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The transnational impacts of global climate change for Germany

Abridged version

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The transnational impacts of global climate change for Germany

Abridged version

by

Martin Peter, Madeleine Guyer, Dr Jürg Füssler
INFRAS AG, Zürich

In association with

Professor Birgit Bednar-Friedl, Nina Knittel, Dr Bachner Gabriel Wegener
Center for Climate and Global Change, University of Graz, Graz

Professor Reimund Schwarze
Viadrina European University, Frankfurt (Oder)

On behalf of the German Environment Agency

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Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
info@umweltbundesamt.de
Internet: www.umweltbundesamt.de

[f/umweltbundesamt.de](https://www.facebook.com/umweltbundesamt.de)

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Table of contents

Abstract	6
1 The international dimension of climate change impacts	10
2 Germany feels the impacts of climate change through foreign trade	12
3 Germany's exposed trade partners.....	15
4 Opportunities and risks through foreign trade	18
5 Quantitative model analysis and main findings	21
6 Regional and sectoral strategic directions in trade and climate policy	25
7 Direct recommendations.....	29
8 Bibliography.....	37
9 Annex.....	39

Abstract

Climate change is a global challenge. It manifests itself through changes in the frequency and intensity of extreme regional weather events and gradual changes in the climate. Just like the current coronavirus pandemic, the impacts of climate change make themselves felt in every country irrespective of their geophysical and political boundaries. The Paris Agreement therefore stipulates that adapting to climate change is to be considered as a global challenge. The international dimension of climate change adaptation has been given too little consideration to date. So far, the impacts of climate change have mostly only been observed and examined within national borders. Depending on the extent of its global integration and interaction with other vulnerable countries, a country may, however, be indirectly affected to varying degrees by the international impacts of climate change. This applies both to developed and developing countries. These international impacts of global climate change are of particular relevance to countries which are strongly interwoven with the global economy, such as Germany.

On behalf of the German Environment Agency, a research project with the title “Impact CHAIN: the impacts of global climate change on the economy and society in Germany” was commissioned to examine the potential impacts of global climate change on the German economy through foreign trade flows. The results of the project provide an overview of the potential impact chains of global climate change on the German economy. The project used a qualitative analysis to consider the influences of climate change on the German economy and then evaluated their relevance. Some impact chains were subsequently selected to be used in a global macroeconomic model that would investigate the exposure and relevance of climate change-induced disruptions. Lastly, adaptation strategies and measures were developed that would be suitable to be deployed against the most significant global effects.

The project was overseen by INFRAS AG (Dr J Füssler, M. Peter, M. Guyer) in close collaboration with partner organisations. The Wegener Center at the University of Graz (Professor B. Bednar-Friedl, N. Knittel, Dr G. Bachner) carried out the quantification and economic modelling of interdependencies. Professor M. von Unger (Atlas Environmental Law Advisory) assisted the research team with legal expertise on embedding the activities into the European financial framework. Professor R. Schwarze from Viadrina European University in Frankfurt (Oder) was responsible for integrating the measures into the EU and international policy context.

Greater overall risks due to global climate change for Germany’s imports than for exports

Germany’s ten largest trading partners, whether for imports or exports, are made up of European nations plus the USA and China. As far as climate change-related disruptions are concerned, like Germany these countries are considered to be financially comparatively resilient.

China – number one for imports and number five for exports – is one exception, however. Viewed as a whole, China is likewise one of the less climate-vulnerable countries. However, production processes in some of the country’s regions, for example along the Yangtze or Huang He rivers, are exposed to significant climate-induced risks.

In 2015, around six per cent (55 billion euros) of German imports and four per cent (approx. 50 billion euros) of its exports were spread among twelve countries or regions around the world that are considered highly climate-vulnerable. Of those countries, Brazil, India, South Africa, Vietnam and Thailand had the highest volumes of trade by a large margin.

The risks associated with imports would likely be higher for the German economy than those associated with exports. The German economy is exposed to such risks through the following impact chains, among others:

- Storms, flooding and heat will increasingly afflict buildings, production facilities and warehouses in climate-vulnerable countries. In many sectors it will be difficult to replace suppliers and production sites at short notice.
- In agriculture, climate impacts often affect large areas. Sustained periods of heat, torrential rain and powerful storms can hugely impair agricultural production and sometimes even destroy entire harvests. Large cultivation areas are required for some globally traded products, for example soya, which are only available in certain parts of the world and are therefore difficult to replace. This likewise applies to the processing of agricultural products in Germany and their subsequent export. For example, Germany exports more coffee products than any other country. Producers are consequently heavily dependent on the productivity of growing regions located abroad.
- Of all the forms of goods traffic, shipping will be particularly affected. More frequent extreme weather events and sea level rise will be a cause for concern for ports and container terminals. Germany would profit, however, if the shipping season were extended due to retreating sea ice or if the Northwest Passage were to be opened up.

