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Effects of international climate policy for India: Evidence from a national and global CGE model

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Abstract: In order to reach the two degree target it is necessary to control CO₂ emissions also in fast growing emerging economies such as India. The question is how the Indian economy would be affected by e.g. including the country into an international climate regime. Existing analyses with either a global model or a single country computable general equilibrium model miss important aspects such as distributional issues or international repercussions. By soft-linking models of these two classes, we provide a more detailed view on these issues. In particular, we analyze different options of transferring revenues from domestic carbon taxes and international transfers to different household types and how different assumptions on exchange rates affect transfer payments. We also show effects stemming from international price repercussions. Our analysis focusses on how these transmission channels affect welfare of nine different household types.

Key words: Computable General Equilibrium Model, International Climate Policy, India

JEL classifications: C68, O53, Q54, Q56

1. Introduction

While India is still a developing country, carbon emission reductions in the country are needed in order to avoid a global temperature rise of more than 2 degrees compared to pre-industrial times. Furthermore, realizing the relatively cheap abatement options in India helps to minimize global mitigation costs. In 2008, India ranked third in terms of absolute emissions after China and the US (if Europe is not taken as one entity) (World Bank, 2012). If the current rapid economic growth in India continues, emissions will rise further in the next decades unless climate policy counteracts this trend.

That India is still a developing country is reflected in its per capita income of only US\$ 1410 and 32.8% of the population living on less than \$_{PPP} 1.25 per day in 2010; per capita emissions of 1.5t CO₂ in 2008 are only one third of world average (World Bank, 2012). Not surprisingly, India's primary goal is to develop its economy and to reduce poverty.

Since mitigation efforts are costly and could conflict with the need to develop, most global climate regime proposals include measures to at least partly compensate India for their mitigation costs. In particular, many emission trading proposals include surplus allowances that India can sell on an international carbon market (see e.g. van Ruijven et al, 2012).

Past assessments of costs that India would face under a global climate change regime are mostly carried out with the help of global models (see van Ruijven et al., 2012). The studies mostly find that India would gain or face only little economic cost when joining an international climate regime. Global models are useful because climate change is a global problem and only global models can analyze where abatement is most efficient. However, global models typically only represent the Indian economy in a very aggregated way and furthermore often reduce cost estimates for India to a single aggregate figure such as impact on GDP or welfare. There is for example no information on distributional or regional impacts of climate policy.

In addition, single country models are used to assess the effects of climate policy measures for India. Many of these assessments are carried out with energy system models which have a particular focus on the energy system (see e.g. Shukla and Dhar, 2011). The models do not only include expensive renewable energy technologies, but a portfolio of specific policies such as urban planning and transport infrastructure (Shukla et al., 2008). Computable

general equilibrium (CGE) models in contrast are able to include economy wide repercussions resulting from climate policy and to analyze distributive impacts. Single country CGE models can include multiple agents/households (such as rural/urban) or are able to use sub-regions.

For India, Fischer-Vanden et al. (1997) apply the Second Generation Model to assess the cost of stabilizing Indian emissions as well as the impact of domestic carbon taxes and of participating in different international regimes. Bussolo and O'Connor (2001) use a single country model for India to assess impacts of climate policy on four different regions within India taking into account ancillary benefits of CO₂ reduction. In more recent studies, Murthy et al. (2007) with an activity analysis model and Ojha (2009) with a CGE model analyze the impact of Indian climate policy on poverty. Both models include different household types.

In these models India is modeled as a small open economy, i.e. it is implicitly assumed that national climate policy is carried out in absence of climate policy abroad and has no effect on world markets. Since in reality, India's economy is large enough to influence world markets, several models include assumptions on the international carbon market. Both Fischer-Vanden et al. (1997) and Ojha (2009) analyze global regimes based on grandfathering and equal per capita allowances. Fischer-Vanden et al. (1997) take international carbon prices from independent global studies, while Ojha (2009) assumes a fixed price of US\$ 10 or 20 throughout the model period. Murthy et al. (2007) compute the necessary monetary inflow to compensate for the welfare loss of domestic climate policy, so no assumption on international regimes or carbon prices is needed.

While national models have an advantage of describing the Indian economy at more detail, e.g. by incorporating several agents, global models are able to simulate international carbon markets and repercussions on international energy markets. In this paper we want to bring together both types of models to overcome the shortcomings of the existing analyses which are either very aggregated or ignore international repercussions. We do so by soft-linking the multi-region CGE model DART to a one-country CGE model for India, so that we can take advantage of the specific capabilities of both types of models. In particular, we analyze on the one side in more detail the distribution and allocation effects of international climate policy regimes for India, while on the other side we account for two important implications of

a global regime, namely the impact of international transfer payments and price repercussions on international markets.

As mentioned above, financial transfers are seen as means to compensate for mitigation costs. In some cases these financial flows can be substantial and can influence exchange rates and thus competitiveness of countries. This issue was first debated between Keynes and Ohlin in 1929, but has also been applied to climate change regimes (McKibbin et al., 1999a, 1999b). The multi-regional, perfect foresight model of McKibbin et al. includes a more sophisticated representation of international financial flows based on returns to investment and trade in carbon permits. While there is no explicit modeling of exchange rates in DART, the national model captures some of the exchange rate movements. Furthermore, we analyze distributive impacts of capital flows.

Concerning price repercussions on international markets, ambitious climate policy has the effect that carbon intensive products become (relatively) more expensive, and that fossil fuels are demanded less. Countries that are net importers of fossil fuels – such as India – can thus profit from lowered energy prices (net of carbon prices) through improved terms of trade. CGE models are able to capture these repercussions as the interplay between markets is taken into account. This fuel price effect is acknowledged in global models (e.g. Böhringer and Rutherford, 2002) but to our knowledge not in any national model study for India. In our analysis we pass on variations in international fuel prices that show up in the global model to the national model so that the impact of changes in terms of trade is accounted for. At the same time, the national model shows which agents in the economy profit from this effect.

Since a considerable share of the population in India still lives below the poverty line, the impact on poor household groups is of particular importance. We thus focus on distributional impacts of climate policy and analyze how carbon pricing, (international) transfer payments and international price repercussions affect different household groups. Compared to earlier studies mentioned above, we extend the simulation horizon to 2050 and incorporate current climate policy (Copenhagen pledges) into the analysis. By using harmonized models, there is greater consistency when feeding global data on the carbon price into the national model. By soft-linking the two models we aim in particular to shed light on the following research questions: How do additional insights from a national model

change when taking into account that the rest of the world is also engaging in climate change and causing changes on international markets? How robust are the results from the national model when changing the outside world? How does the more detailed analysis of the national model compare to the international broad picture?

The paper is structured as follows: Sections 2 and 3 describe the model and the policy scenarios, respectively. Focusing on distributive effects for different household types as mentioned above, section 4 discusses the role of capital inflows, while section 5 assesses the importance of repercussions on the international fossil fuel markets. Section 6 concludes.

2. Model description

In this study, two computable general equilibrium (CGE) models are used. While DART is a multi-regional model of the entire world economy, IEG-CGE (Pradhan and Ghosh, 2012a, b) is a national model of the Indian economy. Both models are multi-sectoral, recursive dynamic models solving for a sequence of static one-period equilibria for future time periods. The time horizon of this study is 2050.

DART is based on the GTAP 7 data set (Narayanan and Walmsley, 2008) with the base year 2004, aggregated to 12 sectors and 13 regions including India (see appendix, table A1). Based on bottom-up information, the electricity sector is split into conventional generation and new generation technologies from four renewable sources (wind, solar, biomass, and hydro); additionally electricity generation with carbon capture and storage (CCS) from gas and coal is introduced as a latent technology (Weitzel, 2010). Electricity from different generation technologies are assumed to be perfect substitutes, each technology has a convex cost function and exhibits learning.

