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Full economic impacts of sea level rise:
loss of productive resources and transport disruptions

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Abstract: We use the latest version of the GTAP multi-sector / multi-country model to assess the impact of sea level rise on transport infrastructure. Using DIVA output as input, our results indicate that Global GDP is depressed, but European GDP is less affected compared to the rest of the world. Sea level rise as projected in the IPCC RCP8.5 scenario causes global welfare losses of USD 61 billion in 2050. These losses are mainly caused by productivity losses in sea transport. We show that globally the welfare losses exceed the direct transportation cost changes by 30%, with substantial regional variation. Developed regions adjust better to increases in transportation costs than developing regions. Through transport, sea level rise causes significant changes to the global economy.

JEL classification: Q54

Key words: climate change, computable general equilibrium, CGE, sea level rise, transportation disruptions, water transport.

Introduction

Sea-level rise (SLR) is one of the key impacts of climate change. The coastal zone is home to many people, important habitats, and key infrastructure, including the harbours that are essential to international trade. Although SLR is one of the most studied impacts, our knowledge on the subject is still incomplete. This paper is the first to study the effects of SLR on marine navigation from a global economic perspective.

SLR induced losses of land and capital in coastal areas can induce a domino effect on the global economy. Computable General Equilibrium (CGE) models have been used to assess the wider economic implications of various SLR scenarios with and without adaptation (Bosello, Eboli, and Pierfederici 2012, Bosello et al. 2012, Bosello, Roson, and Tol 2007, Darwin and Tol 2001, Deke et al. 2001). In this paper, the latest global SLR scenarios of DIVA are used to update the assessment of the broader economic impact of SLR-induced coastal land and capital loss.

Another potentially important effect of SLR and climate change in coastal areas is their effect on sea transportation networks. Sea ports can be affected by climate change in several ways (Becker et al. 2012, Nursey-Bray and Miller 2012, Peterson et al. 2008). Climate change can affect transportation through sea level rise (SLR), heavier precipitation, increasingly severe storms, increased number of hot and cold days, et cetera. As identified by Peterson et al. (2008), the locations of ports and airports could become unsuitable, creating a need for non-trivial capital investment. Other problems such as storm surges might disrupt the operations of the sector through potential freight damages or delays due to a need for alternative routes.

More than 80% of the international trade of goods (by value) is carried by sea transport, and the percentage is even higher for developing countries[1]. Any distortion of the transportation sector would have effects not only for the industry itself, but also for other industries connected directly or indirectly to it, affecting both developed and developing countries.

International trade is one of the most important drivers of economic growth. Hence, disrupted and unreliable transportation can affect economic growth (Crafts and Leunig 2005). Changes in international transportation costs can create imbalances in the global economy. As transportation costs increase, market prices of transport-intensive products may increase. In this way, the initial effects caused by changes in the cost of transport could propagate to other sectors of the economy (Koetse and Rietveld 2009).

This paper describes a model that assesses the macroeconomic implications, both direct and indirect (general equilibrium), of climate change-induced transportation disruptions on a global scale. It then applies it to the latest global SLR projections from the DIVA model, taking into account direct loss of land and capital as well as disruptions in sea transport.

Section 2 reviews the literature on CGE assessments of the impacts of SLR, and on the economic impact of disruptions in (sea) transport. Section 3 discusses the methods and data that were used for our assessment. Section 4 describes the simulation scenarios and Section 5 presents the results of the simulations. Section 6 discusses sensitivity analyses on key parameters in the CGE model, and Section 7 concludes.

1 http://unctad.org/en/pages/publications/Review-of-Maritime-Transport-(Series).aspx

Review of literature

Loss of productive resources

The literature estimating the effects of SLR on the economy using a static GCE model is rather limited. This methodology in general has been employed in order to allow sector and region specific impacts of climate change.

Darwin and Tol (2001) estimate the economy-wide effects of 0.5 meters SLR with and without optimal protection (based on the FUND model). The authors model SLR as a decrease in the endowment of land and capital in the economy, with a differentiation between types of land and its uses.

Bosello, Roson, and Tol (2007) estimate the costs of 0.25 meters of global SLR based on a CGE model. SLR is included in the model as a reduction of the endowment land available. Protection costs are added to the model as investment through a displacement effect on consumption. The economy-wide effects are smaller than the direct costs indicating that the economic processes are able to minimise the initial negative effect of SLR. Bigano et al. (2008) extend the analysis of Bosello, Roson, and Tol (2007) to estimate the interaction between SLR and tourism in the economy after a 0.25 meter SLR. On the modelling side, the authors introduce tourism shocks exogenously in the system by "shifting factors in the demand patterns and national incomes". Protection costs are not considered in the model in contrast to Bosello, Roson, and Tol (2007).

Similarly, Bosello et al. (2012) compared the results of the DIVA model and a CGE model of SLR focusing on land losses only for Europe. The authors find a huge gap between the massive direct losses through the DIVA model and the benign GDP effects of SLR derived from the CGE model.

The literature assessing the economic effects of SLR through CGE modelling has focused traditionally on static modelling structures as described above. A part of the literature though has considered dynamic modelling structures.

Deke et al. (2001), using the DART model, consider a recursive dynamic CGE to investigate the effects of different coastal protection costs. These costs are introduced to the model as a decrease of investments on the capital accumulation process. Eboli, Parrado, and Roson (2010) use the dynamic, multi-regional CGE model ICES to address climate change impacts on economic growth. The model is based on capital and international-debt accumulation processes linking multiple static equilibria. The model includes, additional to SLR changes, productivity changes due to climate change as a reduction in labour productivity. The authors conclude that there are significant global economic effects from climate changes but the regional and sectoral changes are more prominent. Roson and Van der Mensbrugghe (2012), use the ENVISAGE model that includes a dynamic CGE model to address the economic impacts of SLR, variations in crop yields, water availability, human health, tourism and energy demand. Their results show that the effects of climate change on the economy are significant, especially for developing countries in the long run.

Dynamic modelling structures provide a better representation of the economic effects of SLR by allowing for propagation of those effects over time. At the same time, dynamic CGE models are based on forecasts of the future thus introducing one more layer of uncertainty into the model.

In this study we adopt a static CGE model allowing us to focus on the input-level uncertainty making our results more robust.

Disruptions in transport networks

Chhetri et al. (2016), based on the Container Terminal Operation Simulation (CTOS) model, assess the vulnerability of ports to different extreme weather events, including flooding focusing on data from the port of Sydney. Based on their analysis, extreme weather events cause delays in operations and reduce the overall productivity of the port significantly. Their results suggest that, in lack of any adaptation measures, the productivity losses in ports due to flooding measured in the number of containers moved out of the yard is almost 10% in a 24 hour period.

Sánchez-Arcilla et al. (2016) review the potential physical impacts of climate change on the Mediterranean harbours. Based on their review, SLR has both direct and indirect effects on the harbours' functionality. The initial effects of SLR include overtopping and flooding. The change in water depths can potentially modify the wave propagation patterns affecting breakwater stability and sourcing, harbour siltation and agitation. Additionally, SLR can affect navigation due to decreased clearance under bridges. In our analysis these physical changes translate to economic consequences through reduction in the harbours' productivity.

Suarez et al. (2005) discuss the regional effects of flooding on transportation. The article models the indirect economic effects of flooding in the Boston Metro Area on the road network, excluding the railway, seaports and airports. The authors use the Urban Transportation Modelling System (UTMS) to simulate changes in the transportation structure in the Boston Metro Area by looking at flow changes of traffic in the urban road network. Those changes are imposed in the model by changes caused by flooding due to SLR, heavy rainfall and others. The authors conclude that an increase in SLR of 0.3cm per annum increases the delays and cancelation of trips substantially, by the year 2100, but the associated cost is not large enough to warrant changes in the infrastructure.

Chu (2016) analyses the impact of climate and economic factors change on freight transportation in Taiwan. The author finds significant effects from weather conditions on freight movement in Taiwan after controlling for global economic crises, oil prices and GDP changes.

While not related to SLR, the study of Tsuchiya, Tatano, and Okada (2007) on the economic effects of earthquakes in Japan is of interest because their CGE analysis suggests that the disruption of transportation networks by earthquakes causes significant direct and indirect economic losses.

The aforementioned literature has focused on the full economic effects of sea level rise through land loss and coastal protection, ignoring changes to the transportation sector. Previous studies of the transportation sector focussed on natural disasters and either omit water transport or analyse on a local scale. The novelty of the present paper is the fact that it builds upon a computable general equilibrium model that incorporates water transport changes caused by SLR on a global scale. We are going a step further by analysing both the direct and indirect effects of water transport distortions in addition to changes in agricultural land and regional capital.

Methods and data

Methods

In order to analyse the direct and indirect economic effects of coastal land and capital loss and climate-induced transportation disruptions, we use a computable general equilibrium model (CGE) based on the GTAP 6.2 model and the GTAP 8 database and make a link to the DIVA model.

The use of a computable general equilibrium model was chosen because of its ability to simulate changes in prices and quantities in an economy as a result of an exogenous shock which is in our case SLR. An important attribute of the CGE models is that they move away from the individual agent by looking at the whole economy and the interconnections between all agents (firms, households, governments), thus providing the economy-wide effects of SLR. The choice of the GTAP model is based on the fact that it is a CGE trade model fully equipped to analyse changes in the trade patterns of regions resulting from SLR.

GTAP model

In general equilibrium theory, the economy is considered as a set of interrelated markets, where market agents (consumers and producers) freely buy and sell commodities in the form of final and intermediate goods and services and factors of production. There is a market for each commodity traded in the economy. Consumers own resources, from the sale of which, at given market prices, they earn an income. This income determines their consumption opportunities. Given this income, they choose the consumption bundle that maximizes their utilities. Firms transform inputs into outputs in a way that maximizes their profits, given market prices and the firms' technological possibilities. In equilibrium, market prices are such that demand equals supply for all commodities. If firms operate with constant returns to scale technologies, they earn zero profits in equilibrium.

The Global Trade Analysis Project (GTAP) is a widely used comparative-static multi-regional and multi-sectoral CGE model (Hertel et al. 2007). It employs a detailed benchmark equilibrium dataset with a broad coverage of (trade) distortions and explicit statistics on transport margins. The model assumes a global bank to mediate between world savings and investments, and a region specific set of equations for consumer demand that allows for different responses to price and income changes across regions.

Commodities

The GTAP model distinguishes between three types of commodities: 1) endowments or factors of production, 2) goods and services that are internationally traded, and 3) capital goods. GTAP has an aggregation facility that allows the user to specify the desired aggregation of endowments, goods and services and regions for a specific model application. At the most disaggregated level, the benchmark equilibrium dataset (version 8) contains information on five endowment commodities, 57 goods and services, and 129 regions, benchmarked at the year 2007. Each good or service is produced by one sector with the same name as the good or service.

Endowments

Endowment commodities include land, skilled and unskilled labour, capital and natural resources. Endowment commodities cannot be traded internationally. The supply of endowment commodities is exogenous. The supply of labour is fixed, hence there is no trade-off between labour and leisure. In general, GTAP does not account for unemployment: all labour is supplied at the going wage rate. In model applications, some endowment commodities can be assumed to adjust imperfectly to sectoral changes, that is, their marginal product value does not necessarily have to be equalised over all uses in the counterfactual equilibrium. Land and natural resources are often assumed to adjust imperfectly. The quasi-fixed nature of natural resources is used to simulate diminishing returns for natural resource-based sectors such as agriculture, fisheries, forestry and mineral extraction.

Goods and services

GTAP includes data on 57 goods and services, from the primary (agriculture and mining), secondary (industry) and tertiary (services) sectors. All goods and services are assumed to be internationally traded.

Capital goods

Capital goods are produced by the capital goods sector. This sector does not use any value-added endowments; it just receives intermediate goods from the other sectors. A ‘global bank’ coordinates the production of capital goods: it collects savings from all regions and distributes these savings according to a rule that equates rates of return across regions (Hertel, 1997).

Production and consumption functions

Producers employ technologies that exhibit constant returns to scale. The production structure of firms is modelled through nested Constant Elasticity of Substitution (CES) functions that allow these firms to have substitution possibilities among different factors of production. Technological change is represented by a technological change parameter *a*.

In percentage change terms, a CES production function can be written as (Hertel 1997):

Eq. 1

where q_i is the percentage change in the quantity of input *i*, σ is the elasticity of substitution, *p* is the percentage change of the output price and p_i is the percentage change of the price of input *i*, *q* is the percentage change in the quantity of output, and *a* is the technological change parameter. For future reference, note that a *negative shock* to the technological change parameter *a* will *increase* the quantity of input *i* that is needed to produce a given quantity of *q*.

Households allocate their income among private consumption, public consumption, and savings according to a Cobb-Douglas utility function. At the next level of the demand system, households choose their preferred private and public consumption bundles. Aggregate private and public consumption are allocated between particular goods and services to maximize constant differences of elasticity (CDE) and Cobb-Douglas utility functions, respectively. At the lowest level a choice is made between imported and domestic goods according to a CES utility function (Hertel 1997, Hanslow 2000).

International trade and international transport services

The benchmark equilibrium dataset of GTAP 8 contains information on all bilateral trade flows of goods and services among its regions. It also contains regional information on trade taxes, such as import tariffs and export subsidies, and some information on non-tariff barriers, such as the Multi Fibre Agreement. This dataset is unique in its detail and coverage (McDougall and Dimaranan 2002)

International transport services are provided by a global sector. Total demand for transport services is derived from the difference between free-on-board (fob) export values and care-insurance-freight (cif) import values of each traded commodity for each specific route. Summing up all traded commodities and all routes gives the total demand for transport services. The individual regions supply these services. Their value shares in the global transport industry remain constant over policy simulations (Hertel 1997).