The export economy is also exposed to risks. However, there are also opportunities with exports:

- Climate change will inhibit global economic growth. Such a slowdown will go hand in hand with negative effects on purchasing power and private consumption. For an export nation like Germany, this is an adverse outlook. This is because comparatively less climate-vulnerable countries such as Spain, Italy and many non-EU nations will also be affected by the economic slowdown effect of climate change.
- At the same time, the German economy could benefit from new, potentially fast-growing markets: firstly in the field of climate adaptation and disaster risk reduction, and secondly because more and more eco-friendly products will be purchased and more money invested in low carbon emission systems and technologies. This will require German companies to keep up the pace, or rather to increase their lead, in fields such as e-mobility.

Analysis of selected impact chains shows trade relations within the EU are less severely affected

As part of the Impact CHAIN project, a macroeconomic scenario analysis for Germany showed that climate-change induced disruptions that occur outside Europe have a much greater impact on the German economy than climate-change consequences that originate within Europe's boundaries. This comes down to the fact that the EU region is comparatively less severely affected by the direct impacts of climate change.

For regions outside the EU, the three modelled impact chains (changes to labour productivity, changes in agricultural yields, sea level rise including adaptation) entailed sharp declines in welfare and gross domestic product (GDP), especially in China, India, South and Southeast Asia, the Middle East and Africa.. The purchasing power of the countries in these regions declines considerably, compared with the reference development without climate change. This has extensive indirect negative impacts for Germany as a trading partner.

In the analysed climate change scenarios, Germany's imports suffered heavier losses than its exports. Depending on the sector this has a negative impact on the production chains of German companies to varying degrees. For imports, it is apparent in the modelling that as a result of climate change Germany would increasingly obtain its import goods from the EU area and less so from regions outside the EU. For exports, the modelling shows that demand abroad for services and building contracts would diminish considerably, whereas Germany would see a greater demand both within the EU and in non-EU countries for machinery and electronic devices (engineering services). It will be particularly important to preserve Germany's technological competitiveness in this sector.

The results show that Germany is considerably exposed to global climate change. On the one hand this affects the international export markets for German companies, and imports of important intermediate goods for production processes within Germany in particular on the other. The study recommends that economic operators review their strategies towards trade links and, wherever possible, seek to diversify the risks to earnings from intermediate services exposed to the impacts of climate change. It also suggests reducing significant dependencies on individual substances from countries hit hardest by climate change. As a consequence of this, the degree of globalisation in the production of goods in Germany is likely to decrease slightly. In other words more intermediate services would come from the EU and fewer from the rest of the world.

In its modelling, the study took two climate scenarios into account, considered only the international channel of influence of the trade in goods, quantified just three of the numerous impact chains and did not incorporate any extreme weather events or tipping points. The result therefore depicts a conservative minimum estimate of Germany's exposure to international climate-change induced disruptions.

Similar analysis for the United Kingdom, Switzerland and Austria confirms the conclusion of this study for Germany that the consequences of climate change through foreign trade alone are of the same size as the economic impacts of climate change within national borders.

Possible adaptation strategies and measures: diversification and adaptation support

It would be wrong to seek a general reduction in international trade relations based on these results. Such a strategy would also lead to a significant decline in welfare in Germany. Global trade and the division of labour in the production of goods and services are built on the relative strengths of every country. They also lead to an interconnectedness that is vital for global social and political stability. This stems from fundamental welfare-based considerations. Even economic modelling of trade between the various regions of the world arrives at the same conclusion. As the main contributors to global warming, industrialised nations have a key responsibility in climate change mitigation and supporting climate change adaptation in the more severely affected parts of the world.

The resilience of the German economy can be strengthened through increased diversification of global trade. This must be accompanied by targeted support for adaptation measures in the most severely affected regions of the world that are important to Germany with regard to its imports and exports and cannot easily be replaced. This includes emerging countries in South and Southeast Asia as well as China.