IEG-CGE consists of 18 sectors that are rather similar to the DART sectors (see appendix, Table A2). The main data source is a Social Accounting Matrix (SAM) for India (for 2003-04) developed by Ojha et al. (2009) that includes a decomposition of the electricity sector into three separate sub-sectors (hydro, nuclear and non-hydro). For this study the non-hydro sector was further disaggregated into thermal and wind/solar electricity and in addition a sector that uses CCS technology (coal) to produce electricity was created. The CCS

technology sector is similar to the thermal electricity sector, but is less efficient and produces emission free coal based electricity.

Producer behavior in both models is derived from cost minimization for a given output or equivalently profit maximization. All industry sectors are assumed to operate in perfectly competitive markets and at constant returns to scale. Multi-level nested separable constant elasticity of substitution (CES) function describes the technological possibilities (see appendix, figure A1 for the nesting structure). Primary factors include labor and capital and in DART also land. Factor markets are assumed to be perfectly competitive as well and there is full employment of all factors which are sectorally mobile, but in DART regionally immobile.

Households maximize utility subject to income and prices, and household demand is modeled through the Linear Expenditure System (LES) that first satisfies basic needs. The remaining consumption good is a composite of an energy aggregate and a non-energy aggregate. Household income comprises of income derived from factor income, and transfers from the government and rest of the world. Households also save a fixed part of their incomes, and pay taxes to the government. While in DART there is one representative agent in each region, households in IEG-CGE are classified into nine categories: five of them are rural and four of them are urban. The three labor households (two in rural and one in urban) are considered to be poor households. The factor income shares of the different household groups are presented in Table 1.

[Table 1 about here]

Both models follow an investment-driven closure, i.e. aggregate investment is fixed. In DART only households save at a fixed exogenous rate. In IEG-CGE aggregate savings is the sum of household, government, corporate and foreign savings and adjusts to satisfy the saving-investment balance. Again, the household savings rate is fixed. Foreign savings is assumed to be fixed while the real exchange rate is flexible. Government expenditure for consumption of goods and services, transfers to households and enterprises are fixed as well as subsidies rates. Government savings is residually determined.

In DART, all regions are linked by bidirectional trade flows of all commodities except the investment good and in both models domestic and foreign commodities are imperfect (Armington) substitutes. They are also distinguished by the country of origin in DART. There is no direct balance of trade constraint, only at the global level trade has to be balanced

In DART, the major exogenous, regionally different driving factors of the model dynamics are population growth, labor productivity growth, human capital growth and capital accumulation. Rather similar, IEG-CGE assumes exogenously determined growth in total factor productivity (TFP), labor force, government consumption expenditure and aggregate investment. Capital accumulation is in both models driven by an exogenous depreciation and savings rates. In order to capture future increases in energy efficiency, an energy efficiency growth rate is assumed. In DART, the autonomous energy efficiency improvement is 1% per year, for the electricity sector 0.1%; in IEG-CGE it is 1.5%.

In both models GDP growth is calibrated according to the OECD Environmental Outlook (OECD, 2012) by adjusting factor productivities. In DART, CO₂ emissions of the baseline scenario (see section 3.1) are calibrated by adjusting the elasticities of fossil fuel supply to match global CO₂ emissions. In CGE-IEG, exogenous drivers for CO₂ emissions are world market prices of fossil fuels and energy efficiency improvement (Johansson et al., 2012). Furthermore, changes in the international price (exogenous) of fossil fuels are taken into account by using price projections for these commodities.

3. Scenarios

3.1. Baseline scenario [BAU]

The models were harmonized with respect to GDP and population (i.e. labor force) projections. The GDP path follows the reference scenario of the OECD Environmental Outlook (OECD, 2012). The population projections are based on the medium variant of UN World Population Prospects (UNDESA, 2011). Globally, the population is projected to increase to 9.5 billion people in 2050, with 1.6 billion in India. Energy use and therefore CO₂ emissions differ between the models (see also Johansson et al. (2012) for a more detailed comparison on energy use). In DART, global emissions reach 54 Gt CO₂, with India contributing 8.3 Gt. In IEG-CGE baseline emissions are only 5.5 Gt in 2050. As figure 1 shows,

emissions in IEG-CGE are growing slightly faster than emissions in DART in the near future, while emission projections in DART are higher after 2030. Both models project little changes in the carbon intensity of energy in the baseline; a higher improvement in the energy intensity in IEG-CGE explains the difference in CO₂ emissions.

3.2. Climate policy scenarios

The basic climate policy scenario prescribes global emissions to reach the 2 degree target with 50% probability (see Johansson et al. (2012) for a detailed discussion on the pathway). The emission path incorporates the Copenhagen pledges until 2020. Globally, emissions peak in 2020 at a level of 34 Gt CO₂ and are subsequently reduced to 17.6 Gt in 2050. Compared to the (global) baseline emissions, this is a reduction of 67%, or 17% below 1990 emissions. A global harmonization of marginal abatement cost is reached via global emission trading.

For India CO₂ emission reductions are determined endogenously: In the global model DART they are the result of equalizing marginal abatement costs globally. In the national model, CO₂ prices are taken from DART and imposed as a domestic carbon tax to all users of fossil fuels. This is a methodology used by Fisher-Vanden et al. (1997) and Shukla et al. (2008), however in this study it is potentially more consistent because the global and the national model are harmonized to some degree. Due to differences in abatement potential and costs in the two models, the policy pathways turns out to be somewhat different. Both models stay near the baseline close to 2020, followed by a longer stabilizing period. After 2020 and the expiration of the Copenhagen pledges, effort has to be increased in order to reach the 2 degree target. This leads to a higher global CO₂ price which also slows Indian CO₂ emissions.¹ Emissions in both models peak in the 2040s and decline towards 2050. For both models, abatement potential becomes increasingly scarce, especially after 2040, which leads to high CO₂ prices of 441 US \$₂₀₀₄ in 2050, compared to 146 US \$₂₀₀₄ in 2040 (see Table 2 or Johansson et al. (2012) for the whole path). Compared to the baseline, both models show improvement in both carbon and energy intensity.

[Figure 1 about here]

¹ There is even a slight decline following 2020, as marginal abatement costs in India are lower than in other countries. This is however only a local peak as emissions reach a higher level later due to the high economic growth.

We model a common-but-differentiated-convergence [CDC] regime allowing developing countries to have later emission peaking than developed countries (Höhne et al., 2006). We assume that all countries first fulfill their (high) Copenhagen pledges and subsequently Annex I countries converge to 1.7 t CO₂ per capita in 2040, while other countries start their 30 year convergence period between 2020 and 2035 (see also Johansson et al. (2012) for a more detailed description on the assumptions). In this regime, India enters 2030 and converges in 2060. India's allowances peak at 4.23 Gt in 2030, and amount to 3.29 Gt in 2050 (see also figure 1).

3.3. Capital inflow assumptions

In both models India sells emission allowances on the international carbon market under the CDC regime. Because financial transfers are calculated as $(Allowances - actual\ emissions) * carbon\ price$ and actual emissions in the two models differ, capital inflows are also not equal between the model.² Table 2 shows that the magnitude of financial flows is rising over time, due to the rising CO₂ price. When the revenue is expressed as a ratio of GDP, a drop around 2040 is visible due to lower surplus emissions in that year. Generally, the DART model projects a higher amount of permits sold on the international carbon market than IEG-CGE hence capital flows are higher.