General equilibrium

When one or more exogenous variables of the model are changed by the analyst (or "shocked" in model jargon), the model computes a new, counterfactual equilibrium. GTAP employs the following four equilibrium conditions:

1. *Market clearance*. In equilibrium, supply equals demand for all commodities (endowments and traded commodities).

2. *No excess profits*. In equilibrium, firms (including the global transport sector) can exactly pay for their factors of production (labour, capital), but they do not earn excess profits. This is commonly called the zero profits assumption.

3. *Regional budget constraint*. In equilibrium, each regional household spends its total income (on private consumption, government consumption and savings).

4. *Global savings equal global investments*. In equilibrium, global investments equal global savings. This equilibrium condition is not an explicit restriction in the GTAP model, but follows from the above conditions by virtue of Walras' law. This equality serves as a consistency check of GTAP model solutions.

A graphical exposition of the GTAP model can be found in the appendix (Brockmeier 2001).

DIVA model

The Dynamic Interactive Vulnerability Assessment (DIVA) model is an integrated impact-adaptation model of coastal systems that analyses the biophysical and socio-economic effects of SLR and socio-economic development on a regional and global scale. The DIVA model incorporates coastal erosion, coastal flooding, wetland changes and salinity intrusion.

Additionally, adaptation to SLR is taken into account in terms of raising dikes and nourishing shores and beaches (Hinkel 2005, Hinkel et al. 2013, Hinkel et al. 2014, Vafeidis et al. 2008).

DIVA produces two outputs that are relevant for our study under the RCP 8.5 (J14) scenario with SSP2 socioeconomic conditions, considering dike raising (SED + SLR) for the year 2050[2]. These are regional projections of land losses due to submergence and expected sea-flood damage costs due to SLR. The land loss represents the land annually lost by submergence in km^2. Land is lost by submergence if it is unprotected *and* has a flood return period of one year or less. In the early years land loss might be negative if the relative SLR is negative. This can be interpreted as a land gain. The annual expected sea-flood damage cost in million USD (2014) take into account flood depth, which means higher damages on assets that are flooded by 1m than on assets that are flooded by 0.5m.

The links between DIVA and GTAP

We use outputs of the DIVA model in two ways.

First, we use DIVA projections of SLR-induced losses of land and capital as inputs in the GTAP model. The DIVA projections are used to calculate exogenous changes ("shocks") to regional endowments of land and capital. The absolute changes that are produced by DIVA, i.e., km^2 of land lost and millions of USD of costs are translated into percentage decreases of total regional

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2 DIVA model version: RISES_GLOBAL_GR+AD1+UI030+RPL001.

endowments. The percentage change of land endowment loss per region is calculated as the area of land that is annually lost by submergence in squared kilometres, if it is unprotected *and* has a flood return period of one year or less, as a share of total agricultural land area in km^2. Data on the amount of agricultural land per country is derived from FAO (FaoStat 2015). The assumption is that agriculture will absorb most of the flooding shock but the ability of this sector to adapt in order to reduce economic damages should not be disregarded (Yohe and Schlesinger (2002). The percentage-change shock to the *capital endowment* is equal to the percentage share of the expected sea-flood *cost* in regional GDP in the period of the event as estimated by the DIVA model. These percentage decreases of endowments are used as inputs ("shocks") in the GTAP model. The GTAP model computes a counterfactual equilibrium in which the economy adjusts to these losses.

Additionally, the outputs of DIVA are used as *indicators* of the relative vulnerability of regions to climate change and SLR-induced disruptions of sea transport networks. Transportation disruptions are simulated by a negative shock to the water transport specific technological change coefficient (i.e. productivity) for all regions (the parameter *a* in Eq. 1). Since there is no available information at this point on a global scale of the port functionality changes due to SLR, we use a reference point of 10% reduction in productivity as estimated by Chhetri et al. (2016). We assume that the region-specific productivity changes are a function of the amount of land and capital loss due to SLR, derived from the DIVA model and from two additional scenarios based on Hallegatte et al. (2013).

There is no direct way to use DIVA outputs to assess the decline in productivity of sea transport, but we use DIVA outputs as indicators to assess regions' *relative* declines in the productivity of sea transport. For this purpose, we normalise DIVA indicators of loss of land and capital respectively on a scale between 0 and 1 for the regions in our aggregation. The normalisation can be done in various ways, but we chose to transform DIVA indicators to probabilities. Probabilities have a natural range between 0 and 1. Specifically, we assume that the indicator *X*, e.g. mean annual capital loss, has a normal distribution. For a given observation of the indicator *x*, we can determine the probability $P(X \leq x)$ that a randomly selected observation would be *x* or lower. We thus transform the DIVA indicators and the data derived from Hallegatte et al. (2013) in probabilities *P*. In the scenarios we multiply the P's with a factor *f* (~21.4) so that the average regional productivity losses equals the assumed global productivity loss, e.g. the reference point of circa 10%. The factor *f* is kept constant throughout the different scenarios to make cross-scenario comparability possible.

Figure 1 Basic model representation

Data

Regional aggregation

The regional aggregation in the model has been chosen in such a way to accurately represent international sea trade. The aggregation of the 13 regions is based on a combination of proximity, geophysical characteristics concerning SLR, port productivity in TEU's[3] and economic activity. The regions include North and Latin America, North-West, North-East and South Europe, Ex-Soviet Union countries, Africa, West Asia, Central Asia, East Asia, China, Japan-Korea-Singapore, and Oceania.

Figure 2 Regional aggregation of GTAP 8 data

Sectoral aggregation

The GTAP sectors are aggregated into eight sectors, including agriculture, energy and energy production, transportation-intensive and non-transportation-intensive manufacturing industries, air, water, and other transport, and other services. We used an intuitive method to make a distinction between transportation-intensive and non-transportation-intensive industries, based on the available GTAP 8 data. For each of the 57 GTAP 8 sectors we have calculated the proportion of transportation costs in total costs. Sectors that have a proportion of transportation costs in total costs of 1% or more are classified as transportation intensive (see Table 1).

Table 1 Manufacturing industries classified as transportation intensive

Table 2 presents the complete regional and sectoral aggregation of the GTAP data that was used in our study.

3 Twenty-foot equivalent unit, is a unit of cargo capacity describing the capacity of container ships and container terminals. The measure is based on the volume of a 20 feet long (~6 m) container.

Table 2 Regional and sector aggregation

Scenarios

We use three alternative scenarios to simulate the general equilibrium effects of the disruptions in the sea transport sector caused by SLR. These scenarios also include losses of land and capital due to SLR, so we also use a reference scenario, including only region-specific loss of land and capital due to SLR. We use five additional scenarios to test the sensitivity of our results on transport.

The reference scenario, L&C, examines the economic implications of estimated loss of land and capital in coastal areas due to SLR in 2050, according to DIVA's elaboration of the RCP 8.5 (J14) climate change scenario as described by Jevrejeva, Grinsted, and Moore (2014) for the RISES-AM project. This scenario is included for comparability to the previous literature.

The following scenarios address the economic implications of disruptions of sea transport networks due to climate change. The LC_Un10 scenario assumes globally-uniform decreases in the productivity of sea transport of 10%. This scenario provide first-order conditional estimates of the potential global economic effects of climate-changed induced disruptions to sea transport networks. This central scenario of 10% is based on the port productivity losses due to flooding estimated by Chhetri et al. (2016).

To further examine regional variation in the economic implications, the LC_DIVA_L and LC_DIVA_C scenarios use indicators from DIVA to assess the relative risks to sea transportation in different regions. Scenario LC_DIVA_L uses land losses as an indicator of the risk to sea transportation, while, in a sensitivity analysis, scenario LC_DIVA_C uses capital losses as an indicator of risk. In these scenarios, the global mean decrease in the productivity of sea transports is 10% (as in the LC_Un10 scenario), but regional productivity losses are scaled according to the respective indicators of risk. Additionally these scenarios include land and capital reductions due to SLR as in L&C scenario.

The last three scenarios, LC_OECD_DH, LC_OECD_A and LC_OECD_NA are based on an OECD publication from 2013 that assessed the vulnerabilities of 136 port cities across the world to the effects of climate change and SLR, taking socio-economic developments into account (based on (Hallegatte et al. 2013). The current mean protection standard for the 136 cities for coastal floods is 1 in 100 years. The LC_OECD_DH illustrates the situation where and how much (in cm) the dikes are raised in order to maintain the relative risk of 1 in 100 year flood. With climate change and SLR, and *without adaptation*, protection standards will decrease and floods and other disruptions to sea transport infrastructure will become more frequent in the second half of this century. This is illustrated in the sensitivity analysis by scenario LC_OECD_NA. The scenario LC_OECD_A illustrates the situation in which the protection standards of the sea ports are maintained in terms of return periods. So on average, they remain protected against floods with a return period of 1 in 100 years.

The values from the aforementioned scenarios (LC_DIVA_L, LC_DIVA_C, LC_OECD_NA, LC_OECD_A, LC_OECD_DH) are used in the normalisation process as described above to estimate the productivity shocks of sea transport (Table 4).

Table 3 presents an overview of the scenarios and the source of information used in each of them. Table 4 shows the inputs to the GTAP model for each scenario. Table 4 shows that the calculated productivity losses in sea transport vary greatly between the scenarios. Based on **Table** (see

Annex), the LC_DIVA_L productivity shocks correlate negatively with those from all other scenarios. The LC_DIVA_C scenario correlates positively with the OECD scenarios, but the degree of correlation is not very high and not statistically significant based on Spearman's ρ[4]. This means that not only the uncertainty on the global effects of climate change and SLR on the productivity of sea transport is high, but also the regional distribution of the productivity change. This should be taken into account when interpreting the results of our simulations in the next section.

Table 3 Overview of Scenarios. Reference scenario in *italics*, core scenarios in bold.

Table 4 Inputs to the GTAP model in all scenario

Results

Loss of productive resources

Table 5 Percentage changes of GDP and HEV to initial regional GDP due to SLR induces land and capital losses.

Table shows the percentage changes of GDP and Hicksian Equivalent Variation[5] (HEV) to initial regional GDP due to SLR induced land and capital losses based on the L&C scenario without any changes in the sea transport sector. The impacts of loss of productive recourses (i.e. land and

4 Spearman's ρ is a nonparametric measure of statistical dependence between two variables.

5 The HEV can be thought of as the dollar amount that the consumer would be indifferent about accepting in lieu of the price change; it is negative if the price change makes the consumer worse off (Mas-Colell, Whinston, and Green 1995).

capital only) are in line with the similar economic literature on SLR like (Bosello et al. 2012, Bosello, Roson, and Tol 2007). The GDP changes are benign and ranging from -0.004 in Japan-Korea-Singapore to -0.052 in West Asia. Furthermore, the HEV is also very small between -0.003 in Japan-Korea-Singapore and -0.040 in East Asia. Results seem to be disproportional to the imposed shock (see Table 4) indicating the existence of mechanisms that propagate the initial negative effects of SLR in economies that are able to substitute the lost land and capital with alternative recourses.

Disruption in sea transport

The imposed changes in the productivity of ports has a direct effect on the trade balance of each region. Lower sea-port productivity directly translates in higher import and export prices. The immediate effect of the simulated increase in the costs of sea transport is that it increases the prices of goods imported by means of sea transport. It increases the wedge between the price of goods at the port of departure (*Free-On-Board,* fob price) and the price of goods at the port of landing (*Cost, insurance and freight,* cif price).

Higher import prices of goods directly affect consumer prices around the globe, but they also affect production costs of firms that use imported goods as intermediate inputs in their production. In fact, because we assume increased transport costs in all global transport routes for all traded commodities, firms are affected by increased costs of imported intermediate goods from all source countries but on a different rate.

Higher domestic production costs lead to higher domestic and export (fob) prices. This in turn, leads to an additional increase in import (fob) prices, and so forth. This increase in prices is counteracted by behavioural changes of consumers and producers. They adjust their purchases of goods and services in the light of a changing pattern of prices. First, they will substitute between source countries, taking account of the higher transport margins. This will affect the pattern of trade.

Additionally, in the light of increased import prices, consumers and producers will, to the extent possible and according to their preferences, substitute imported goods for domestically produced varieties (saving on increased costs of transportation) and substitute transport-intensive goods for less transport-intensive goods, until the possibilities for beneficial *arbitrage* are exhausted and a new market equilibrium is established.

Table 6 Percentage changes in the trade balance between countries after each simulation scenario

Table 6 describes the percentage change in imports between all regions of the model for the L&C, LC_Un10, LC_OECD_DH and LC_DIVA_L scenarios. The L&C scenario is used as a comparison to the rest of the scenarios that include sea-transport productivity changes.

In the L&C scenario Asian regions seem to have the highest drop of imports from almost all regions and imports in North America seem to be affected the least. The introduction of the 10% uniform drop in sea-port productivity affected most the imports in Latin America, Central Asia and China. We see similar results in the LC_OECD_DH scenario. Last, the results are a bit different in the LC_DIVA_L scenario. Imports to Africa seems to be hit the most followed by Central Asia and Latin America.