Based on an analysis of all the modelled impact chains, researchers recommend a targeted regional combination of trade and climate policy measures to minimise the negative effects on welfare and GDP in Germany:

1a) A strategic strengthening of German trade with regions of the world that cause minimal transnational spillover effects (esp. EU, Turkey, North America).

1b) A wider diversification of operational value chains in order to reduce dependency on individual (vulnerable) countries,

while simultaneously

2) Strategically supporting adaptation measures in regions of the world that cause particularly strong negative transnational effects on trade through climate change (esp. China, India, Southeast Asia).

The aim should be to combine strengthening trade in selected regions, a “strategic diversification of trade” and targeted support for climate change adaptation in emerging countries.

Further publications from the German Environment Agency’s Impact CHAIN project:

- Wie der Klimawandel den deutschen Außenhandel trifft, UBA-Broschüre, 12/2018. Written by Peter M., Guyer M. and Füssler J. Available online at <https://www.umweltbundesamt.de/publikationen/klimawandel-deutscher-aussenhandel>
- Folgen des globalen Klimawandels für Deutschland - Erster Teilbericht: Die Wirkungsketten in der Übersicht, UBA-Reihe Climate Change 20/2019. Written by Peter M., Guyer M. and Füssler J. Available online at <https://www.umweltbundesamt.de/publikationen/folgen-des-globalen-klimawandels-fuer-deutschland>
- Folgen des globalen Klimawandels für Deutschland - Abschlussbericht: Analysen und Politikempfehlungen UBA-Reihe Climate Change 15/2020. Written by Peter M., Guyer M., Füssler J., Bednar-Friedl B., Knittel N., Bachner G., Schwarze R. and Unger M. Available online at <https://www.umweltbundesamt.de/publikationen/folgen-des-globalen-klimawandels-fuer-deutschland-0>
- Knittel, N., Jury, M. W., Bednar-Friedl, B., Bachner, G., & Steiner, A. K. (2020). A global analysis of heat-related labour productivity losses under climate change—implications for Germany’s foreign trade. *Climatic Change*. <https://doi.org/10.1007/s10584-020-02661-1>

1 The international dimension of climate change impacts

There is no denying that in addition to slow-onset changes, climate change will change the frequency, intensity and regional occurrence of extreme weather events. Climate change affects every country in one way or another, irrespective of their political boundaries. The Paris Agreement therefore stipulates that adapting to climate change is to be considered as a global challenge. The international dimension of adapting to climate change has only been given occasional consideration to date. Germany is taking up the issue as part of the German Strategy for Adaptation to Climate Change (DAS), the first progress report of which concluded that further research is needed on this issue. This is because the impacts of climate change are usually only considered and analysed within national boundaries. Depending on the extent of global ties or interactions with vulnerable countries, countries can, however, be indirectly affected by the international consequences of climate change too. This applies both to industrialised and developing countries. These international impacts of global climate change can be of particular relevance to countries which are strongly interwoven with the German economy.

Several international channels of influence through which global climate change can affect an economy are mentioned in the literature (Kohli et al. 2019, Benzie et al. 2016; Bräuer et al. 2009; Schwank et al. 2007). For example through financial markets (exchange and capital markets), trade flows (imports and exports), biophysical influences, labour and migration (see Steineman et al. 2016), health, technology, availability of natural resources and geopolitical risks. Germany is a country with vital international trade relations, a pronounced global division of labour and extensively intertwined industrial production processes. It also places considerable value on imports (especially raw materials, foodstuffs, intermediate products) and exports (especially cars, machinery, chemical products).

Germany is considered less vulnerable to the direct impacts of climate change compared with many of its trade partners, such as the emerging countries in Asia. The consequences of climate change can, however, cause knock-on effects for the national economy in Germany itself through changes in intermediate supply chains or sales markets. In general, ignoring the spillover effects of climate change that arise through foreign trade can lead to a systematic underestimation of the risks of climate change as well as of the opportunities for Germany to adapt. Considering the consequences of international effects through the influence channel of “streams of commerce” is thus vital for Germany.

The issue has gained importance in recent years. Various studies and research projects have examined the international impacts of climate change, principally on northern and central European countries (Finland, United Kingdom, Netherlands, Norway, Germany, Switzerland (Kohli et al. 2019) and the EU). The importance of the issue is increasing for developing countries too. In general, the international dimension of climate change also holds the potential for greater cooperation both between EU member states and also between the EU and other countries (Berry et al. 2017).