[Table 2 about here]

Because DART is based on data in real values, there is no exchange rate. Allowances are allocated to the representative agent (RA) in the respective regions. Changing the allocation of allowances implies a transfer of income from one region to another. Compared to a scenario where the globally efficient reductions are reached via a harmonized global carbon tax so that there are no financial transfers, the RA in India is enjoying a larger endowment of allowances in the CDC scenario which increases national income. This leads in turn to demand changes in India, which are partly fulfilled by domestic production and partly by imports. This means that consumption as well as relative prices rise and therefore Indian trade is affected in DART, but not because there is a change in the exchange rate but through the income transfer as such.

² It is more consistent to assume equal carbon prices in both models instead of equal capital flows, in this way each model is internally consistent.

For the Indian model, international carbon trade is not modeled directly. Instead carbon prices taken from DART are imposed as a carbon tax. The capital flows resulting from carbon trade are calculated from the difference of (exogenous) allowances with (endogenous) actual emissions, multiplied with the (exogenous) carbon price. In all scenarios with capital inflows, demand is increased for the same reasons as explained above. As a result to the capital inflow, the exchange rate decreases, i.e. the rupee appreciates. This leads to higher imports and lower exports such that the trade balance is still fulfilled.

To assess how insights from a national model change when taking into account that the rest of the world is also engaging in climate policy and causing changes on international markets we run a set of scenarios with IEG-CGE based on the carbon prices of DART. The scenarios differ in the dimension of the (real) amount of transfers and the usage of carbon revenue. The (real) amount of capital inflow is varied both by different modeling and policy assumptions:

- [noTr] No international transfers are assumed. This scenario is similar to a globally harmonized carbon tax regime with no compensation payments. The tax rate for the domestic CO₂ price in India is taken from the DART model.
- [Tr-Rup] Transfers take place and are based on the allowances that India is able to sell on the international carbon market under the CDC regime. Here we denominate the transfers in rupees, i.e. fix the exchange rate for the carbon price at the base year. This excludes the effect of the Indian appreciation, i.e. the exchange rate changes are as in the [noTr] scenario in which the exchange rate reacts only to a change in the demand and production structure.
- [Tr- $\text{\$}$] Recognizing that transfer payments will not be carried out in rupees and can potentially shock the exchange rate, we denominate the carbon price in US $\text{\$}$. Due to the appreciation in response to the money inflow, the exchange rate appreciates and the real transfer payments are smaller than in [Tr-Rup].

The revenue from the domestic carbon tax and the transfer payments in the CDC regime can be distributed in various ways. Whenever both types of revenues accrue, we assume that in the IEG-CGE model, both are used for the same purpose:

- [all] Revenues are used for transfers to all households groups based on their population share. This is closest to the assumption of the DART model where one representative agent is receiving all tax revenues and is endowed with allowances, i.e. is receiving the revenue from allowance sales on an international market.
- [poor] Revenues are used for targeted transfer payments only to the poor household groups based on the respective population shares of RH2, RH3, and UH3.
- [gov] Instead of making lump sum payments to households, the revenues are used by the government for investments. This leads to crowding-out and lower savings from households and enterprises.

3.4. Repercussions in international markets

IEG-CGE is a small open economy model, with the underlying assumption that India and the rest of the world do not affect each other through price changes. In the climate policy scenario, there are hence no international repercussions in IEG-CGE. In DART, the main repercussions are twofold: On the one hand, climate policy is carried out globally, hence global world market prices (especially for fossil fuels) change because of the carbon price and a reduced demand for fossil fuels. On the other hand, the Indian economy is affected by the climate policy which is reflected in changing demand patterns, leading to different import and export prices for other goods as well. The latter effect is smaller in terms of price changes.

The repercussions on the international fossil fuel markets are rather large in DART. In terms of modeling, we run a scenario in which international fossil fuel prices are passed on to the IEG-CGE for each simulation year. In DART, export prices for India result from a transformation function where producers produce for the domestic market and the world market. For imports a nested Armington function is used in DART. In the first stage, a composite of goods from different regions is aggregated which in a second step is combined with domestic varieties. Here, we pass on the price of the first step composite to IEG-CGE. The prices are expressed relative to an Indian price index which is used as numeraire in the Indian model.

We differentiate between three scenarios:

- [P-ex] Exogenous prices are assumed for IEG-CGE, which are not changed between the baseline and the policy scenario. This scenario is standard for most single country analyses, but fails to account to repercussions on international markets.
- [P-fuel] Relative changes in fossil fuel prices due to climate policy are passed on from the DART model, i.e. are different between baseline and policy scenario.
- [P-all] Relative prices changes for all sectors due to climate policy are passed on from the DART model. This also accounts for interconnections through intermediate markets. Since sectoral aggregation differs slightly between the two models, the price changes were mapped to different sectors where appropriate (see appendix, table A3).

With the help of these scenarios we can analyze the distributional impact of international price repercussions, i.e. the impact on different household groups and put it in relation to the impacts of climate mitigation. In combination with the variations concerning capital inflows, we can also derive interaction effects between prices and e.g. the exchange rate effect induced by transfer payments.

Generally, the biggest change in import/export prices occurs in energy sectors (oil, coal, gas) so it can be expected that moving from scenario P-ex to P-fuel by passing on fuel price changes from DART do IEG-CGE has a larger effect than moving on to scenario P-all where all prices, including those of industry are passed on.

In the following analysis we are interested in the effects of climate policy on the Indian economy compared to a case without climate policy. The starting point for this analysis is a “basic” [CDC] climate policy scenario which is implemented via a carbon tax in the national CGE model and compared to the business as usual [BAU] scenario. In this “basic” scenario [CDC_noTr_all_P-ex] there are no financial transfers [noTr], tax revenues are used for transfers to all households groups based on the population share [all] and fuel prices are exogenous [P-ex]. We then vary the assumptions in the [CDC] scenario as described above.

4. Simulation results

In this section, we focus on welfare changes for the different household groups in order to assess how different groups are affected by international climate policy. Decomposition of the results is used to identify the importance of different channels that affect households. All

results are taken from the national CGE model if not stated otherwise. We also briefly discuss overall welfare changes in IEG-CGE and DART.

4.1 Capital inflows and allocation

The welfare impacts of our basic [CDC] climate policy scenario implemented via a (domestic) tax are comparable to previous estimations of single-country CGE model. In our first analysis, we vary the recipients of the tax revenue and there are no international transfers. The resulting welfare losses for different household types relative to the BAU scenario without climate policy are shown in figure 2. Not surprisingly, the decision of how to use the revenue of a carbon tax is crucial for how the households' welfare is affected. The top part of figure 2 shows welfare losses for the standard scenario with lump-sum payments of the tax revenue to all households [CDC_noTr_all_P-ex]. In this case poor households as defined above (RH2, RH3, and UH3) can gain substantially. Despite the fact that tax revenue remains below 5% of GDP in 2050, gains for the "poor" RH2 group can reach about 20%. As expected, the per capita payments relative to their consumption expenditure are higher for poorer households. In contrary, richer households are negatively affected. The overall more pronounced effects towards 2050 are due to the high CO₂ tax and the lack of abatement possibilities in the model (see also Johansson et al, 2012). If tax revenue is exclusively redistributed to the three poorest household groups [CDC_noTr_poor_P-ex], these effects are reinforced. Compared to the other richer households groups, urban salaried households (UH2) are relatively unaffected. Welfare gains for poor rural households reach about 70% in 2050.

The picture becomes rather different when government uses the tax revenue for investment. Now the effects are rather similar across household types, though poor households as well as UH2 are affected slightly more adversely than other household classes. The main explanation is that richer households are saving less due to crowding-out and consume more instead. Furthermore, urban households spend a higher share of their income on less carbon intensive services for which the average carbon tax rate is lower. Overall though, total (weighted) welfare losses are smallest in this this scenario. Summarized while distributing tax revenue to households is progressive, using tax revenue for government investment is regressive. At the same time, using the revenue for investment decreases overall costs of climate policy.