Figure 6, shows a collective version of *cause to effects* for the LC_Un10, LC_DIVA_L and LC_OECD_DH scenarios making the comparison between countries and the different scenarios possible. Transport costs are a linear function of the exogenous shock in transportation productivity thus the graph can be interpreted as the relation between the imposed shock and the economy-wide effects of SLR measured by HEV. The relation between transportation costs and HEV seems to be linear in all scenarios. This is due to the linear construction of the GTAP model and the way HEV is defined in the model. Developed regions are clustered in the upper right quadrant indicating that they are the least affected in all cases. Oceania is an exception due to the high transportation costs this region faces. This can also be attributed to the distance of this region to the rest of the developed world in conjunction to the high imposed shocks (see Figure 3 to Figure 5). Developing regions show more variation.

Table 7 Basic direct and indirect effects of sea transport changes combined with the SLR induced land and capital losses

Table 8 Prices (fob) of primary and manufacturing good

Figure 3 Propagation of effects from transport cost to HEV by region in LC_Un10 scenario

Figure 4 Propagation of effects from transport cost to HEV by region in LC_OECD_DH scenario

Figure 5 Propagation of effects from transport cost to HEV by region in LC_DIVA_L scenario

Figure 6 HEV to GDP as a function of changes in transportation prices to GDP

Decomposition of GDP and welfare changes

Approaching GDP from the expenditure side, GDP can be expressed by the following accounting identity:

Eq. 2

Where C denotes final consumption of goods and services, I is (gross) investment, E is exports of goods and services, and M is imports of goods and services. In GTAP, exports E is divided into exports of goods and services to all other countries (E) and exports of transportation services to the 'global' transportation sector (T). The 'global' transportation sector as designed in the GTAP model purchases transport services from all regions and in return it supplies transport services to every region. The accounting identity then becomes:

Eq. 3

Total differentiation of this identity shows how relative *changes* in GDP can be decomposed into relative *changes* in its factors (where percentage changes are denoted by small caps:

:

Eq. 4

The impact of a uniform decrease in the productivity of sea transport has a small effect on the level of GDP between -0.005% and -0.078% under the Un10 scenario and between +0.001% and -0.118% in the LC_OECD_DH scenario across regions. However, the decomposition of GDP in its constituent parts highlights that GDP is not a good indicator of welfare. The increase of economic resources spent on transportation and the decrease in imports suggest that the GDP numbers mask the effects on real income or welfare.

Table 9 Decomposition of GDP changes (in %, see Eq. 4)

Table 9 decomposes the computed percentage change in GDP in all regions in its constituent parts. The decomposition shows a number of things:

1. The total impact on GDP of the uniform loss in productivity of sea transport differs across regions. The smallest impacts are on developed regions and the largest impacts are on developing regions. Of the developed countries Oceania experiences the largest adverse impact on GDP from the LC_Un10, LC_OECD_DH and LC_DIVA_L scenario respectively. Of the developing countries, China, Central Asia and Latin America are hit the hardest. GDP of North and South Europe slightly increases in the LC_OECD_DH scenario, but slightly decreases in the other scenarios.
2. The effects on consumption (*c*), investment (*i*) and exports (*e*) are much larger than the total effects on GDP. A large part of the economic adjustment is through decreases in imports (*m*). As shown in equation 3, a large decrease in imports has a positive effect on GDP. As we argued above, because of the increased transportation costs, consumers and producers will substitute imported goods for domestic goods to the extent possible. All else being equal, this will stimulate domestic production and GDP. This masks to some extent the real costs of the productivity losses in sea transport, measured in utility, because the increase in domestic production is necessary to compensate for the higher costs of imports; it does not increase final consumption relative to the initial situation without SLR. The changes in utility are reported later on.
3. Because of the productivity losses in sea transport more resources have to be employed to supply the same level of transportation services. Ceteris paribus, this stimulates GDP. In the LC_Un10 simulation, the relative change of transportation (*t*) increases between 1.083% and 7.973% but between 1.432% and 10.205% in the LC_OECD_DH scenario and 0.908% and 6.853% in the LC_DIVA_L scenario. However, it is clear that this is not a welfare-improving growth. Again, the increased demand for resources used in

transportation does not increase final consumption relative to the initial situation without SLR.

4. European regions are clustered together. Comparing the LC_DIVA_L with the LC_Un10 we find that the decrease in GDP is the same for all three regions even though the imposed shocks are significantly different but the average European shock is still close to 10%. This is an indication of the intra-European propagation of the adverse effects of SLR that tend to be minimized through the economic processes probably due to the free movement of capital, migration etc. The same holds for the LC_OECD_DH scenario where the average EU shock is half from the one found in the other two results in almost half the average GDP result compared to the LC_Un10 and the LC_DIVA_L.

To get more insight into the causes of the welfare change, the HEV can be decomposed into its constituent parts.

Table 10 GDP and HEV decomposition of main scenarios

The loss in welfare is decomposed into a direct loss due to the higher costs of producing current levels of consumption goods and indirect losses (see Table 10). All regions suffer direct productivity losses in proportion to their use of sea transport for importing goods. Additionally there are direct losses in all regions resulting from the lower endowments Land and Capital available. The indirect effects are: the effect on the efficiency of allocation of resources within economies ('Allocative Efficiency'), the effect on the terms of trade of an economy ('Terms of Trade'), and finally an effect that is related to relative price changes of savings and investments ('Investments – Savings'). Together these direct and indirect effects determine the size of the total welfare loss ('Total HEV') (Huff and Hertel 2000).

Changes in allocative efficiency are due to the reallocation of resources (labour, capital) across sectors in the face of pre-existing market distortions, i.e. distortionary taxes[6]. Reallocation of resources can increase or decrease the so-called 'deadweight loss of taxation'.

Changes in terms of trade are due to relative price changes of imported goods and exported goods of an economy. If relative prices of exports increase more than those of imports, an economy gains a terms of trade advantage. In this case a region can buy more imported goods for the same amount of exports. In the opposite case, an economy experiences a disadvantage in the terms of trade. Here a region needs to export more goods in order to be able to purchase the initial amount of imports. At the global level, the advantages and disadvantages should level out.

The final welfare effect is associated with the relative prices of savings and investments. If an economy has a savings surplus, a relative rise in the price of savings relative to the price of investment goods will benefit the economy. In the GTAP model, the prices of savings and investments goods move closely together (to capture that fact that the majority of savings are invested domestically), so that this effect is rather limited in most simulations (Huff and Hertel 2000).

6 The basic GTAP decomposition analyses market distortions in the form of distortionary taxes by construction. In our case the distortionary taxes are equivalent to the increase in water transportation costs.

Table 14 shows that the global welfare loss of the SLR-induced losses in the productivity of sea transport is USD 48 and circa 50 billion in the Un10 and the LC_DIVA_L respectively. In the LC_OECD_DH scenario the global welfare loss is the highest at USD 61 billion. Most of this loss (~85%) is due to direct productivity losses in sea transport. At the country level there are large differences, due to the various components of welfare loss. Although most countries experience a loss in allocative efficiency, North-West Europe and South Europe experience a gain in allocative efficiency. Deeper investigation of the simulation results shows that these gains are related to a high rate of taxation on sea transport services in European countries. The productivity losses in sea transport increase the use of resources in sea transport (more resources are needed for the same volume of sea transport); hence resources are pulled towards a high-taxed activity, decreasing the deadweight loss of taxation.

Terms of trade (ToT) effects are positive for most developed countries, except for Oceania for all presented scenarios. ToT is negative for all developing countries. Taking a closer look at the changes of prices (Table 8) we find that the Prebisch–Singer hypothesis (Singer 1989), that as the prices of primary commodities decrease relative to the prices of manufacturing goods the terms of trade worsen, holds for all developing regions. Since the decrease of agricultural products is higher relative to the change of manufactured goods causes the decrease in the ToT in agriculture-based economies. This contributes negatively to total HEV. For the countries whose terms of trade improve, the average export prices increase relative to the average import prices; the opposite occurs for those countries whose terms of trade decreases. An interesting result is found in Central Asia where the ToT effect is positive or very small negative in the LC_OECD_DH scenario. Going back to Table 8, the prices of manufactured goods increase in comparison to the decrease in agriculture for all scenarios. This can be an indication that the manufacturing sector in Central Asia is able to absorb part of the negative shock and with the increase in the relative export prices of these sectors to gain a terms of trade advantage. Last comparing China's ToT we find a surplus (LC_Un10 and LC_OECD_DH scenario) which turned into deficit in the LC_DIVA_L. In the other two cases all prices seem to increase more so for manufacturing compared to agriculture that can explain the positive ToT.

Four things can be noticed from the HEV analysis:

1. The welfare losses exceed the GDP losses.
2. The ranking of relative losses across countries between GDP losses and HEV losses is largely similar between North and South, with developing countries suffering the most adverse effects (Figure 3 to Figure 5).
3. Comparing HEV and GDP changes (Table 10) we find that there is a small but positive effect of the transportation shock on HEV for SEU (LC_OECD_DH) accompanied by GDP loses. European countries face the smallest losses in HEV mostly driven by the productivity losses occurred in the transportation sector. This effect is counteracted by welfare increase coming from allocation efficiency and terms of trade.
4. The HEV losses are slightly larger than the direct cost increases of sea transport shown in Table 10. As first noted by Darwin and Tol (2001), the direct cost estimate only includes the impact on the own sector, while a productivity loss in one sector implies an overall

deflation of the economy; the direct cost thus underestimates the true welfare impact. Globally the HEV loss exceeds the direct transportation cost increase. There is however, large regional variation.

Sensitivity analysis

The first point of interest is the global technological change used in the LC_Un10 scenario. As described above initially we assume that there is a uniform decrease of water-transport productivity drop due to SLR. Testing this assumption we run two more simulations setting the productivity losses to 5% and 20% (scenarios LC_Un5 and LC_Un20) respectively. As we can see in Table 11 transportation cost changes, export changes and HEV seem to be linear in all three models i.e. doubling the shock doubles the effect, thus the relative position of the regions remain unchanged. GDP does not follow the same trend as the other variables mentioned above. For most regions as the shock increases the losses of GDP worsen. European regions do not follow this trend. As the productivity shock increases, the GDP losses are getting smaller due to allocative efficiency.

We stress one other assumption of the model concerning the DIVA generated scenario LC_DIVA_L. The aforementioned scenario uses land loss as an indicator of the risk to sea transportation. We evaluate this assumption be developing scenario LC_DIVA_C which uses capital losses as an indicator of risk. Developing countries, excluding Africa, show the highest increase in the exogenous sock, which might be attributed to the existing level of protection against SLR. Despite the significant changes in the exogenous shock, the relative position of the regions seem unchanged. East Asia is affected most in both scenarios and the European countries are the ones least affected.

An additional source of uncertainty is the data source. Based on Hallegatte et al. (2013) we developed the LC_OECD_DH scenario from the level of dike increase required to maintain the relative risk of a 1 to 100 year flood risk constant. Based on the same article we have developed more scenarios (LC_OECD_A and LC_OECD_NA) based on the mean annual losses with and without adaptation respectively. Table 11 shows the main results of those simulations. An intriguing result from the comparison of these simulations is that even though the productivity shocks are different GDP losses and HEV seem to be relatively stable. Exports and transportation costs seem to follow the magnitude of the external productivity shock in every case.

Table 11 Deterministic sensitivity analysis, additional scenarios' main results

Discussion and conclusion

We simulate the total economic effects of productivity losses in the marine transportation sector due to sea level rise using the GTAP computable general equilibrium model with 13 regions. We analyse eight different scenarios for productivity changes. In addition, the economy is affected by SLR through reductions in the available agricultural land and the available capital for each region. In our central case, SLR reduces the productivity of sea transport by some 10%. In response, international trade contracts much more than that. GDP is depressed but much less. Welfare is reduced by $48-61 billion per year. Most of this loss (~85%) is due to direct productivity losses in sea transport. This loss is unevenly distributed across regions. In general, developed regions are able to adjust more to the increases in transportation costs than developing regions.

There are certain weaknesses in the present analysis. The results are based on a static CGE model without any dynamic processes. Flood costs are included in the model as an exogenous reduction of the capital endowment. We assume that the capital reduction due to SLR is uniform to all sectors and not to water transport. Further research is needed on the separation of sector specific capital. In our model we assume that there is no substitutability between transportation nodes. This is because there are no available elasticities of substitution for the transportation nodes in the GTAP model. Additional research is required since transport node substitution would have a significant effect on the results of water transport productivity changes. Further research is also needed in port-specific expected productivity changes due to SLR. To the best of our knowledge this information is not available on a global scale restricting the results to a hypothetical reduction of water transport productivity by an average of 10% based on Chhetri et al. (2016) for our 13 regions. Last, changes in the logistics industry due to shipping through the Northwest Passage and Northern Sea Route (NSR) are omitted. Sufficient data are not yet available and the reliability of this route has not been established yet.