On behalf of the German Environment Agency, the Impact CHAIN research project, which ran for several years, examined how Germany’s foreign trade is affected by the international impacts of climate change. The results of the project were published in Peter et al. 2018, 2019 and 2020, and Knittel et al. 2020. In order to cope with the complexity of the topic and in light of the poor availability of data, Impact CHAIN combines bottom-up approaches to identifying and quantifying potential impact chains with a comprehensive top-down approach to producing economic models of the influences of various climate scenarios on global economic ties through the use of a computable general equilibrium model.

The project was carried out under the supervision of INFRAS AG (Dr J Füssler, M. Peter, M. Guyer) in close collaboration with partner organisations. The Wegener Center at the University

of Graz (Professor B. Bednar-Friedl, N. Knittel, Dr G. Bachner) carried out the quantification and economic modelling of interdependencies. Professor M. von Unger (Atlas Environmental Law Advisory) assisted the research team with his expertise on embedding the activities into the European financial framework. Professor R. Schwarze from Viadrina European University in Frankfurt (Oder) was responsible for integrating the measures into the EU and international policy context.

2 Germany feels the impacts of climate change through foreign trade

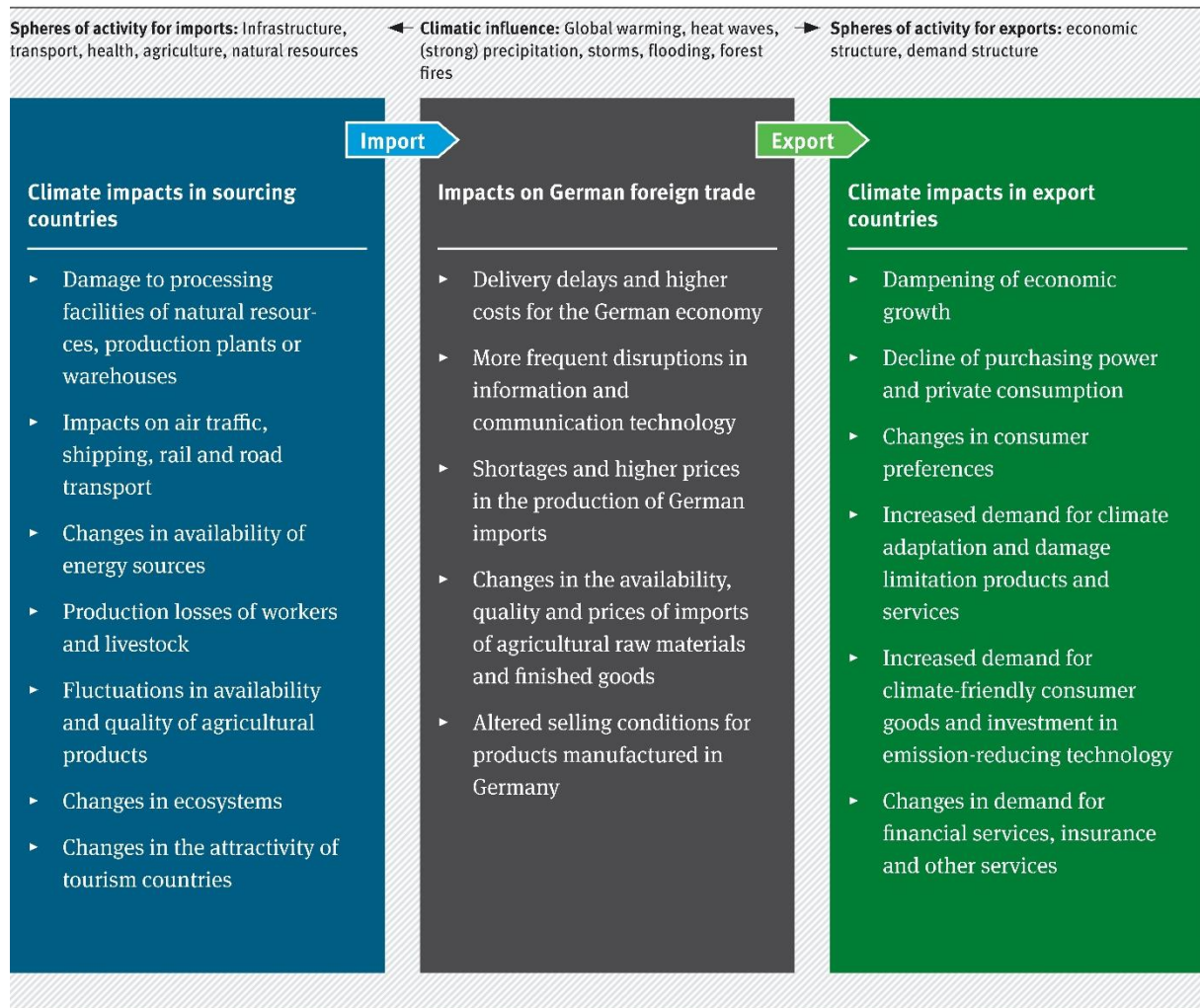
Extreme weather events such as flooding, heat waves, periods of extreme drought and forest fires will become more frequent. While these direct impacts of climate change will be increasingly perceptible even in Germany, it is admittedly less climate-vulnerable compared with other regions of the world. On the one hand, the potential for damage in Central Europe is lower in itself. Especially when compared with particularly hard-hit regions in Asia, Africa and South America. On the other hand, with its highly industrialised economy, Germany has considerably more resources with which to prepare for climate-change related risks and to recover more quickly in the event of damage.