[Figure 2 about here]

In a second step, we add international financial transfers to the model. This reflects an international regime (CDC) in which India is able to sell allowances on an international carbon market. For the start we assume that the revenues from selling allowances are paid in lump sum fashion to the households in addition to the tax payments and that transfers are in US-\$. The starting scenario is thus [CDC_Tr-\$_all_P-ex]. In figure 3, we isolate the effect of additional revenue from effects of different [noTr] scenarios, i.e. we are looking at welfare changes relative to the respective [noTr] scenario. The N-shape of the figures can be explained by the variation of revenues relative to GDP over time as shown in table 2.

When the international transfer payments are distributed on a per capita basis to all households, [CDC_Tr-\$_all_P-ex], poorer households gain more than richer households. The total welfare gains for poorer households from climate policy get stronger, while richer households can only partly offset their welfare losses from the scenario without international transfers. This effect is even stronger when transfer payments are restricted to the poorest household groups [CDC_Tr-\$_poor_P-ex].

When transfer payments are used for government investments [CDC_Tr-\$_gov_P-ex], poor households profit less from the transfers than rich households similar to the case when the tax revenue was used for government investments. Household groups with the highest gains from the capital inflow are in this case richer household types (except UH2). Transfers are able to fully offset the losses from CO₂ emission reductions shown in figure 2 until the 2030s. Poorer households gain relatively little from the transfers under this scheme.

[Figure 3 about here]

Compared to figure 2, which shows impacts of different allocations for domestic carbon tax revenue, the effect from the additional transfers from carbon trading seems rather small. The magnitude of transfer payments reaches about a quarter of the domestic tax revenue. However, the welfare changes induced by the transfer payments are substantially smaller than a quarter of initial gains. This is due to the fact that international transfer payments are paid in foreign currency. Inflow of foreign currency leads to an adjustment of the exchange rate in IEG-CGE which significantly reduces the gains from the transfer payments.

To decompose the total effect shown in figure 3 into a transfer effect and an exchange rate effect, we first compare the welfare changes between a scenario without transfers [CDC_noTr_...] and a scenario with payments in rupees calculated based on an exogenous exchange rate [CDC_Tr-Rup_...] to single out the transfer effect. We then compare the CDC scenario with payments in rupees [CDC_Tr-Rup_...] and in US dollars [CDC_Tr-\$_...], respectively to derive the pure exchange rate effect.

Figure 4 plots the transfer and exchange rate effects for the case where revenues are paid lump-sum to all households on a per capita basis [all]. The transfer effect is larger for poor households than the total effect (cf. figure 3 above). Surprisingly, the transfer effect for richer households is negative despite that all households receive some funds, although for richer households the transfer relative to their expenditure is smaller than for poorer households. The negative welfare effect for the richer households is thus caused by detrimental price changes as there is a shift towards labor intensive production which leads to decreasing non-labor income.

[Figure 4 about here]

The exchange rate effect leads to an additional appreciation and is counteracting the transfer effects. Here, richer households gain while poorer households are experiencing welfare losses. This is due to the fact that richer households consume more goods from sectors that have a higher share of imports and poorer households work in “export” sectors and therefore gain from a currency appreciation. In the absence of an exchange rate adjustment (i.e. when transfer payments are in rupees), the additional demand from transfer receipts leads to quantity changes, while when the transfer payments are denominated in foreign currency, part of the demand shock is absorbed in exchange rate adjustments. The total effect as shown in figure 3 above is smaller than the pure transfer effect, as exchange rate adjustments reduce the transfer effect for the (poorer) households.

4.2 Repercussions of international markets

International repercussions of global climate change are also transmitted via price changes on international markets. In particular, fossil fuel demand and therefore also fossil fuel prices net of carbon costs decline under a CO₂ cap. Single country models do not include export and import price changes on international markets and therefore lack some

important consequences of international climate policy. For DART it is not possible to exclude the price effect³, but the price effect can be separated in the national model. We can also determine the relative importance of fuel prices which show the strongest reaction in the policy scenario compared to the baseline and the price changes of other sectors which stand for the larger share of import and export values. In DART, import prices that India is facing on the world market are reduced by 64% for coal, 56% for crude oil, 52% for refined oil and 38% for gas, respectively. Price changes of other sectors are in the range of $\pm 10\%$.

Figure 5 presents the welfare changes induced by price changes in global fossil fuel markets for different transfer scenarios. For adjustments in fossil fuel prices only [P-fuel], all households gain because India is a fossil fuel (net) importer. In 2030, richer households with a more fossil fuel intensive consumption bundle have relatively higher gains. Poorer households and UH2 consume less fossil fuel or energy intensive goods and thus experience lower gains. In most scenarios this pattern remains throughout the time horizon in the model.

The gains from fossil fuel price repercussions differ however for different distributions of international transfers. When transfers are distributed to all households [all] or used for investments by the government [gov], rich households have larger welfare gains than poorer households. When allocating revenues only to poor households [poor], at least in the long run the poor household have similar gains as richer households because incomes of poorer households rise due to the transfers and thus consumption patterns change towards more direct and indirect fossil fuel use. International price repercussions thus benefit the poor households more in scenarios in which they already have a higher income.

Interestingly, without international transfers the gains from decreased fossil fuel prices are stronger than with international transfers; this holds especially for poorer households. International transfers lead to an appreciation (see section 4.1) which already reduces the cost of (fossil fuel) imports. Taking into account the reduced world market price due to international climate policy thus has a smaller (additional) impact in the presence of international transfers.

³ Veenendaal et al. (2011) adjust natural resources endowments of countries with the aim to hold energy prices fixed in a climate policy scenario. However, the analysis is aimed at determining leakage effects, such changes creates endowment effects which affect welfare, so that welfare comparison is not feasible with this approach.

[Figure 5 about here]

Price changes in the remaining sectors are due to different fossil fuels intensities so that (global) demand patterns change as response to carbon pricing. Despite the fact that the trade volume of non-fossil fuel sectors is large for India, price changes in these sectors have a much smaller impact compared to changes in fossil fuel. Welfare changes between [P-fuel] and [P-all] remain below 0.15% throughout the whole modeling period. There is no clear pattern which household type benefits most from international price changes in sectors other than fossil fuels. Only in the scenario in which only the poor are receiving transfer payments [CDC_Tr-\$_poor_P-all], they benefit from the price effect in the remaining sectors (but still only up to 0.3%). This is due to the fact that the transfer payments lead to higher incomes for the poor households which shift the consumption patterns towards some goods that can now be imported cheaper.

4.3 Overall welfare effects

Table 3 summarizes the welfare changes relative to the BAU for different scenarios and different household types. This reconfirms that different households which have different types of factor income and different consumption preferences can be affected very differently from the climate policy induced price changes and transfers. Only when there are no international transfers and when tax revenue is used for investment purposes welfare losses are relatively equal between households even though this policy is lightly regressive. Using tax revenue for redistributive purposes leads to partly significant gains for the poorer households also compared to the BAU scenario without climate policy. These come however at the cost of efficiency losses leading to higher overall welfare losses. International transfers make this pattern even more pronounced, however they play a smaller role compared to the distribution of the domestic carbon tax revenue.

Fossil fuel price repercussions of international markets decrease the adverse welfare effects as expected, since India as a net energy importer profits from lower fossil fuel prices. Price changes in other sectors have virtually no additional welfare effect. The welfare gains of price changes are larger under a scenario without transfers compared to a scenario with international transfers. As discussed above, the exchange rate appreciation caused by transfer payments reduces the benefits of the fuel price effect.