Annex

Figure A1 Graphical exposition of the GTAP model (Brockmeier 2001)

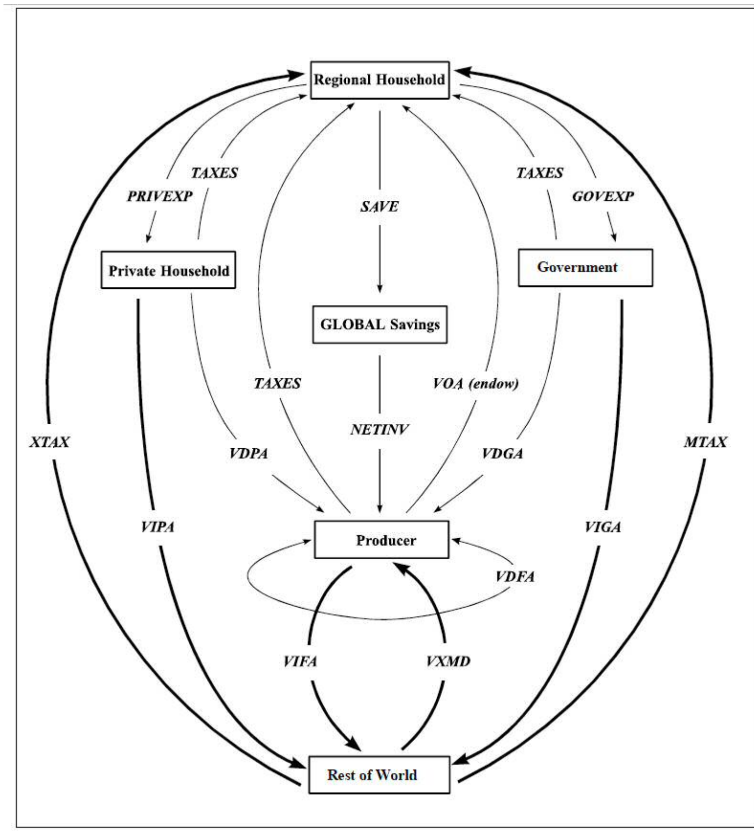

Table A1. Spearman's ρ: Pairwise rank correlation coefficients based on the productivity shocks[7]

	LC_DIVA_L	LC_DIVA_C	LC_OECD_NA	LC_OECD_A	LC_OECD_DH
LC_DIVA_L	1				
LC_DIVA_C	0.022	1			
LC_OECD_NA	-0.183	0.210	1		
LC_OECD_A	-0.094	0.501	0.817*	1	
LC_OECD_DH	-0.259	0.237	0.780*	0.728*	1

7 Star indicates that the coefficients are significant at the 5% level or lower

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Tables

Table 5 Manufacturing industries classified as transportation intensive

Industry	Percentage of transport costs in total costs
Food products nec	1%
Recreation and other services	1%
Construction	1%
Chemical, rubber, plastic prods	1%
Machinery and equipment nec	2%
Trade	4%
Transport equipment nec	5%
Business services nec	11%
Petroleum, coal products	25%

Table 6 Regional and sector aggregation

Regional Aggregation			Sectoral Aggregation		
1	OCE	Australia, New Zealand	1	AGR	All Agriculture
2	EAS	East Asia	2	AIR	Air Transport
3	WAS	West Asia	3	ENY	Energy and energy production
4	NAM	North America	4	NTIND	Non Transportation Intensive industries
5	LAM	Latin America	5	SERV	Other Services
6	NEW	North West Europe	6	TIND	Transportation Intensive industries
7	NEE	North East Europe	7	OTR	Transport Not Elsewhere Classified
8	SEU	South Europe	8	SEA	Water Transport
9	CAS	Central Asia			
10	AFR	Africa			
11	EEF	Ex-Soviet countries			
12	JAK	Japan, Korea, Singapore			
13	CHN	China, Hong Kong			

Table 7 Overview of Scenarios. Reference scenario in *italics*, core scenarios in bold.

Name of scenario	Scenario description	Source of productivity changes
L&C	Land and capital losses due to SLR.	DIVA RCP 8.5 (J14) generated losses based on land loss due to submergence and annual flood costs
LC_Un10	Uniform reduction of productivity of sea transport by 10% to all regions	Chhetri et al. (2016)
LC_Un05	Uniform reduction of productivity of sea transport by 5% to all regions	Variation of Chhetri et al. (2016)
LC_Un20	Uniform reduction of productivity of sea transport by 20% to all regions	Variation of Chhetri et al. (2016)
LC_DIVA_L	Global reduction of productivity of sea transport by 10%, regional variation scaled according productivity changes in sea transport proportional to DIVA estimates of land loss	DIVA RCP 8.5 (J14) generated losses based on land loss due to submergence
LC_DIVA_C	Global reduction of productivity of sea transport by 10%, regional variation scaled according to DIVA generated productivity changes in sea transport proportional to DIVA estimates of capital loss	DIVA RCP 8.5 (J14) generated losses based annual flood costs
LC_OECD_DH	Global reduction of productivity of sea transport by 10%, regional variation according to the an indication of the height to which dikes need to be raised to implement adaptation strategy PL	(Hallegatte et al. 2013), 2050 in the scenario with subsidence and optimistic sea-level rise (SLR-1) with maintaining relative risk by increasing the dike height (PL): assuming that, coastal defences will be raised by more than the level of relative sea level rise
LC_OECD_NA	Global reduction of productivity of sea transport by 10%, regional variation according to Mean Annual Property Losses due to flooding in sea ports without Adaptation	(Hallegatte et al. 2013), 2050 in the scenario with subsidence and optimistic sea-level rise (SLR-1)
LC_OECD_A	Global reduction of productivity of sea transport by 10%, regional variation according to Mean Annual Property Losses due to flooding in sea ports with Adaptation	(Hallegatte et al. 2013), 2050 in the scenario with subsidence and optimistic sea-level rise (SLR-1) with maintaining the defence standards (PD) by assuming that coastal defences will be raised by the same amount as relative sea level rise

Table 8 Inputs to the GTAP model in all scenarios

Region	*L&C*		**LC_Un10**[8]	LC_Un05[8]	LC_Un20[8]	**LC_DIVA_L**[8]	LC_DIVA_C[8]	**LC_OECD_DH**[8]	LC_OECD_NA[8]	LC_OECD_A[8]
	% Land loss	% Capital loss to GDP	% change in productivity sea transport	% change in productivity sea transport	% change in productivity sea transport	% change in productivity sea transport	% change in productivity sea transport	% change in productivity sea transport	% change in productivity sea transport	% change in productivity sea transport
OCE	-0.001	-0.083	-10	-5	-20	-12.0	-18.1	-4.1	-4.3	-4
EAS	-0.005	-0.105	-10	-5	-20	-7.5	-20.5	-13.7	-17.6	-20.3
WAS	-0.000	-0.093	-10	-5	-20	-5.2	-19.5	-4.8	-5.2	-4.9
NAM	-0.002	-0.037	-10	-5	-20	-8.3	-6.7	-12.7	-7.7	-17.1
LAM	-0.001	-0.078	-10	-5	-20	-8.1	-17.2	-17	-10.9	-14.4
NEW	-0.002	-0.042	-10	-5	-20	-6.3	-7.9	-9	-4.4	-4.1
NEE	-0.001	-0.017	-10	-5	-20	-5.3	-2.7	-2.5	-4.3	-3.9
SEU	-0.007	-0.021	-10	-5	-20	-21.1	-3.4	-3	-4.3	-3.9
CAS	-0.003	-0.057	-10	-5	-20	-11.7	-12.1	-10.3	-14.4	-18.3
AFR	-0.002	-0.054	-10	-5	-20	-21.0	-11.3	-15	-13.7	-10.5
EEF	-0.003	-0.027	-10	-5	-20	-8.7	-4.4	-2.5	-4.4	-4
JAK	-0.003	-0.009	-10	-5	-20	-5.6	-1.6	-15.6	-20.5	-8.5
CHN	-3.3E-06	-0.053	-10	-5	-20	-4.4	-11.0	-20.3	-13.5	-12.6
	Mean values		-10	-5	-20	-9.7[9]	-10.1[9]	-10.1[9]	-9.7[9]	-9.8[9]

8 The L&C land and capital shocks are used in all other scenarios additional to the water transport productivity socks indicated
9 The mean values are approximately 10 but not equal to 10 due to the *f* factor (~21.4) in the normalisation process. This factor is kept constant throughout the different scenarios to make cross-scenario comparability possible.

Table 5 Percentage changes of GDP and HEV to initial regional GDP due to SLR induces land and capital losses.

	L&C			
	% Land loss	**% Capital loss**	**Δ%GDP**	**HEV/GDP**
OCE	-0.001	-0.083	-0.030	-0.020
EAS	-0.005	-0.105	-0.050	-0.037
WAS	-0.000	-0.093	-0.052	-0.041
NAM	-0.002	-0.037	-0.011	-0.008
LAM	-0.001	-0.078	-0.034	-0.024
NWE	-0.002	-0.042	-0.017	-0.012
NEE	-0.001	-0.017	-0.008	-0.007
SEU	-0.007	-0.021	-0.010	-0.009
CAS	-0.003	-0.057	-0.027	-0.022
AFR	-0.002	-0.054	-0.024	-0.016
EEF	-0.003	-0.027	-0.013	-0.011
JAK	-0.003	-0.009	-0.004	-0.004
CHN	-3.3E-06	-0.053	-0.024	-0.019

Δ%GDP: Percentage change in GDP, HEV/GDP: Hicksian Equivalent Variation to initial GDP

Table 9 Percentage changes in the trade balance between countries

L&C

From \ To	OCE	EAS	WAS	NAM	LAM	NWE	NEE	SEU	CAS	AFR	EEF	JAK	CHN
OCE	-0.041%	-0.081%	-0.061%	-0.028%	-0.028%	-0.046%	-0.049%	-0.043%	-0.063%	-0.038%	-0.044%	-0.043%	-0.068%
EAS	-0.038%	-0.071%	-0.061%	-0.039%	-0.035%	-0.045%	-0.041%	-0.044%	-0.050%	-0.026%	-0.031%	-0.042%	-0.055%
WAS	-0.051%	-0.058%	-0.082%	-0.027%	-0.047%	-0.058%	-0.061%	-0.053%	-0.046%	-0.051%	-0.063%	-0.017%	-0.054%
NAM	-0.022%	-0.053%	-0.039%	-0.012%	-0.016%	-0.020%	-0.017%	-0.020%	-0.034%	-0.018%	-0.019%	-0.020%	-0.035%
LAM	-0.050%	-0.081%	-0.067%	-0.042%	-0.047%	-0.052%	-0.046%	-0.051%	-0.056%	-0.048%	-0.044%	-0.042%	-0.065%
NWE	-0.020%	-0.048%	-0.036%	-0.011%	-0.017%	-0.019%	-0.018%	-0.019%	-0.026%	-0.015%	-0.021%	-0.019%	-0.031%
NEE	-0.006%	-0.030%	-0.021%	0.003%	0.000%	-0.003%	-0.002%	-0.004%	-0.016%	0.000%	-0.007%	-0.002%	-0.016%
SEU	-0.007%	-0.034%	-0.021%	0.005%	-0.002%	-0.004%	-0.002%	-0.003%	-0.017%	0.001%	-0.006%	-0.005%	-0.013%
CAS	-0.018%	-0.046%	-0.031%	-0.009%	-0.015%	-0.018%	-0.015%	-0.018%	-0.028%	-0.008%	-0.014%	-0.017%	-0.027%
AFR	-0.035%	-0.054%	-0.058%	-0.009%	-0.021%	-0.037%	-0.034%	-0.037%	-0.039%	-0.032%	-0.034%	-0.025%	-0.045%
EEF	-0.019%	-0.029%	-0.024%	0.008%	-0.001%	-0.003%	-0.008%	0.002%	-0.023%	-0.002%	-0.015%	0.013%	-0.013%
JAK	0.008%	-0.017%	-0.006%	0.016%	0.013%	0.011%	0.013%	0.011%	0.001%	0.016%	0.011%	0.012%	0.000%
CHN	-0.011%	-0.041%	-0.030%	-0.004%	-0.010%	-0.016%	-0.015%	-0.016%	-0.026%	-0.009%	-0.018%	-0.012%	-0.026%

LC_Un10

From \ To	OCE	EAS	WAS	NAM	LAM	NWE	NEE	SEU	CAS	AFR	EEF	JAK	CHN
OCE	-0.049%	0.167%	1.347%	0.945%	-1.996%	0.842%	-0.804%	0.977%	-2.735%	1.039%	0.973%	-0.872%	-0.325%
EAS	-1.097%	-0.364%	-0.151%	0.139%	-0.844%	0.424%	0.162%	-0.482%	-0.482%	-0.248%	0.173%	-0.374%	0.116%
WAS	-1.304%	-0.555%	-0.241%	0.142%	-1.163%	0.053%	-0.465%	-0.142%	-0.259%	-1.631%	-0.337%	0.139%	-1.026%
NAM	-0.741%	-0.190%	-0.137%	-0.198%	-2.120%	0.377%	0.370%	-0.122%	-0.079%	-0.587%	-0.411%	-0.017%	-0.951%
LAM	1.213%	1.363%	0.179%	0.631%	0.109%	0.617%	-3.986%	0.145%	-7.493%	0.462%	0.626%	-5.380%	-3.825%
NWE	-0.818%	-0.312%	-0.531%	-0.332%	-1.229%	0.144%	-0.003%	0.085%	0.435%	-0.712%	-0.720%	0.284%	-0.350%
NEE	-0.733%	-0.293%	-0.731%	-0.779%	-1.373%	0.121%	-0.015%	0.159%	0.189%	-0.776%	-0.267%	0.256%	-0.018%
SEU	-0.703%	-0.072%	-0.596%	-0.548%	-1.136%	0.360%	0.219%	0.091%	-0.080%	-1.031%	-0.580%	1.406%	-0.290%
CAS	-0.731%	-1.001%	-0.404%	-0.147%	-1.151%	0.091%	-0.235%	0.066%	-1.323%	-0.891%	-0.251%	0.011%	-1.335%
AFR	-0.617%	-0.751%	-0.987%	-0.134%	-1.855%	-0.085%	-0.081%	0.415%	-0.413%	0.215%	-0.820%	1.232%	-0.907%
EEF	0.208%	-0.211%	-0.698%	-0.184%	-1.994%	-0.066%	1.046%	-0.403%	-0.234%	-1.136%	0.131%	0.673%	-0.218%
JAK	-1.239%	-0.560%	-0.493%	-0.314%	-1.344%	-0.150%	-0.427%	0.069%	-0.089%	-0.196%	-0.571%	0.452%	-0.622%
CHN	-0.996%	-0.452%	-0.928%	-1.153%	-1.689%	-0.323%	-0.679%	-0.166%	-0.394%	-0.724%	-0.067%	0.019%	1.374%