Figure 1 explained: climatic influences (temperature, precipitation, extreme events etc.) affect natural (e.g. agricultural land, people and livestock) and material systems (e.g. buildings and infrastructure) in sourcing countries and can lead to interruptions in the production of intermediate goods that are in demand in Germany and other countries. Crop failures or diminished quality of imported agricultural products as a result of climate change have similarly negative effects on the German economy. Climatic changes can also affect modes of transport, transport routes and infrastructure either positively or negatively.

With regard to exports, climate change will hold back economic growth on a global level as measured by gross domestic product. Such a slowdown will go hand in hand with, for example, negative effects on purchasing power and private consumption. However, climatic changes also have an impact on the demand for products and capital goods. It is expected, for example, that more eco-friendly products will be purchased in the future. This will also affect the German export market.

Figure 1: Overview of impact chains

How climate change affects German foreign trade



Sources: INFRAS

Most climate impacts in sourcing and export countries can be intensified or displaced by overriding influences or global trends such as (access to) financial markets, policy environment, migration, health or technology (see box below). These overriding channels of influence can be affected by climate change, but can also, regardless of climate change, exert an often stronger influence on impact chains, than climatic influences do themselves.

Overriding channels of influence

▶ **Finance:** Climate change can have an influence on international investment, the financial sector and insurance. Notwithstanding the above, access to financial markets as well as currency and interest levels also affect impact chains.

▶ **Policy environment:** Climate policy can lead to new regulations (e.g. promotion of low-emission technologies) and policies (e.g. introduction of carbon taxes). However, the political stability and geopolitical decisions, regardless of climate change can influence the impact chains either positively or negatively and, depending on the particular ruling, even superpose climate-change aspects.

▶ **Migration:** Changes in regional climate conditions as well as shifts in vegetation zones can adversely affect the economic foundations of entire regions and cause migration flows that far

exceed any migration movement seen to date. The consequences for Germany are the subject of an ongoing debate. Climate change amplifies the existing risks in this regard.

► **Health:** Changes in climate conditions can cause diseases and impairments to both human and animal health. Health aspects are included in the analysis through various spheres (imports: people and animals; exports: pattern of demand).

► **Technology:** Developments in technology play a critical role both in adapting to climate change and in mitigation measures. However, technological progress occurs regardless of climate change and exerts considerable influence on certain impact chains.

► **Price volatility of raw materials:** Climate change can result in shortages of and consequently in an increased price volatility of raw materials. Price volatility that has no connection with climate change – caused by speculation, for example – is usually of greater importance.

3 Germany's exposed trade partners

Countries are exposed to the direct impacts of climate change to varying degrees. Exposure and vulnerability to the impacts of climate change can be illustrated using various indices. The indices contain information about the degree to which countries are affected by climate change. For example they outline expected biophysical effects brought about by changes in precipitation, droughts, heat waves and extreme weather events for individual countries and their ability to adapt to such challenges.

The Notre Dame Climate Change Index (ND-GAIN)¹ and the Germanwatch Global Climate Risk Index (CRI)² were included in the present analysis.