[Table 3 about here]

Table 3 also contains welfare changes experienced by the representative agent in DART for two scenarios (with and without international transfers). The closest scenarios in IEG-CGE contain transfers to all households and price repercussions in all sectors. Welfare losses in DART are smaller compared to IEG-CGE. With transfers Indian welfare even increases in DART. This means that different underlying economic structures (SAM) and different assumptions about elasticities imply cheaper abatement options in DART than in IEG-CGE. As a consequence, the gains from international transfers are larger in DART because of the larger amount of surplus emissions in DART (cf. table 2). Different assumptions on the exchange rate adjustment also contribute the differences, as in IEG-CGE international transfers lead to an appreciation with reduced the welfare gains.

5. Conclusion

For ambitious climate policy in line with achieving the two degree target, it is necessary to include India into a global climate regime. There is however a fear that this comes at a cost of lower economic growth and that especially poor households would suffer from carbon pricing. Traditional impact analysis of climate mitigation in India has been carried out with single country models which lack international repercussions or with global models which represent the Indian economy in a highly aggregated manner. This paper shows that both classes of models miss important features for the Indian economy. Soft-linking these two model types can give a more detailed and accurate view for India.

In the global model with only one representative agent in particular distributional effects are missing. For India, such effects are crucial for policy makers when assessing the impacts of climate mitigation policy. As the national model shows, welfare effects can differ significantly for different household types so that average welfare numbers are of little use. In addition, redistribution of revenue from a carbon tax and international transfers to poorer households – which cannot be captured in the global model – does benefit the poorer households but comes at the cost of overall higher GDP/welfare losses. The analysis also shows that accounting for the international transfers often ignored in national models indeed reduces negative welfare effects for India. Income distribution is furthermore affected by international price repercussions which are also normally not accounted for in

national models. By passing on price changes from the global to the national model we can show that poor household groups benefit least from lower international fossil fuel prices and also have higher welfare losses when revenues are used for investments which is most efficient in terms of GDP or overall welfare losses. This does not mean that revenues need to be allocated to poor households exclusively; we show that transfers to all households on a per capita basis already make poor households better off than the baseline. Generally, accounting for international price repercussions has significant implications for the outcome of the national model.

We also see that the rather small negative or even positive welfare effects of international climate policy have to be treated with care. Even though the differences in our model analyses partly stem from different implicit abatement costs, neglecting exchange rate adjustments and overall welfare effects of different revenue recycling lead to overly optimistic results in the global model.

While the model soft-linking allows a more detailed view on distributional effects of international climate policy in India and allows identification of the relative importance of the different channels, our scenarios are necessarily highly stylized. Other use of the revenues such as financing clean energy or other “green technologies” would be possible but cannot be analyzed in our modeling framework. The insights could be further improved through a more complete coupling which could include a further harmonization of the baseline scenarios and potentially also feedbacks from the Indian model to the global model.

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Tables

Table 1: Factor income shares of different household groups in percent for base year (2004)

Household group	Labor income share	Capital income share	Total income share	Share of rural/urban population (2000)
Rural non-agricultural self-employed (RH1)	8.3	8.5	8.4	13.8
Rural agricultural labor (RH2)*	15.9	0.1	7.0	31.1
Rural other labor (RH3)*	5.0	0.4	2.4	7.4
Rural agricultural self-employed (RH4)	14.0	34.0	25.2	37.8
Rural other households (RH5)	3.5	12.5	8.6	9.9
Urban self-employed (UH1)	10.1	13.7	12.1	39.2
Urban salaried (UH2)	36.3	3.0	17.6	40.0
Urban casual labor (UH3)*	5.5	1.0	3.0	14.3
Urban other households (UH4)	1.3	4.5	3.1	6.4

Calculations from SAM; population shares from Sundaram and Tendulkar (2003); share of rural population in total population was about 72 percent in 2001 (GOI, 2011). Households marked with an asterisk are considered as poor in this study. Remaining capital income goes to public and private enterprises and government.

Table 2: Surplus allowances, CO₂ prices and resulting international transfer revenues in the policy scenario.

year	surplus allowances (Mt CO ₂)		CO ₂ price (US\$/tCO ₂)	International transfer revenues			
	DART	IEG		billion US\$		% of baseline GDP	
				DART	IEG	DART	IEG
2015	401.4	-73.3	1.9	0.8	-0.1	0.1%	0.0%
2020	680.0	81.5	6.8	4.6	0.6	0.2%	0.0%
2030	2071.4	1366.6	71.1	144.4	95.3	3.2%	2.1%
2040	1173.6	346.4	145.7	166.8	49.2	2.0%	0.6%
2050	1461.9	681.2	440.8	567.3	264.4	4.7%	2.2%

Table 3: Changes in accumulated and discounted welfare in selected scenarios.

Model	Intl. transfer	Revenue allocation	Intl. prices	Welfare changes relative to BAU										overall
				RH1	RH2	RH3	RH4	RH5	UH1	UH2	UH3	UH4		
IEG-CGE	no	all	ex	-3,4	12,1	5,4	-5,6	-7,3	-5,3	-1,3	0,7	-7,8	-3,4	
IEG-CGE	no	poor	ex	-9,7	43,8	25,0	-11,7	-12,4	-10,5	-4,3	12,8	-12,3	-5,1	
IEG-CGE	no	gov	ex	-2,4	-2,7	-3,0	-2,2	-2,3	-2,4	-3,0	-3,1	-2,1	-2,4	
IEG-CGE	US\$	all	ex	-2,6	13,8	6,5	-4,8	-6,6	-4,6	-0,9	1,5	-7,3	-2,6	
IEG-CGE	US\$	poor	ex	-9,6	49,0	28,4	-11,6	-12,3	-10,4	-4,3	14,9	-12,2	-4,5	
IEG-CGE	US\$	gov	ex	-1,5	-2,7	-2,8	-1,0	-1,0	-1,4	-2,9	-2,8	-1,0	-1,6	
IEG-CGE	no	all	fuel	-2,5	12,9	6,1	-4,6	-6,3	-4,4	-0,7	1,4	-6,9	-2,5	
IEG-CGE	no	all	all	-2,5	12,9	6,1	-4,6	-6,3	-4,4	-0,7	1,4	-6,9	-2,5	
IEG-CGE	US\$	all	all	-1,8	14,4	7,1	-3,9	-5,7	-3,8	-0,4	2,1	-6,4	-1,9	
DART	no	RA	all										-0,2	
DART	yes	RA	all										4,3	

“Overall” refers to a weighted average (weight by household consumption expenditure) for IEG-CGE and of the representative agent (RA) for DART. Household types in italics are considered as poor.