LC_DIVA_L

From \ To	OCE	EAS	WAS	NAM	LAM	NWE	NEE	SEU	CAS	AFR	EEF	JAK	CHN
OCE	-0.497%	-0.074%	0.728%	0.550%	-1.770%	0.690%	-0.063%	-0.566%	-4.078%	0.755%	0.458%	-0.247%	0.005%
EAS	-1.048%	-0.265%	0.005%	0.109%	-0.630%	0.480%	0.374%	-2.295%	-0.728%	-1.012%	0.049%	-0.074%	0.181%
WAS	-1.042%	-0.258%	0.019%	0.384%	-0.679%	0.442%	0.167%	-1.093%	-0.108%	-3.747%	-0.234%	0.166%	-0.188%
NAM	-0.561%	-0.185%	-0.198%	-0.179%	-1.680%	0.314%	0.283%	-0.542%	-0.018%	-0.953%	-0.453%	0.013%	-0.532%
LAM	1.014%	1.019%	0.458%	0.413%	0.068%	0.795%	-1.551%	-2.927%	-9.276%	-1.312%	0.293%	-2.539%	-1.212%
NWE	-0.537%	-0.303%	-0.500%	-0.298%	-0.986%	0.068%	-0.059%	0.427%	0.685%	-0.854%	-0.726%	0.138%	-0.395%
NEE	-0.456%	-0.254%	-0.524%	-0.642%	-1.071%	0.130%	0.023%	0.370%	0.348%	-1.150%	-0.324%	0.166%	-0.180%
SEU	-0.526%	-0.138%	-0.489%	-0.519%	-0.943%	0.227%	0.109%	-0.011%	-0.090%	-1.988%	-0.669%	1.055%	-0.311%
CAS	-0.738%	-0.879%	-0.386%	-0.262%	-1.018%	0.085%	-0.036%	-0.696%	-1.700%	-2.195%	-0.436%	-0.007%	-0.755%
AFR	-0.882%	-0.985%	-0.949%	-0.377%	-1.681%	-0.211%	-0.180%	-0.384%	-0.891%	-0.059%	-1.165%	0.301%	-0.739%
EEF	0.594%	0.014%	-0.222%	0.062%	-1.336%	0.399%	0.953%	-1.523%	-0.143%	-2.434%	0.127%	0.557%	0.073%
JAK	-1.098%	-0.445%	-0.399%	-0.266%	-1.053%	-0.022%	-0.152%	-0.058%	0.011%	0.042%	-0.581%	0.254%	-0.411%
CHN	-0.620%	-0.164%	-0.382%	-0.750%	-1.124%	0.089%	-0.052%	-0.478%	-0.200%	-1.131%	0.037%	0.230%	0.670%

LC_OECD_DH

From \ To	OCE	EAS	WAS	NAM	LAM	NWE	NEE	SEU	CAS	AFR	EEF	JAK	CHN
OCE	0.931%	0.592%	1.978%	1.609%	-3.387%	1.922%	2.329%	2.474%	-1.974%	1.885%	1.822%	-1.598%	-1.236%
EAS	-0.999%	-0.464%	0.289%	0.212%	-1.304%	0.740%	0.976%	0.685%	-0.339%	-0.373%	0.510%	-0.725%	0.009%
WAS	-1.155%	-0.738%	0.177%	0.305%	-1.683%	0.524%	0.815%	0.767%	-0.206%	-2.338%	0.305%	0.287%	-2.220%
NAM	-0.941%	-0.116%	-0.157%	-0.185%	-3.232%	0.496%	0.448%	0.173%	-0.071%	-0.694%	-0.159%	0.053%	-1.756%
LAM	1.539%	1.926%	1.501%	0.865%	-0.143%	1.537%	1.292%	2.268%	-7.357%	0.503%	1.895%	-9.000%	-9.386%
NWE	-1.248%	-0.248%	-0.563%	-0.342%	-1.509%	0.151%	-0.050%	-0.060%	0.403%	-0.805%	-0.530%	0.605%	-0.127%
NEE	-1.109%	-0.232%	-0.530%	-0.933%	-1.818%	0.205%	0.119%	0.124%	0.196%	-0.933%	-0.298%	0.546%	0.505%
SEU	-1.018%	0.038%	-0.384%	-0.646%	-1.530%	0.452%	0.294%	0.178%	-0.059%	-1.376%	-0.272%	2.015%	-0.271%
CAS	-0.722%	-1.232%	-0.037%	-0.050%	-1.604%	0.417%	0.697%	0.601%	-1.245%	-1.193%	0.194%	0.060%	-2.719%
AFR	-0.953%	-1.242%	-0.520%	-0.321%	-3.113%	0.075%	0.560%	0.664%	-0.635%	0.203%	-0.187%	1.760%	-2.171%
EEF	-0.364%	-0.358%	-0.356%	-0.425%	-3.463%	0.031%	0.964%	0.152%	-0.340%	-1.788%	0.262%	0.826%	-0.597%
JAK	-1.392%	-0.747%	-0.526%	-0.453%	-1.947%	-0.126%	0.012%	0.096%	-0.218%	-0.189%	-0.394%	0.748%	-1.064%
CHN	-1.748%	-1.119%	-1.141%	-2.051%	-3.050%	-0.776%	-0.485%	-0.452%	-1.010%	-1.538%	-0.703%	-0.498%	2.905%

Table 10 Basic direct and indirect effects of sea transport changes combined with the SLR induced land and capital losses

	LC_Un10					LC_DIVA_L					LC_OECD_DH				
	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	HEV/GDP	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	HEV/GDP	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	HEV/GDP
OCE	-10%	-0.117	-0.670	-0.057	-0.148	-12.0%	-0.140	-0.589	-0.054	-0.133	-4.1%	-0.048	-0.772	-0.062	-0.163
EAS	-10%	-0.191	-0.400	-0.072	-0.238	-7.5%	-0.143	-0.317	-0.066	-0.189	-13.7%	-0.261	-0.539	-0.082	-0.322
WAS	-10%	-0.136	-0.528	-0.074	-0.239	-5.2%	-0.070	-0.415	-0.065	-0.169	-4.8%	-0.065	-0.470	-0.065	-0.181
NAM	-10%	-0.026	-0.459	-0.016	-0.057	-8.3%	-0.022	-0.390	-0.015	-0.047	-12.7%	-0.033	-0.620	-0.019	-0.075
LAM	-10%	-0.144	-0.994	-0.072	-0.195	-8.1%	-0.117	-0.812	-0.064	-0.159	-17.0%	-0.245	-1.477	-0.096	-0.300
NWE	-10%	-0.028	-0.129	-0.010	-0.015	-6.3%	-0.018	-0.104	-0.009	-0.006	-9.0%	-0.025	-0.150	-0.007	-0.006
NEE	-10%	-0.045	-0.179	-0.013	-0.063	-5.3%	-0.024	-0.119	-0.007	-0.030	-2.5%	-0.011	-0.118	-0.002	-0.006
SEU	-10%	-0.031	-0.046	-0.005	-0.032	-21.1%	-0.066	-0.172	-0.012	-0.089	-3.0%	-0.009	0.026	0.000	0.000
CAS	-10%	-0.082	-0.743	-0.078	-0.188	-11.7%	-0.096	-0.755	-0.086	-0.211	-10.3%	-0.084	-0.866	-0.082	-0.202
AFR	-10%	-0.120	-0.464	-0.066	-0.230	-21.0%	-0.252	-0.768	-0.111	-0.431	-15.0%	-0.179	-0.598	-0.087	-0.330
EEF	-10%	-0.086	-0.359	-0.045	-0.116	-8.7%	-0.075	-0.371	-0.044	-0.112	-2.5%	-0.021	-0.251	-0.035	-0.081
JAK	-10%	-0.050	-0.571	-0.010	-0.074	-5.6%	-0.028	-0.416	-0.007	-0.033	-15.6%	-0.078	-0.820	-0.015	-0.126
CHN	-10%	-0.103	-0.784	-0.072	-0.188	-4.5%	-0.046	-0.502	-0.049	-0.103	-20.3%	-0.210	-1.355	-0.118	-0.366

ΔTC/GDP : Change in transportation costs to initial GDP, Δ% X: Percentage change of exports, Δ%GDP: Percentage change in GDP, HEV/GDP: Hicksian Equivalent Variation to initial GDP

Table 11 Prices (fob) of primary and manufacturing goods

	L&C			LC_Un10			LC_DIVA_L			LC_OECD_DH		
	Agriculture	Tran_Intens	Other_Ind	Agriculture	Tran_Intens	Other_Ind	Agriculture	Tran_Intens	Other_Ind	Agriculture	Tran_Intens	Other_Ind
OCE	-0.060	0.020	0.220	-2.286	-2.406	-2.754	-1.477	-1.369	-1.560	-3.610	-4.121	-4.741
EAS	-0.236	0.052	0.219	-1.922	-0.238	-0.512	-2.008	-0.215	-0.388	-2.341	-0.259	-0.689
WAS	-0.046	0.115	0.229	0.078	0.083	0.613	-0.562	-0.404	-0.021	-0.477	-0.305	0.125
NAM	-0.020	-0.007	0.093	0.520	1.069	1.233	0.437	0.884	1.038	0.388	1.317	1.495
LAM	-0.003	0.087	0.171	-5.027	-4.064	-4.207	-4.032	-3.116	-3.196	-6.793	-5.458	-5.692
NWE	-0.045	0.009	0.016	1.626	1.908	1.983	1.295	1.615	1.662	1.940	2.364	2.425
NEE	-0.050	-0.025	-0.026	1.405	1.497	1.773	1.103	1.219	1.367	1.685	1.885	1.957
SEU	-0.055	-0.027	-0.031	1.107	1.335	1.456	0.936	1.229	1.504	1.410	1.671	1.715
CAS	-0.203	0.002	0.056	-1.211	0.551	0.812	-0.956	0.796	1.084	-1.610	0.455	0.731
AFR	-0.065	0.055	0.103	-0.749	0.064	0.278	0.189	1.198	1.555	-0.171	0.725	1.016
EEF	-0.080	0.014	-0.016	-0.282	-0.344	-0.147	-0.762	-0.721	-0.551	-0.683	-0.100	-0.033
JAK	-0.087	-0.072	-0.049	2.534	1.398	2.073	1.622	1.144	1.556	4.031	2.026	3.105
CHN	-0.261	0.000	0.020	0.374	1.144	1.319	-0.328	0.425	0.503	2.209	2.983	3.381

Table 12 Decomposition of GDP changes (in %, see Eq. 4)

L&C

	c	C/GDP	i	I/GDP	e	E/GDP	t	T/GDP	m	M/GDP	Δ%GDP
OCE	-0.022	0.741	-0.022	0.264	-0.056	0.207	-0.027	0.003	-0.019	0.215	-0.030
EAS	-0.041	0.671	-0.054	0.225	-0.053	0.590	-0.030	0.007	-0.042	0.494	-0.050
WAS	-0.045	0.691	-0.058	0.239	-0.050	0.421	-0.037	0.010	-0.038	0.361	-0.052
NAM	-0.009	0.852	-0.017	0.196	-0.020	0.125	-0.024	0.002	-0.012	0.175	-0.011
LAM	-0.027	0.784	-0.028	0.197	-0.056	0.201	-0.031	0.004	-0.022	0.186	-0.034
NWE	-0.013	0.781	-0.026	0.203	-0.020	0.356	-0.025	0.016	-0.018	0.356	-0.017
NEE	-0.007	0.785	-0.029	0.226	-0.003	0.387	-0.022	0.022	-0.014	0.420	-0.008
SEU	-0.010	0.801	-0.031	0.254	-0.003	0.276	-0.022	0.007	-0.018	0.339	-0.010
CAS	-0.023	0.720	-0.046	0.315	-0.021	0.256	-0.023	0.007	-0.033	0.299	-0.027
AFR	-0.018	0.748	-0.016	0.222	-0.035	0.367	-0.029	0.005	-0.017	0.342	-0.024
EEF	-0.011	0.705	-0.031	0.238	-0.006	0.330	-0.022	0.010	-0.017	0.284	-0.013
JAK	-0.005	0.729	-0.028	0.240	0.010	0.241	-0.021	0.021	-0.019	0.232	-0.004
CHN	-0.020	0.525	-0.043	0.396	-0.015	0.369	-0.030	0.014	-0.031	0.303	-0.024