ND-GAIN and CRI Index

The ND-GAIN Index emerged from the Environmental Change Initiative of the University of Notre Dame. The Index was developed to support decision-makers from the public and private sectors with questions relating to climate adaptations and in identifying adaptation measures. The ND-GAIN Index shows the vulnerability of a country to climate change and also measures the readiness of that country to make effective use of private and public investment for adaptation activities. It contains 74 variables which reflect 45 core indicators (Chen et al. 2015). Germanwatch's CRI Index, conversely, concentrates on extreme weather events and the associated financial and human losses. The CRI shows how severely countries are affected by extreme weather events such as floods, storms, heat waves etc. The index examines the impacts on human life as well as direct economic losses.

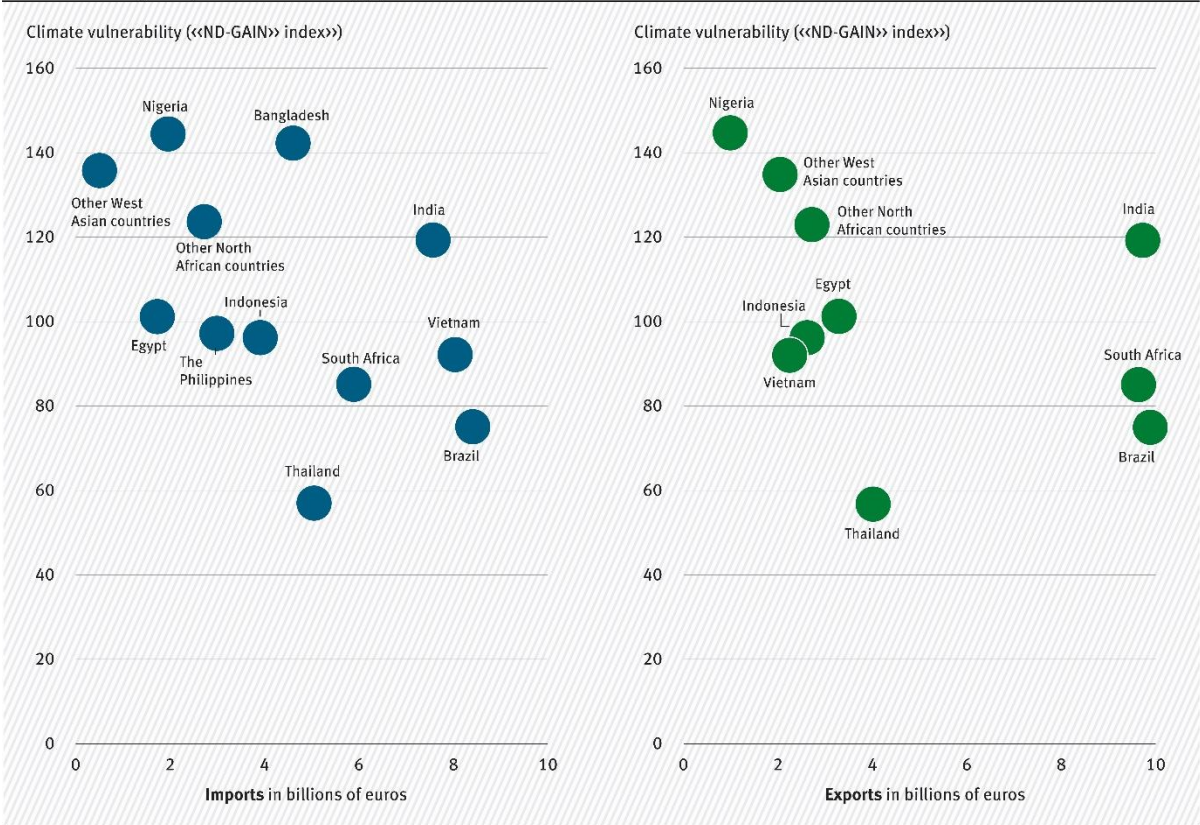
Germany's extremely vulnerable and relevant trade partners are listed below in Figure 2. Countries were deemed to be highly vulnerable if they had a ND-GAIN rank (the higher the rank, the more vulnerable the country) of 75 or more. Thailand, an extremely vulnerable country based on the analysis of the Germanwatch Global Climate Risk Index (CRI) was also included.