Figures

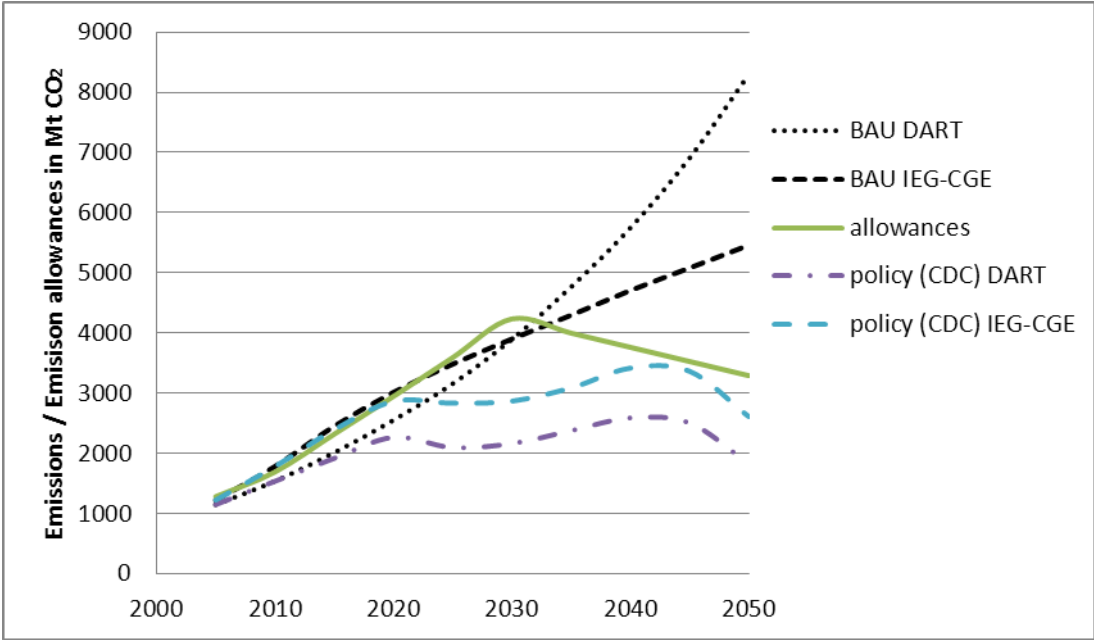


Figure 1: Indian emissions under the BAU and policy scenarios in DART and IEG-CGE. Emissions allowances for international emission trading are also shown.

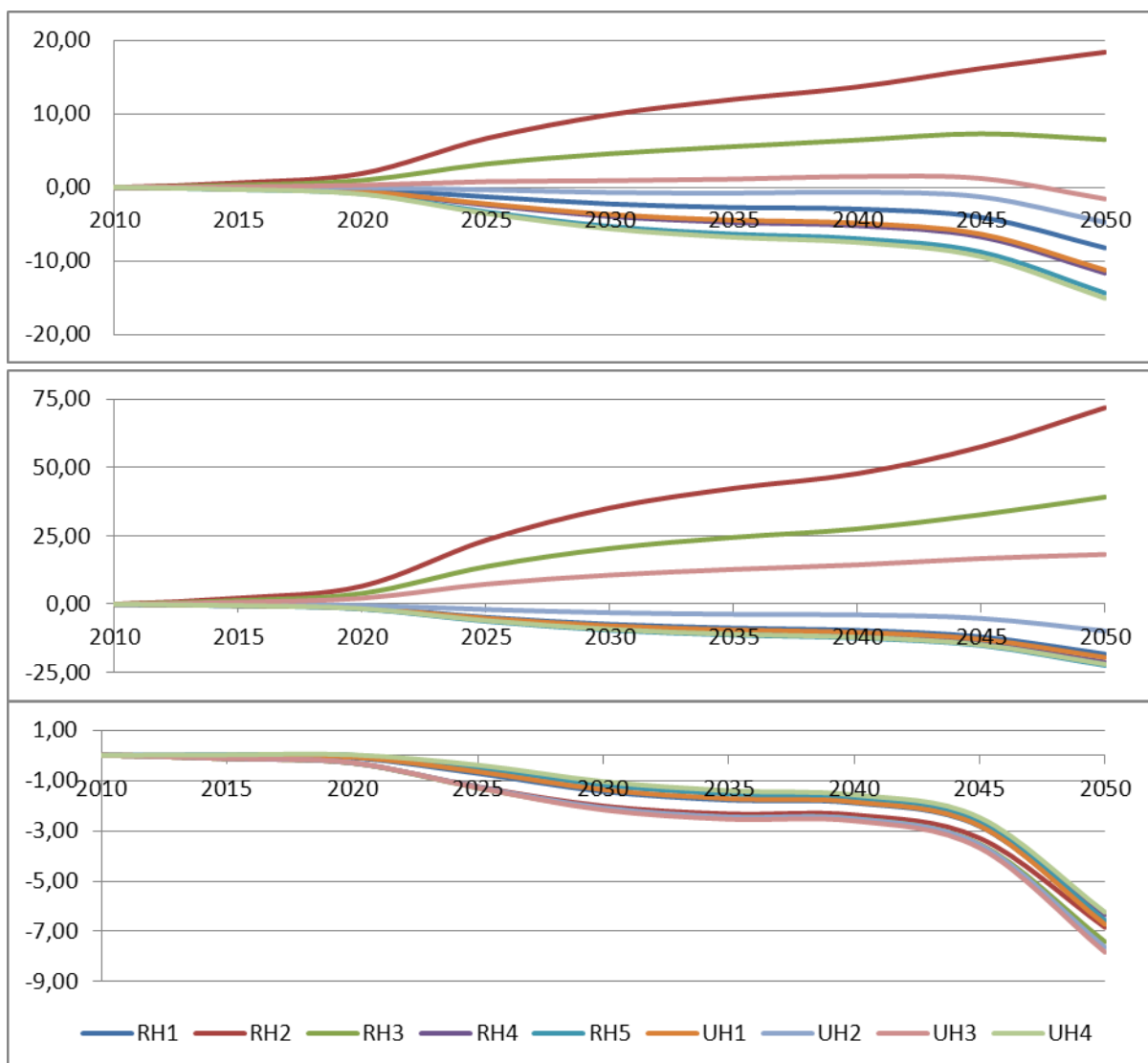


Figure 2: Welfare impact (% Hicks EV) for different households of climate change policy compared to the [BAU] scenario without climate policy. The top panel shows welfare impacts of scenario [CDC_noTr_all_P-ex] where revenues flow to all households, in the middle revenues go to poor households exclusively [CDC_noTr_poor_P-ex] and at bottom revenues are used for investments by the government [CDC_noTr_gov_P-ex].