LC_Un10

	c	C/GDP	i	I/GDP	e	E/GDP	t	T/GDP	m	M/GDP	Δ%GDP
OCE	-0.155	0.741	-0.334	0.264	-0.440	0.207	3.542	0.003	-1.059	0.215	-0.057
EAS	-0.236	0.671	-0.384	0.225	-0.346	0.590	5.167	0.007	-0.698	0.494	-0.066
WAS	-0.259	0.691	-0.251	0.239	-0.467	0.421	5.433	0.010	-0.859	0.361	-0.072
NAM	-0.061	0.852	-0.057	0.196	-0.538	0.125	2.167	0.002	-0.622	0.175	-0.017
LAM	-0.204	0.784	-0.491	0.197	-0.656	0.201	5.937	0.004	-1.600	0.186	-0.069
NWE	-0.016	0.781	0.029	0.203	-0.253	0.356	5.571	0.016	-0.013	0.356	-0.003
NEE	-0.069	0.785	-0.104	0.226	-0.284	0.387	3.673	0.022	-0.235	0.420	-0.007
SEU	-0.035	0.801	-0.034	0.254	-0.122	0.276	2.813	0.007	-0.156	0.339	0.002
CAS	-0.189	0.720	-0.210	0.315	-0.741	0.256	7.973	0.007	-0.881	0.299	-0.070
AFR	-0.252	0.748	-0.466	0.222	-0.399	0.367	4.424	0.005	-1.033	0.342	-0.063
EEF	-0.114	0.705	-0.063	0.238	-0.310	0.330	1.083	0.010	-0.499	0.284	-0.045
JAK	-0.084	0.729	-0.062	0.240	-0.661	0.241	5.698	0.021	-0.473	0.232	-0.006
CHN	-0.186	0.525	-0.143	0.396	-0.860	0.369	6.538	0.014	-1.028	0.303	-0.068

Table 13c Decomposition of GDP changes (in %, see Eq. 4)

LC_DIVA_L

	c	C/GDP	i	I/GDP	e	E/GDP	t	T/GDP	m	M/GDP	Δ%GDP
OCE	-0.140	0.741	-0.266	0.264	-0.443	0.207	2.987	0.003	-0.950	0.215	-0.053
EAS	-0.186	0.671	-0.290	0.225	-0.271	0.590	4.447	0.007	-0.519	0.494	-0.061
WAS	-0.183	0.691	-0.155	0.239	-0.332	0.421	4.691	0.010	-0.538	0.361	-0.063
NAM	-0.051	0.852	-0.038	0.196	-0.456	0.125	1.868	0.002	-0.503	0.175	-0.015
LAM	-0.166	0.784	-0.373	0.197	-0.548	0.201	5.079	0.004	-1.261	0.186	-0.060
NWE	-0.006	0.781	0.050	0.203	-0.209	0.356	4.778	0.016	0.031	0.356	-0.003
NEE	-0.032	0.785	-0.027	0.226	-0.204	0.387	3.115	0.022	-0.090	0.420	-0.003
SEU	-0.099	0.801	-0.162	0.254	-0.247	0.276	2.353	0.007	-0.489	0.339	-0.006
CAS	-0.212	0.720	-0.234	0.315	-0.776	0.256	6.853	0.007	-0.989	0.299	-0.079
AFR	-0.473	0.748	-0.976	0.222	-0.765	0.367	3.670	0.005	-2.109	0.342	-0.111
EEF	-0.109	0.705	-0.062	0.238	-0.299	0.330	0.908	0.010	-0.479	0.284	-0.045
JAK	-0.037	0.729	0.014	0.240	-0.488	0.241	4.889	0.021	-0.157	0.232	-0.002
CHN	-0.101	0.525	-0.064	0.396	-0.526	0.369	5.645	0.014	-0.484	0.303	-0.046

LC_OECD_DH

	c	C/GDP	i	I/GDP	e	E/GDP	t	T/GDP	m	M/GDP	Δ%GDP
OCE	-0.172	0.741	-0.421	0.264	-0.400	0.207	4.635	0.003	-1.148	0.215	-0.062
EAS	-0.319	0.671	-0.525	0.225	-0.471	0.590	6.614	0.007	-0.985	0.494	-0.074
WAS	-0.198	0.691	-0.141	0.239	-0.374	0.421	7.005	0.010	-0.547	0.361	-0.062
NAM	-0.081	0.852	-0.081	0.196	-0.716	0.125	2.791	0.002	-0.852	0.175	-0.019
LAM	-0.312	0.784	-0.788	0.197	-1.026	0.201	7.613	0.004	-2.608	0.186	-0.093
NWE	-0.007	0.781	0.066	0.203	-0.301	0.356	7.153	0.016	0.036	0.356	0.003
NEE	-0.006	0.785	0.042	0.226	-0.244	0.387	4.749	0.022	0.024	0.420	0.006
SEU	0.001	0.801	0.053	0.254	-0.067	0.276	3.673	0.007	0.035	0.339	0.010
CAS	-0.202	0.720	-0.221	0.315	-0.845	0.256	10.205	0.007	-0.956	0.299	-0.071
AFR	-0.363	0.748	-0.692	0.222	-0.545	0.367	5.642	0.005	-1.500	0.342	-0.084
EEF	-0.079	0.705	-0.021	0.238	-0.213	0.330	1.432	0.010	-0.287	0.284	-0.035
JAK	-0.145	0.729	-0.134	0.240	-0.952	0.241	7.296	0.021	-0.880	0.232	-0.010
CHN	-0.366	0.525	-0.303	0.396	-1.566	0.369	8.303	0.014	-2.165	0.303	-0.116

Table 14 GDP and HEV decomposition of all scenarios

L&C

	HEV decomposition						GDP decomposition						
	Allocative efficiency	Endowment Effect	Productivity Change	Terms of Trade	IS[10]	Total HEV	Government consumption	Private Consumption	Capital goods	Exports	Transport sales	Imports	Total difference
OCE	-78.5	-139	0	13.1	0.5	-204	-33	-137	-59	-120	-1	42	-307
EAS	-90.3	-433	0	41.8	-1.7	-483	-49	-307	-157	-403	-3	273	-647
WAS	-129	-765	0	54.7	-9.1	-849	-140	-502	-287	-445	-8	289	-1092
NAM	-334	-986	0	-10.6	-4.2	-1334	-165	-1089	-553	-407	-8	337	-1885
LAM	-162	-558	0	32.8	-2.0	-689	-107	-491	-155	-315	-3	117	-955
NWE	-423	-1039	0	1.9	3.1	-1457	-239	-1024	-652	-865	-50	771	-2060
NEE	-21.7	-48.1	0	-10.4	0.0	-80.1	-15	-55	-81	-12	-6	74	-94
SEU	-96.9	-249	0	-34	-4.7	-384	-61	-286	-352	-32	-7	277	-462
CAS	-71.8	-301	0	-6.2	0.8	-378	-44	-245	-251	-93	-3	171	-465
AFR	-57.8	-176	0	16.7	-0.7	-218	-32	-151	-48	-171	-2	78	-325
EEF	-35.5	-153	0	-2.1	0.9	-189	-27	-107	-124	-33	-4	80	-215
JAK	-57.3	-104	0	-96.9	11.3	-247	-35	-173	-382	135	-24	249	-229
CHN	-64.8	-642	0	-0.7	5.8	-702	-105	-284	-626	-209	-16	345	-894

LC_Un10

	HEV decomposition						GDP decomposition						
	Allocative efficiency	Endowment Effect	Productivity Change	Terms of Trade	IS[10]	Total HEV	Government consumption	Private Consumption	Capital goods	Exports	Transport sales	Imports	Total difference
OCE	-359	-139	-404	-599	-14.5	-1516	-222	-959	-908	-944	101	2339	-594
EAS	-381	-432	-1537	-731	-13.7	-3094	-217	-1838	-1123	-2744	498	4477	-947
WAS	-584	-764	-2545	-1042	-37.5	-4972	-724	-3003	-1247	-4146	1107	6451	-1562
NAM	-1169	-986	-8195	630	349	-9370	-716	-7851	-1847	-11085	769	17971	-2759
LAM	-1238	-557	-2015	-1816	126	-5501	-587	-3911	-2728	-3827	631	8356	-2066
NWE	381	-1039	-3414	2423	-215	-1864	-83	-1460	735	-12020	10983	581	-1263
NEE	-81.1	-48.1	-757	109	5.6	-772	-93	-571	-286	-1409	998	1199	-163
SEU	126	-249	-1685	260	118	-1429	-106	-1158	-389	-1833	891	2353	-243
CAS	-971	-301	-2082	49	11.3	-3293	-249	-2129	-1157	-3478	1029	4584	-1400
AFR	-606	-176	-1695	-559	-20.4	-3056	-318	-2190	-1374	-1987	291	4692	-886
EEF	-577	-153	-622	-631	20.1	-1962	-232	-1131	-255	-1727	188	2396	-761
JAK	-413	-104	-4736	1252	-127	-4128	-306	-3125	-839	-9220	6731	6114	-646
CHN	-1816	-642	-4939	650	-201	-6948	-651	-2970	-2101	-11904	3401	11525	-2699

10 IS: Investments/savings effect on HEV

LC_DIVA_L

	HEV decomposition						GDP decomposition						
	Allocative efficiency	Endowment Effect	Productivity Change	Terms of Trade	IS[10]	Total HEV	Government consumption	Private Consumption	Capital goods	Exports	Transport sales	Imports	Total difference
OCE	-321	-139	-496	-398	-15.5	-1370	-229	-452	-121	-303	-2	-596	-1704
EAS	-303	-432	-1119	-585	-14.4	-2453	-91	-149	132	-281	0	-1362	-1750
WAS	-384	-764	-1253	-1139	21.6	-3519	-91	142	75	-698	0	-1627	-2200
NAM	-982	-986	-6712	594	261	-7825	1162	8978	2924	1366	24	-7936	6517
LAM	-1000	-557	-1603	-1415	83.6	-4492	-1460	-3770	-809	-1394	-17	-1596	-9047
NWE	472	-1039	-2085	2085	-230	-797	2917	8672	3115	5383	224	-5512	14799
NEE	-17.7	-48.1	-385	88.3	-0.9	-363	222	705	288	454	24	-784	910
SEU	-186	-248	-4030	349	155	-3960	355	3340	1379	1202	35	-5086	1226
CAS	-1108	-301	-2482	177	22.4	-3691	-79	492	673	231	1	-2625	-1306
AFR	-1212	-175	-4015	-221	-98.2	-5721	-112	1660	785	31	9	-4324	-1951
EEF	-567	-153	-534	-663	24.9	-1892	-220	-150	-19	-413	-10	-731	-1543
JAK	-201	-104	-2554	1130	-125	-1855	672	3221	1269	1225	93	-2675	3804
CHN	-983	-642	-2085	-6.62	-83.7	-3800	-5	460	675	447	10	-2413	-826

LC_OECD_DH

	HEV decomposition						GDP decomposition						
	Allocative efficiency	Endowment Effect	Productivity Change	Terms of Trade	IS[10]	Total HEV	Government consumption	Private Consumption	Capital goods	Exports	Transport sales	Imports	Total difference
OCE	-408	-139	-156	-960	-13.1	-1676	-604	-1645	-647	-795	-8	-322	-4021
EAS	-508	-432	-2186	-1051	-9.8	-4187	-168	-114	290	-414	0	-2728	-3134
WAS	-387	-764	-1154	-1553	94.2	-3764	-42	260	139	-780	2	-1813	-2233
NAM	-1518	-985	-10704	380	435	-12392	1649	13531	4530	2002	35	-13154	8594
LAM	-1915	-557	-3688	-2459	176	-8443	-2639	-6423	-1263	-2420	-30	-3721	-16497
NWE	765	-1039	-3034	2687	-162	-784	4332	12781	4598	7865	325	-8377	21524
NEE	51.4	-48.1	-176	94.5	10.7	-67.4	395	999	415	690	38	-823	1714
SEU	361	-249	-465	251	120	18.9	1056	3520	1507	1577	42	-2054	5648
CAS	-1037	-301	-2147	-56.9	14.2	-3527	-101	164	557	112	0	-2411	-1680
AFR	-887	-176	-2672	-607	-37.8	-4380	-74	1083	559	-198	7	-3088	-1712
EEF	-420	-153	-142	-723	61.7	-1376	-46	39	121	-199	-1	-586	-672
JAK	-690	-104	-7795	1654	-146	-7080	739	6285	2438	2185	138	-8506	3279
CHN	-3539	-641	-11150	2332	-543	-13541	269	3642	4118	3161	59	-12078	-829