¹ Website of ND-GAIN: <http://index.gain.org/>

² Website of Germanwatch: <https://www.germanwatch.org/14638>

Figure 2: Highly vulnerable and relevant trade partners

Particularly exposed trading partners (2015)



Note: Trading volume (horizontal axis) and climate vulnerability (vertical axis) of Germany’s relevant trade partners for imports (left) and exports (right) in the year 2015. The trading volumes are based on data from the Federal Statistical Office (Destatis 2017). Climate vulnerability is depicted on the basis of a corresponding index: the ND-GAIN Index.

In 2015, around six per cent (55 billion euros) of German imports and four per cent (approx. 50 billion euros) of its exports were spread among twelve countries or regions³ around the world that are considered highly climate-vulnerable (see Figure 2). Of these regions and countries, Brazil, India, South Africa, Vietnam and Thailand contributed the largest trading volumes by some distance (sum of imports and exports). This does not mean that the six per cent of total imports and four per cent of exports will disappear due to impending climate change. They are however particularly exposed to potential changes. Considerable further proportions of imports and exports are likewise exposed, but not to the same high degree. Information from this descriptive and statistical analysis based on current trade data and climate change exposure indicators provides the first indications of particularly vulnerable countries/commodity groups as well as affected sectors in Germany.

The features of the ND-GAIN Index

The ND-GAIN Index assesses two aspects: vulnerability and readiness. The vulnerability score measures the exposure, sensitivity and ability to adapt to the impacts of climate change. The readiness score measures the capacity of a country to attract investment and to convert those funds into adaptation activities. In order to aggregate indicators and be able to compare countries

³ This includes Egypt, Bangladesh, Brazil, India, Indonesia, Nigeria, the Philippines, South Africa, Thailand, Vietnam in addition to other North Africa and West Asian countries.

with one another, the raw data is scaled into dimensionless values. This scaling follows a 'proximity to reference point' approach, which measures the distance of a country to an optimal point. The reference point varies depending on the indicator (0 for vulnerability aspects and 1 for readiness aspects). The aggregated score allows the countries to be ranked. A higher rank is associated with a combination of greater vulnerability and lower readiness.

The following analysis steps determined the selection of countries in Figure 2.. First of all, the countries of particular importance for Germany from a foreign trade perspective were identified, as well as those which cannot be examined more closely over the course of the project due to their having negligible or substitutable import or export links. The initial selection of countries includes 10 EU states, which make up 81% of EU imports, and 10 EU states on the export side, which account for 82% of all EU exports. Among the non-EU countries, 33 import countries accounting for 92% of the total non-EU imports were selected, and 33 export countries that receive 93% of all of Germany's exports to non-EU states. In the next step, the trading volumes from this initial selection of countries were blended with the ranks from the ND-GAIN Index. This allowed conclusions to be drawn that combined importance and vulnerability. The same process was completed with the CRI Index. The selection from the ND-GAIN analysis was then supplemented by the three most vulnerable countries from the CRI Index. The analysis with the CRI Index is important in this respect because focussing on extreme weather events for the impact chains of trade flows is crucial. The most vulnerable countries (with a ND-GAIN rank of 75 or higher) were incorporated from this selection of countries for the purpose of analysing the impact chains. Cross-referencing them with trading volumes produces a selection of countries that are simultaneously severely affected by climate change and also important for Germany's foreign trade. These countries are therefore also important for the German economy. This selection is represented in Figure 2. There are other countries, however, that are relevant to Germany as foreign trade partners and will be significantly (but not extremely) affected by climate change. This group includes China, Mexico, Saudi Arabia, Turkey, Malaysia, the United Arab Emirates, Russia, Italy and Spain (countries with a ND-GAIN rank lower than 75).

Even if the analysis of relevant and highly vulnerable countries suggests that Germany's other trading partners are not important, it would be incorrect to simply invert this argument. The example of China in particular demonstrates that very severe climate impacts with dramatic consequences on production processes (Willner 2018) and therefore on Germany's supply chains, can occur in China too.. Production must be suspended if a factory is flooded following heavy rain, which leads to financial losses not only in China but – through trade relations – in Germany too. Imported goods from China, e.g. data processing devices and electronic equipment, are examples of such exposed import commodities. The vulnerability of China is considerably lower than, for example, Brazil, Vietnam and India according to the ND-GAIN Index.