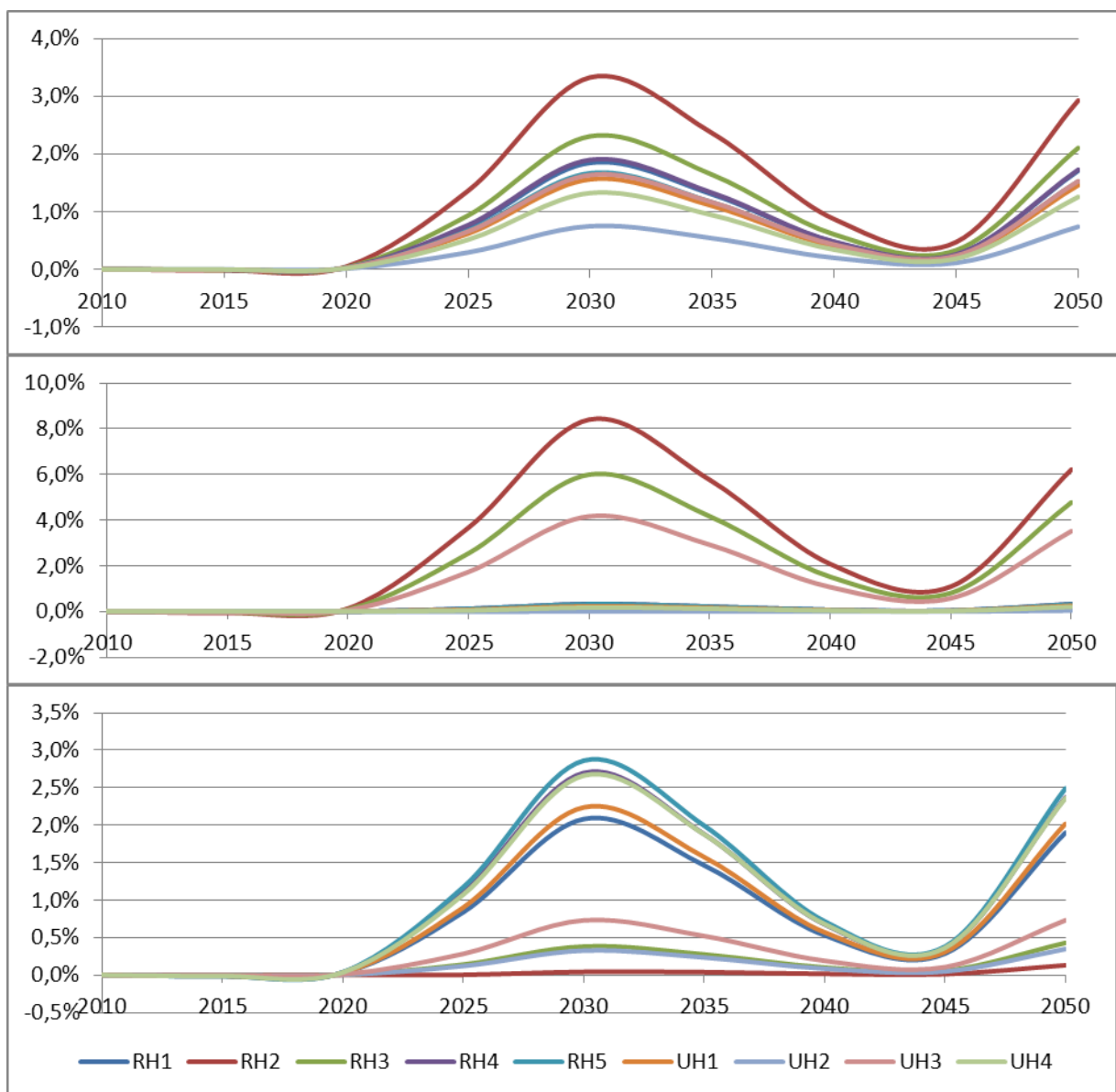


Figure 3: Welfare improvement of different households due to financial transfers relative to [noTr] scenario (same carbon price) under different allocation schemes: All households [CDC_Tr-\$_all_P-ex] (top), poor households [CDC_Tr-\$_poor_P-ex] (middle) and government [CDC_Tr-\$_gov_P-ex] (bottom).

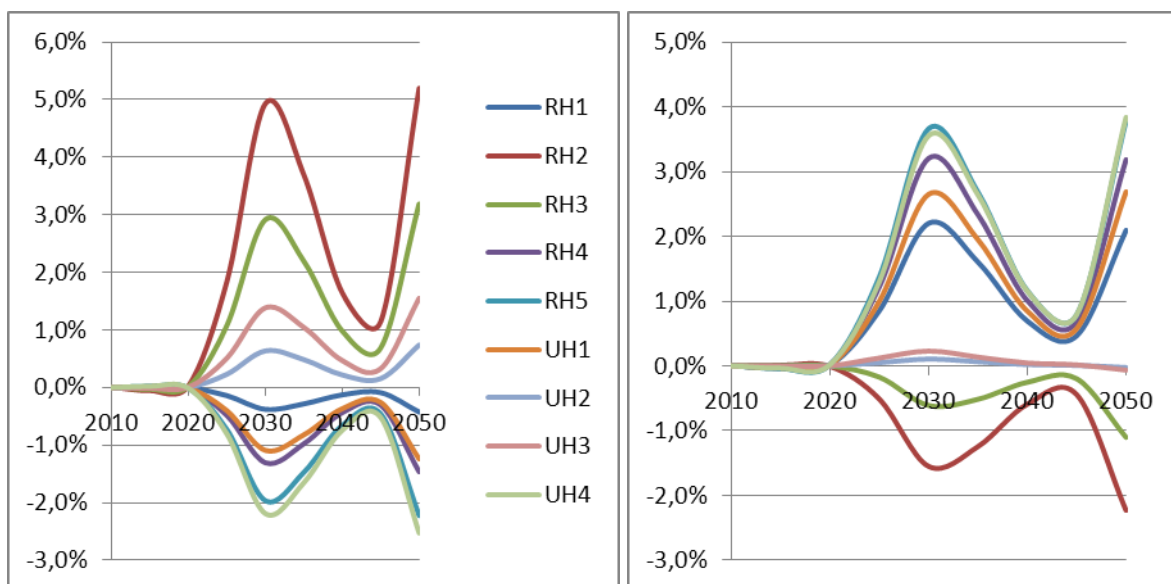


Figure 4: Decomposition of the total effect of international payments. Welfare changes of transfer payments (to all households, cf. figure 3, top panel) decomposed into pure transfer effect (left) and an exchange rate effect (right).