Table 15 Deterministic sensitivity analysis, additional scenarios' main results

	LC_Un5					LC_Un10					LC_Un20				
	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	EV/GDP	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	EV/GDP	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	EV/GDP
OCE	-5%	-0.058	-0.345	-0.043	-0.081	**-10%**	**-0.117**	**-0.670**	**-0.057**	**-0.148**	-20%	-0.233	-1.430	-0.091	-0.304
EAS	-5%	-0.095	-0.214	-0.060	-0.133	**-10%**	**-0.191**	**-0.400**	**-0.072**	**-0.238**	-20%	-0.382	-0.838	-0.100	-0.486
WAS	-5%	-0.068	-0.274	-0.063	-0.135	**-10%**	**-0.136**	**-0.528**	**-0.074**	**-0.239**	-20%	-0.272	-1.128	-0.101	-0.484
NAM	-5%	-0.013	-0.228	-0.014	-0.031	**-10%**	**-0.026**	**-0.459**	**-0.016**	**-0.057**	-20%	-0.052	-1.003	-0.023	-0.117
LAM	-5%	-0.072	-0.503	-0.052	-0.106	**-10%**	**-0.144**	**-0.994**	**-0.072**	**-0.195**	-20%	-0.288	-2.115	-0.117	-0.399
NWE	-5%	-0.014	-0.071	-0.014	-0.013	**-10%**	**-0.028**	**-0.129**	**-0.010**	**-0.015**	-20%	-0.057	-0.264	-0.002	-0.020
NEE	-5%	-0.023	-0.087	-0.010	-0.033	**-10%**	**-0.045**	**-0.179**	**-0.013**	**-0.063**	-20%	-0.090	-0.393	-0.019	-0.132
SEU	-5%	-0.016	-0.024	-0.008	-0.020	**-10%**	**-0.031**	**-0.046**	**-0.005**	**-0.032**	-20%	-0.062	-0.099	0.001	-0.062
CAS	-5%	-0.041	-0.365	-0.051	-0.101	**-10%**	**-0.082**	**-0.743**	**-0.078**	**-0.188**	-20%	-0.164	-1.622	-0.141	-0.391
AFR	-5%	-0.060	-0.237	-0.044	-0.118	**-10%**	**-0.120**	**-0.464**	**-0.066**	**-0.230**	-20%	-0.240	-1.000	-0.117	-0.494
EEF	-5%	-0.043	-0.173	-0.028	-0.061	**-10%**	**-0.086**	**-0.359**	**-0.045**	**-0.116**	-20%	-0.173	-0.799	-0.085	-0.246
JAK	-5%	-0.025	-0.270	-0.007	-0.037	**-10%**	**-0.050**	**-0.571**	**-0.010**	**-0.074**	-20%	-0.100	-1.271	-0.018	-0.158
CHN	-5%	-0.052	-0.381	-0.047	-0.099	**-10%**	**-0.103**	**-0.784**	**-0.072**	**-0.188**	-20%	-0.207	-1.723	-0.129	-0.394

ΔTC/GDP : Change in transportation costs to initial GDP, Δ% X: Percentage change of exports, Δ%GDP: Percentage change in GDP, HEV/GDP: Hicksian Equivalent Variation to initial GDP

	LC_OECD_DH					LC_OECD_A					LC_OECD_NA				
	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	EV/GDP	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	EV/GDP	Pr. shock	ΔTC/GDP	Δ% X	Δ%GDP	EV/GDP
OCE	**-4.1%**	**-0.048**	**-0.772**	**-0.062**	**-0.163**	-4.0%	-0.046	-0.638	-0.055	-0.136	-4.3%	-0.050	-0.823	-0.065	-0.174
EAS	**-13.7%**	**-0.261**	**-0.539**	**-0.082**	**-0.322**	-20.3%	-0.388	-0.665	-0.092	-0.412	-17.6%	-0.337	-0.624	-0.090	-0.387
WAS	**-4.8%**	**-0.065**	**-0.470**	**-0.065**	**-0.181**	-4.9%	-0.067	-0.432	-0.063	-0.173	-5.2%	-0.070	-0.436	-0.066	-0.173
NAM	**-12.7%**	**-0.033**	**-0.620**	**-0.019**	**-0.075**	-17.1%	-0.045	-0.774	-0.020	-0.097	-7.7%	-0.020	-0.388	-0.016	-0.047
LAM	**-17.0%**	**-0.245**	**-1.477**	**-0.096**	**-0.300**	-14.4%	-0.208	-1.230	-0.084	-0.250	-10.9%	-0.157	-1.107	-0.078	-0.218
NWE	**-9.0%**	**-0.025**	**-0.150**	**-0.007**	**-0.006**	-4.1%	-0.012	-0.136	-0.005	0.005	-4.4%	-0.012	-0.110	-0.007	0.003
NEE	**-2.5%**	**-0.011**	**-0.118**	**-0.002**	**-0.006**	-3.9%	-0.018	-0.142	-0.004	-0.017	-4.3%	-0.019	-0.109	-0.005	-0.018
SEU	**-3.0%**	**-0.009**	**0.026**	**0.000**	**0.000**	-4.0%	-0.012	-0.002	-0.001	-0.007	-4.3%	-0.013	0.009	-0.002	-0.007
CAS	**-10.3%**	**-0.084**	**-0.866**	**-0.082**	**-0.202**	-18.3%	-0.150	-1.168	-0.126	-0.339	-14.4%	-0.118	-0.967	-0.103	-0.266
AFR	**-15.0%**	**-0.179**	**-0.598**	**-0.087**	**-0.330**	-10.5%	-0.125	-0.467	-0.068	-0.243	-13.7%	-0.164	-0.490	-0.078	-0.283
EEF	**-2.5%**	**-0.021**	**-0.251**	**-0.035**	**-0.081**	-4.0%	-0.035	-0.239	-0.034	-0.080	-4.4%	-0.038	-0.205	-0.034	-0.075
JAK	**-15.6%**	**-0.078**	**-0.820**	**-0.015**	**-0.126**	-8.5%	-0.042	-0.621	-0.009	-0.061	-20.5%	-0.102	-0.827	-0.020	-0.176
CHN	**-20.3%**	**-0.210**	**-1.355**	**-0.118**	**-0.366**	-12.6%	-0.131	-1.011	-0.089	-0.247	-13.5%	-0.140	-0.914	-0.081	-0.233

ΔTC/GDP : Change in transportation costs to initial GDP, Δ% X: Percentage change of exports, Δ%GDP: Percentage change in GDP, HEV/GDP: Hicksian Equivalent Variation to initial GDP

	LC_DIVA_L					LC_DIVA_C				
	Pr. shock	**ΔTC/GDP**	**Δ% X**	**Δ%GDP**	**EV/GDP**	**Pr. shock**	**ΔTC/GDP**	**Δ% X**	**Δ%GDP**	**EV/GDP**
OCE	**-12.0%**	**-0.140**	**-0.589**	**-0.054**	**-0.133**	-18.1%	-0.211	-0.726	-0.060	-0.165
EAS	**-7.5%**	**-0.143**	**-0.317**	**-0.066**	**-0.189**	-20.5%	-0.392	-0.611	-0.090	-0.383
WAS	**-5.2%**	**-0.070**	**-0.415**	**-0.065**	**-0.169**	-19.5%	-0.264	-0.744	-0.096	-0.385
NAM	**-8.3%**	**-0.022**	**-0.390**	**-0.015**	**-0.047**	-6.7%	-0.018	-0.349	-0.015	-0.042
LAM	**-8.1%**	**-0.117**	**-0.812**	**-0.064**	**-0.159**	-17.2%	-0.248	-1.102	-0.083	-0.247
NWE	**-6.3%**	**-0.018**	**-0.104**	**-0.009**	**-0.006**	-7.9%	-0.022	-0.128	-0.010	-0.011
NEE	**-5.3%**	**-0.024**	**-0.119**	**-0.007**	**-0.030**	-2.7%	-0.012	-0.107	-0.004	-0.012
SEU	**-21.1%**	**-0.066**	**-0.172**	**-0.012**	**-0.089**	-3.4%	-0.010	-0.006	-0.003	-0.009
CAS	**-11.7%**	**-0.096**	**-0.755**	**-0.086**	**-0.211**	-12.1%	-0.099	-0.871	-0.094	-0.235
AFR	**-21.0%**	**-0.252**	**-0.768**	**-0.111**	**-0.431**	-11.3%	-0.136	-0.480	-0.070	-0.246
EEF	**-8.7%**	**-0.075**	**-0.371**	**-0.044**	**-0.112**	-4.4%	-0.038	-0.264	-0.031	-0.076
JAK	**-5.6%**	**-0.028**	**-0.416**	**-0.007**	**-0.033**	-1.7%	-0.008	-0.419	-0.005	-0.010
CHN	**-4.5%**	**-0.046**	**-0.502**	**-0.049**	**-0.103**	-11.0%	-0.114	-0.792	-0.072	-0.193

ΔTC/GDP : Change in transportation costs to initial GDP, Δ% X: Percentage change of exports, Δ%GDP: Percentage change in GDP, HEV/GDP: Hicksian Equivalent Variation to initial GDP

Figures

Figure 2 Basic model representation

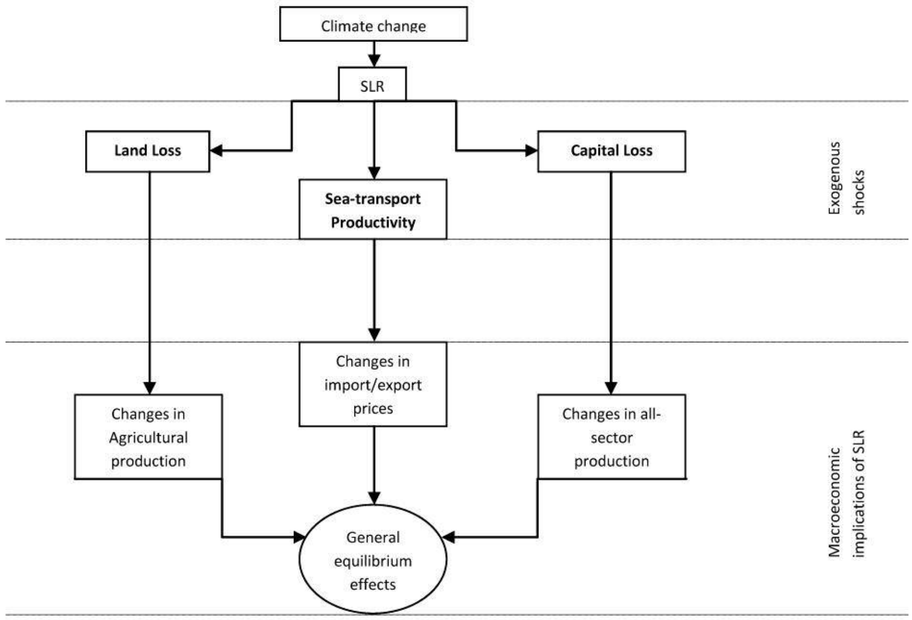


Figure 2 Regional aggregation of GTAP 8 data

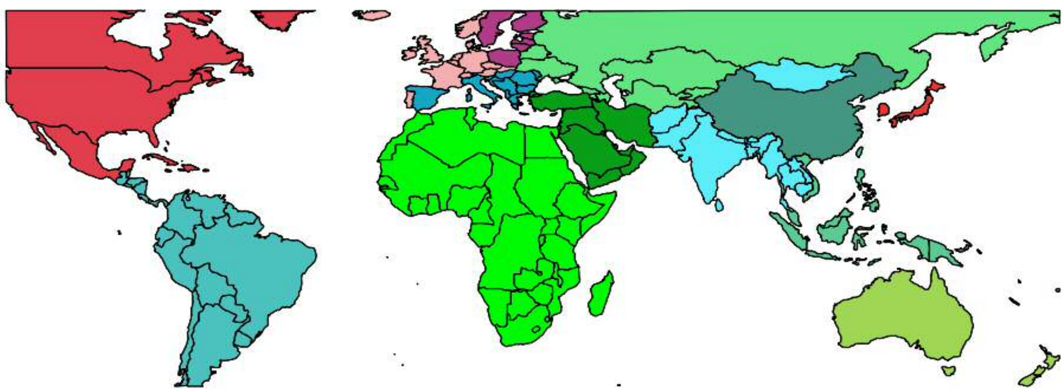


Figure 3 Propagation of effects from transport cost to HEV by region in LC_Un10 scenario

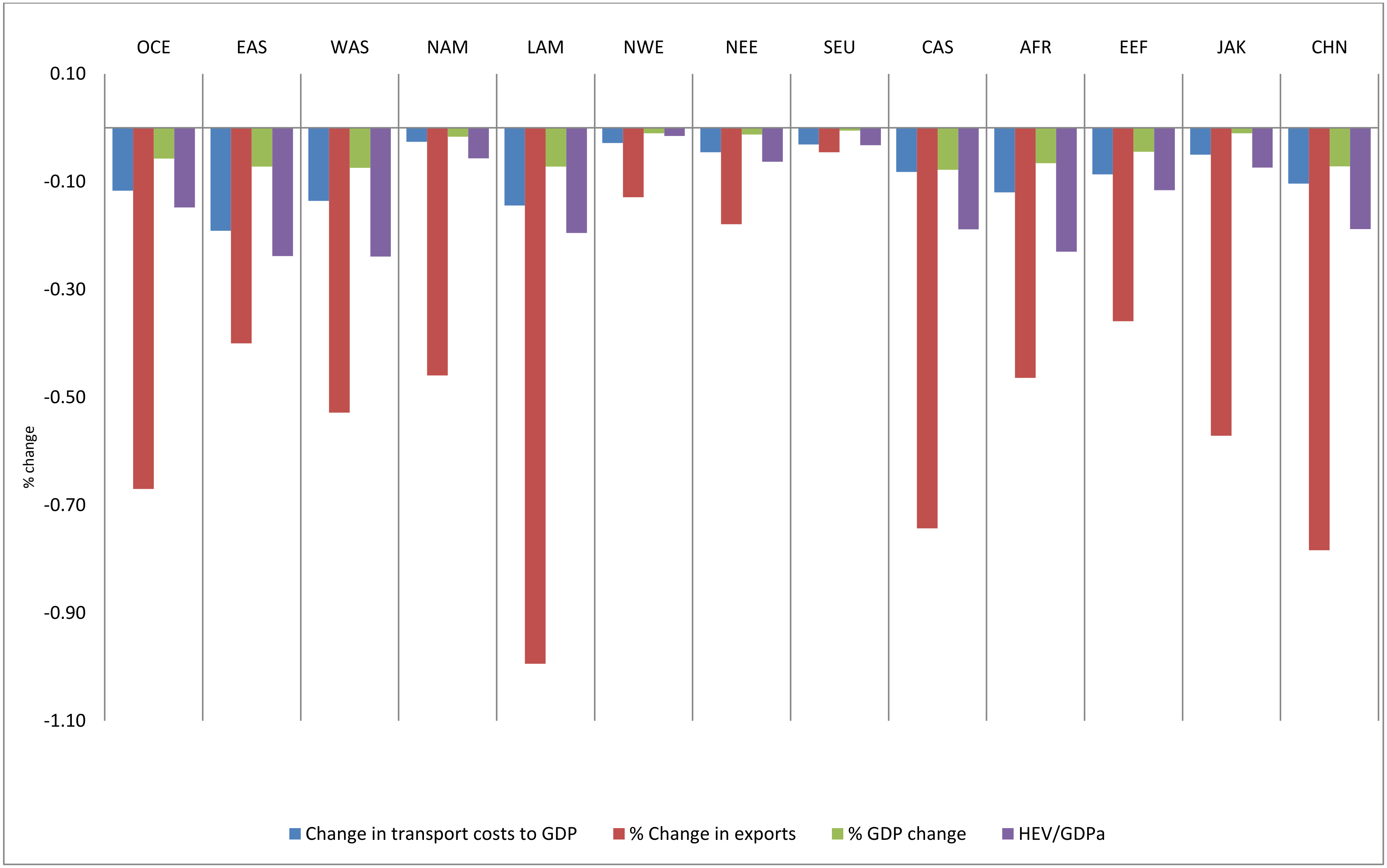


Figure 4 Propagation of effects from transport cost to HEV by region in LC_OECD_DH scenario

