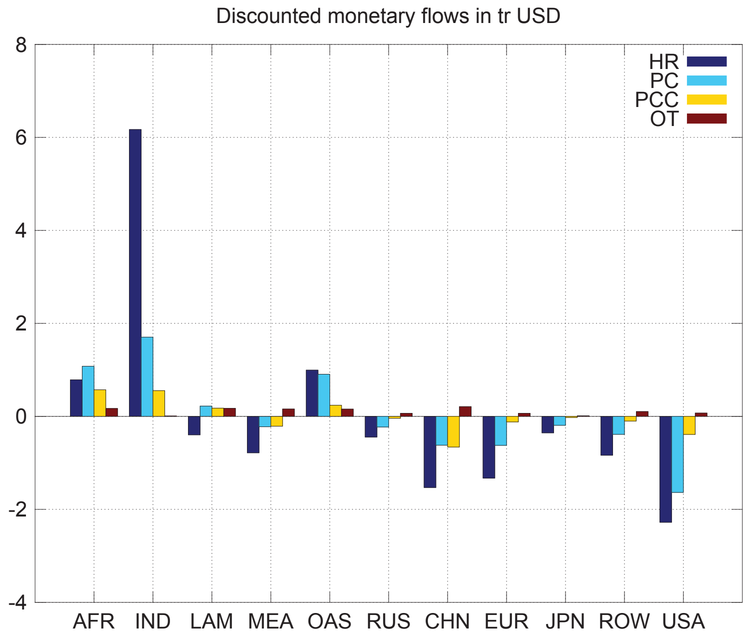

Figure 1: Total, discounted transfers under the three conventional schemes and a hypothetical optimal transfers scheme for the grand coalition (it is not feasible as 1.3 tr USD are missing)

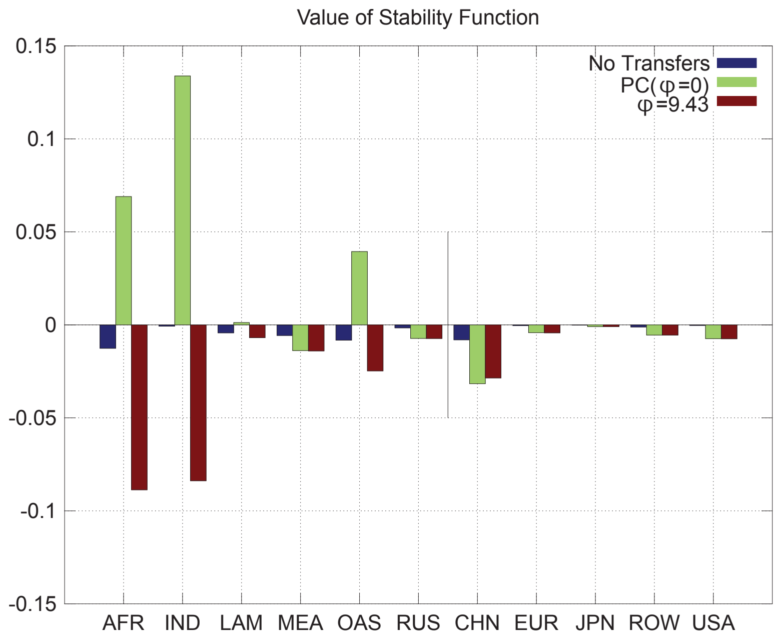

Figure 2: Stability function (payoff inside the coalition net of payoff outside of the remaining coalition) the grand coalition under 1) No transfer payments and 2) under the PC-Scheme without a climate curse and with the curse present (see equation (1))

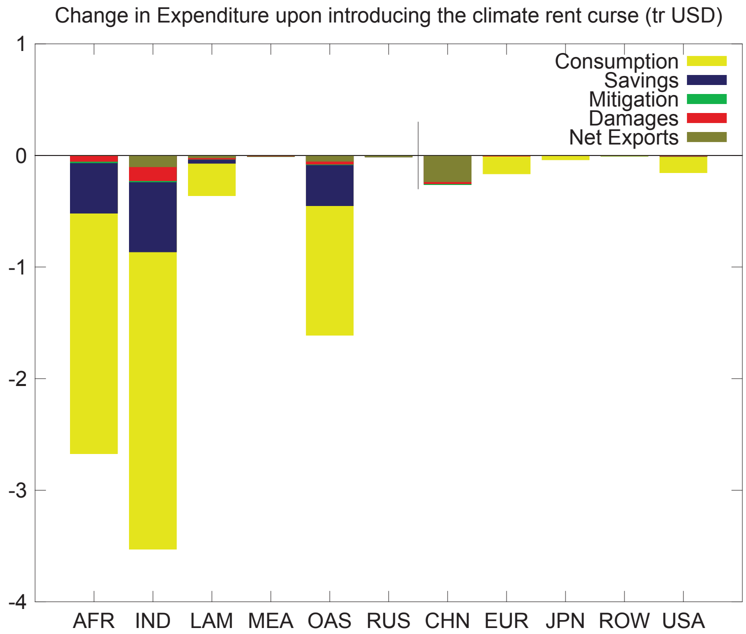

Figure 3: Discounted sum of difference in budget-decisions when no adverse effects occur ($\varphi = 0$) to when the climate finance curse is taken into account ($\varphi = 9.43$) (entire time horizon), inside the grand coalition and with the PC-scheme implemented

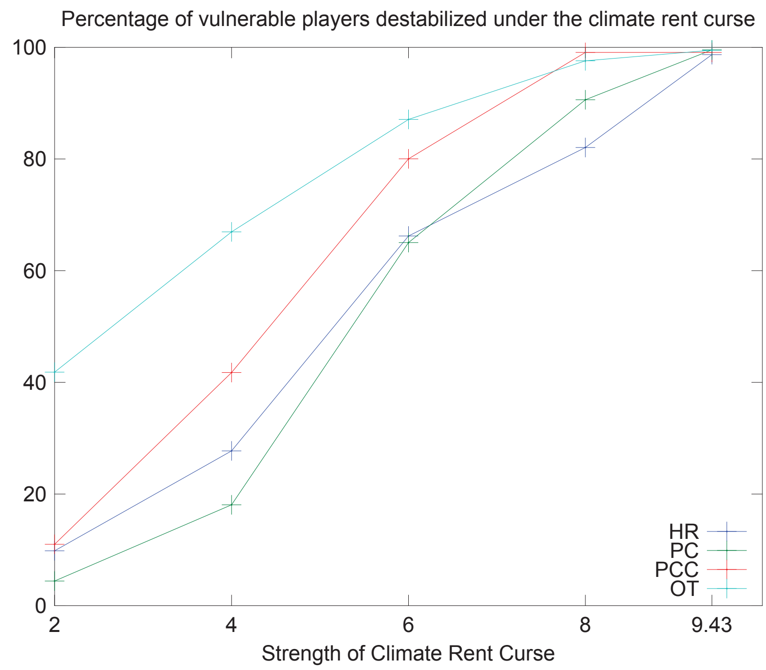

Figure 4: Percentage of affected players encouraged to participate by the transfer scheme without any adverse effect and destabilized under different strengths of the climate rent curse (for φ see equation (1))