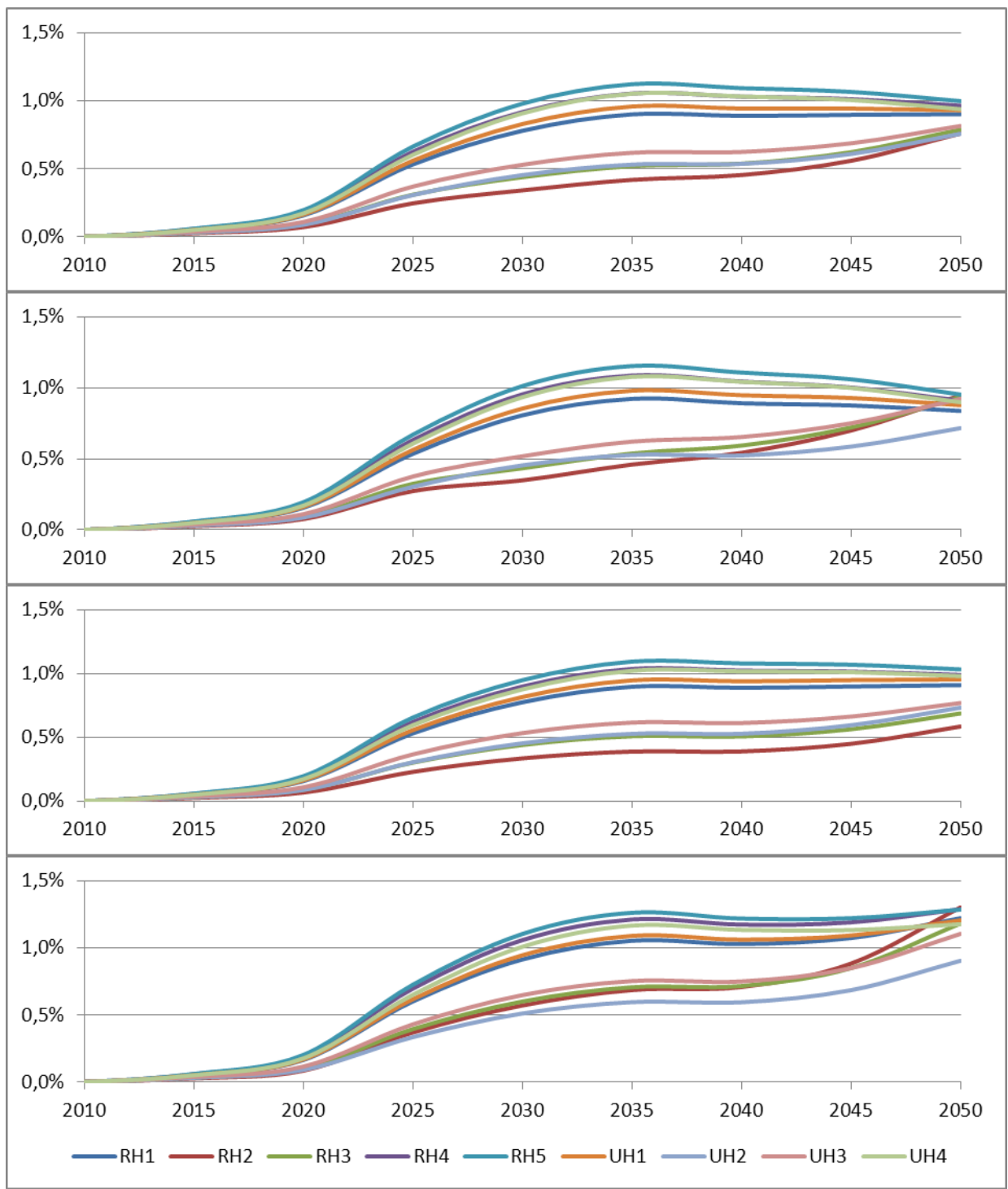


Figure 5: Welfare changes induced by price changes in global fossil fuel under different transfer scenarios. The four parts (top to bottom) show the impact from switching from [P-ex] to [P-fuel] under [CDC-US\$_{all}...], [CDC-US\$_{poor}...], [CDC-US\$_{gov}...], and [CDC-no_{all}...].

Appendix

Table A1: Regional and sectoral aggregation of the DART model

Regions		Sectors	
WEU	Western Europe	Energy Sectors	
EEU	Eastern Europe	COL	Coal
USA	United States of America	CRU	Crude Oil
CAN	Canada	GAS	Natural Gas
ANZ	Australia, New Zealand	OIL	Refined Oil, Coal Products
JPN	Japan	ELE	Electricity ^a
FSU	Former Soviet Union	Other sectors	
CPA	China, Hong-Kong	AGR	Agricultural Production
IND	India	ETS	Energy Intensive Production
LAM	Latin America	CRP	Chemical Products
PAS	Pacific Asia	OLI	Other light industries
MEA	Middle East and Northern Africa	OHI	Other heavy industries
AFR	Sub-Saharan Africa	MOB	Mobility
		SVCS	Services

^a The electricity sector is split into conventional generation and renewable electricity generation in the following forms as perfect substituted: Wind, solar, hydro, and biomass. Generation from coal and gas with CCS is implemented as latent technology.

Table A2: Sectors in IEG-CGE.

Energy sectors	Other sectors
Coal	Agriculture
Oil	Manufacturing 1 (Food and Beverages, Textiles, Wood, Minerals)
Gas	Manufacturing 2 (Paper, Fertilizers, Cement, Iron and Steel, Aluminum, Chemicals)
Oil products	Manufacturing 3 (Plant and Machinery)
Thermal (fossil) electricity	Construction
CCS electricity	Road Transport
Hydro electricity	Other Transport (Rail/Sea/Air)
Nuclear electricity	Other Services
Wind/solar electricity	
Biomass electricity	

Table A3: Sectoral mapping in DART and IEG-CGE for international price adjustments.

Sectors in DART	Sectors in IEG
OLI	Manufacturing 1
ETS, CRP	Manufacturing 2
OHI	Manufacturing 3
SVCS	Construction, Other Services
MOB	Road Transport, Other Transport

Agriculture and energy sectors (coal, oil, gas, oil products, electricity) are the same in both models. For price comparisons in sectors where one sector of the DART model corresponds to two sectors of IEG-CGE, the price is used for both IEG-CGE sectors. In the case of the ETS and CRP sectors in DART which correspond only to one sector of IEG-CGE, a weighted average based on import/export volumes is calculated.

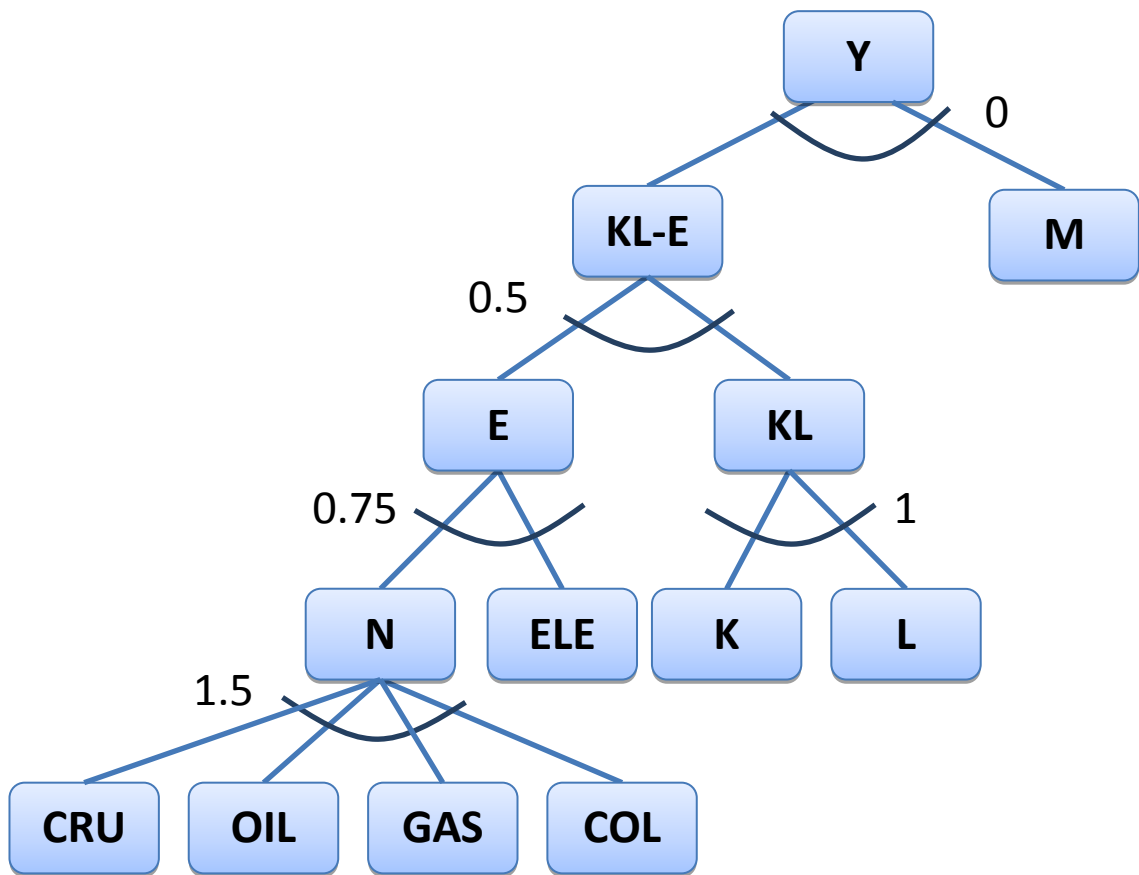


Figure A1: The main CES production structure and substitution elasticities for each sector and region in the DART model. Y = output, K = capital, L = labor, E = energy, M = intermediates, N = non-electricity. Fossil fuel inputs (crude oil, refined oil, natural gas and coal) are associated with CO₂ emissions in fixed proportions. For the production of refined oil, input of crude oil and coal are treated as intermediates M at the top nest (Leontief), no direct carbon emissions are associated with the use of this energy feedstock. The remaining fossil fuels (crude oil, natural gas and coal) use a fixed resource at the top nest. The elasticity between the fixed resource and the remainder of the production function is scaled to achieve a given global supply taken from OECD (2012). Production structure in IEG-CGE follows the same nesting, however elasticity values may differ. In IEG-CGE renewable and non-renewable electricity generation are assumed to be imperfect substitutes. The electricity sector in IEG-CGE therefore contains a more complex sub-nesting.