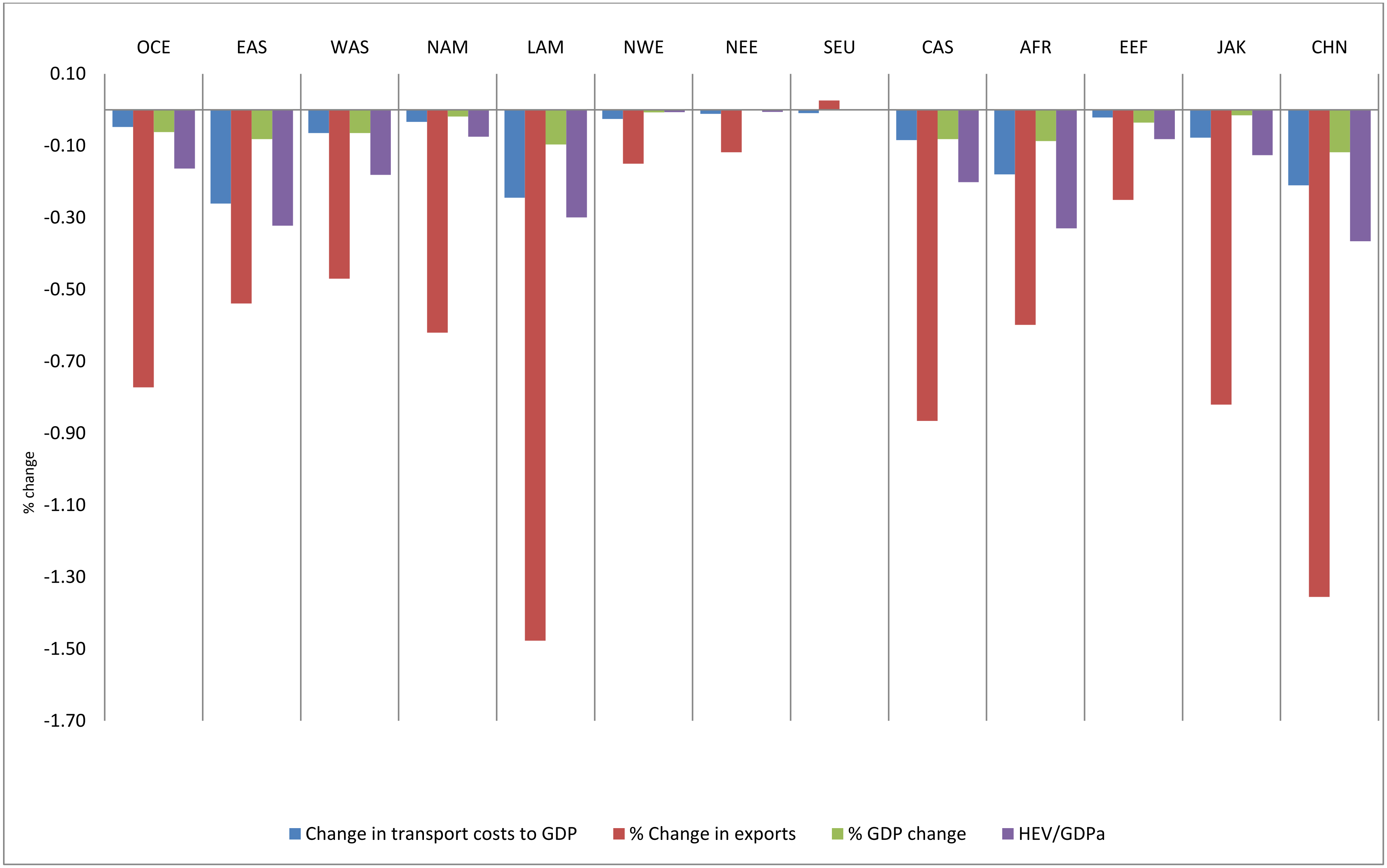


Figure 5 Propagation of effects from transport cost to HEV by region in LC_DIVA_L scenario

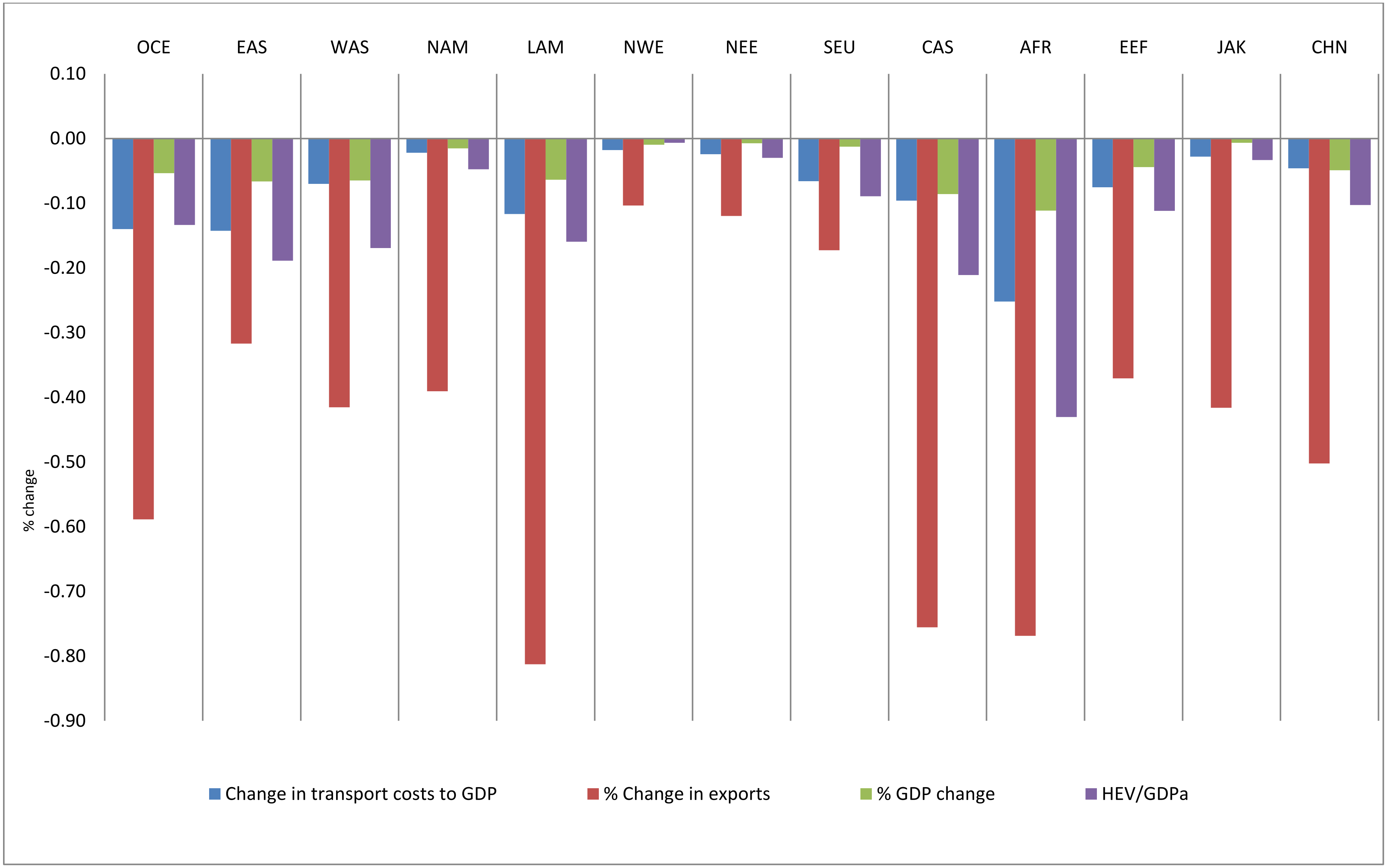
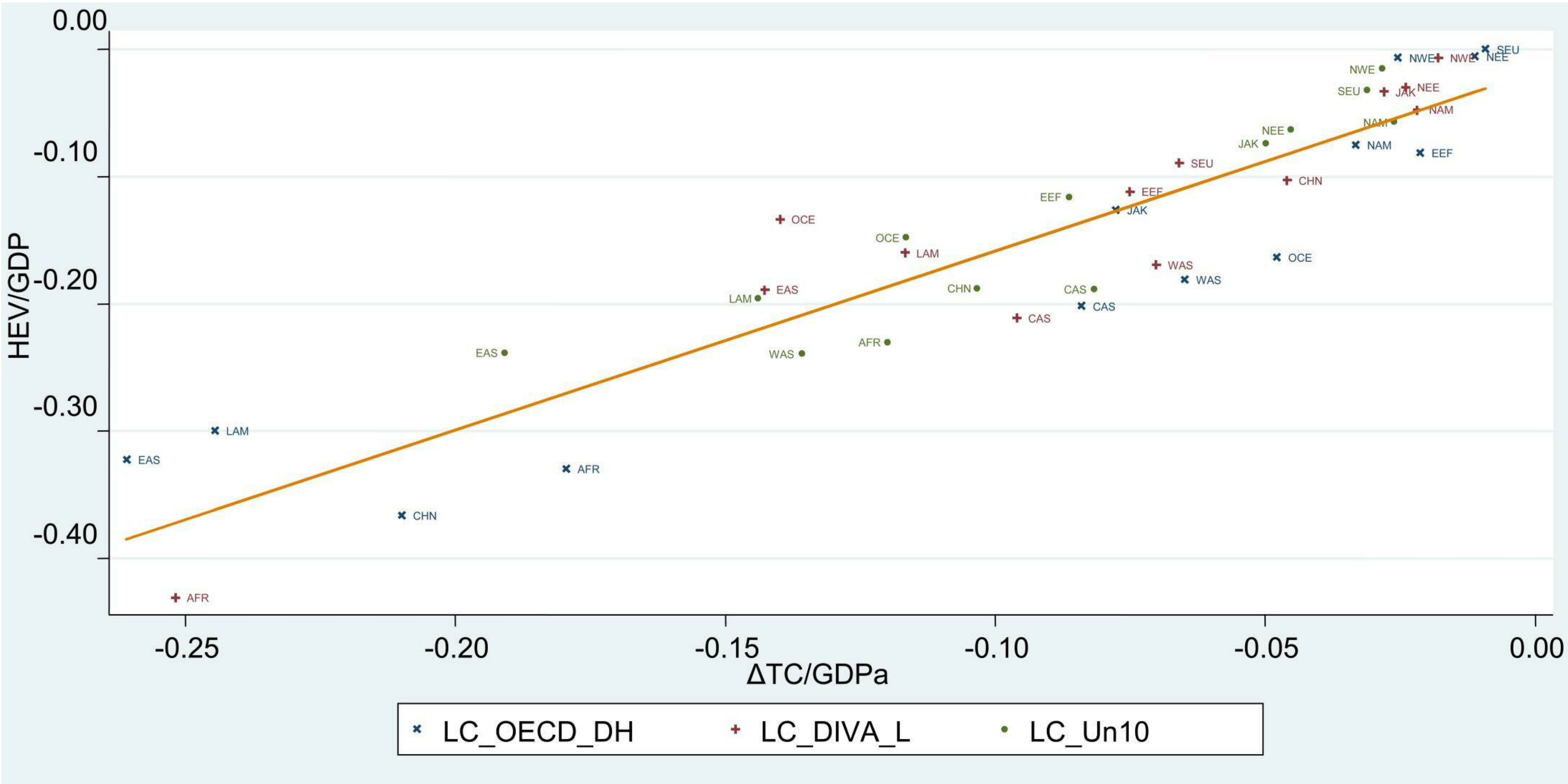


Figure 6 HEV to GDP as a function of changes in transportation prices to GDP



ΔTC/GDP : Change in transportation costs to initial GDP, HEV/GDP: Hicksian Equivalent Variation to initial GDP