4 Opportunities and risks through foreign trade

Importers and producers in Germany incur higher costs when imports to Germany are delayed or do not arrive at all and can no longer be delivered in the desired quantity and quality. Products made by affected German producers for the domestic market and export become more expensive, cannot be delivered on schedule or only in diminished quality. Conversely, the better the import system works, the more successful the German economy will be. The question is, what are the most important impact chains through which climate change will influence German import activities in the coming decades?

In the previous chapter, Germany’s trading partners that are exposed to climate change were identified. Based on the links with these trade partners, the potential economic risks and opportunities for Germany were then evaluated along the 23 chains of impact mentioned in Chapter 2. The classification of the impact chains was developed by the project team. This aggregation was preceded by an exploratory literature analysis of climate impacts abroad in relation to Germany’s trade channels. It should be noted that this overview does not represent a definitive description of the issue or an evaluation thereof. The overview provides a basis for discussion of the issue in Germany and a starting point for the analysis in the research project.

An assessment of the economic risks and opportunities for Germany was developed for each chain of effect. This assessment comprises the relevance of climate impacts, the economic significance of the chain of effect and substitution possibilities. The scoring is based on assessments drawn from interviews with experts and discussions within the project team and with the client as well as from literature research.

The results show that greater economic risks are expected on the import side (see Figure 3) than on the export side (Figure 4).

Figure 3: The economic risks and opportunities of imports (I)

	No risk	Low risk	Medium risk	High risk
Opportunities High				
Opportunities Medium			Energy sources 10	Shipping traffic 2 Agricultural products 3
Opportunities Low		Tourism	Forestry systems 9	
None Opportunities	Livestock	Road transport Aquatic systems	Infrastructure 4 Construction & raw materials 5 Labour force 6 Air traffic 7 Rail traffic 8	Buildings, production facilities, warehouses 1

Assessment of the risks and opportunities that climate change brings to imports into Germany through various impact chains. The most important impact chains, for which it is assumed there will be medium to high risks and/or opportunities, will be outlined in the present paper. Sources: INFRAS

On the **import side**, it is to be expected that the international consequences of climate change will have a negative impact on the German economy. This is primarily due to damages and

production losses as a result of extreme weather events for manufacturing companies based in other parts of the world. Damages and production losses in (intermediate) goods result in delays in delivery and consequently rising production costs in Germany. The availability of certain intermediate goods that cannot easily be substituted in the German economy will worsen, which may inhibit Germany’s production potential. This will have negative consequences for the German national economy. In agricultural production, climate impacts often affect large areas. Sustained periods of heat, torrential rain events and powerful storms can hugely impair agricultural production and sometimes even destroy entire harvests. Very large cultivation areas are required for some globally traded products, for example soya, which are only available in certain regions of the world. Agricultural products are also processed in and exported from Germany. For example, Germany exports more coffee products than any other country. Producers are consequently heavily dependent on the productivity of growing regions located abroad. Furthermore, due to the fact that there are extensive ties between different sectors, the international impacts of climate change on modes of transport, transport routes and infrastructure are consistently assessed as considerable (particularly in shipping). More frequent extreme weather events and sea level rise will be a cause for concern for ports and container terminals. Germany would also benefit, however, if the shipping season were extended due to retreating sea ice or if the Northwest Passage could be opened up.

The assessment of the economic risks and opportunities for German exports is presented in the following Figure 4. There are more opportunities in exports, but the risks are also high.

Figure 4: the economic risks and opportunities of exports (E)

Risks and opportunities in exports (E)				
	No risk	Low risk	Medium risk	High risk
Opportunities High	Investments Climate adaptation 4			Climate-friendly Consumer goods 3 Investments Climate change mitigation 3
Opportunities Medium		Preferences for Foods 5		
Opportunities Low		Consumer preferences Insurance services Other services	Financial services 6	
None Opportunities				Economic growth 1 Purchasing power, consumption 2

Assessment of the risks and opportunities that climate change brings to exports out of Germany through various impact chains. The most important impact chains, for which it is assumed there will be medium to high risks and/or opportunities, will be outlined in the present paper. Sources: INFRAS

On the **export side**, the impacts resulting from changes to economic structures in severely climate-exposed economies that create demand for goods and services from Germany are of particular relevance. Climatic influences can affect the economic strength of a country through various channels. Poorer countries with lower resilience to an increase in, for example, extreme weather events or gradual changes are more likely to experience a slowdown in GDP growth and a loss of purchasing power. A decline in GDP also entails a decrease in the level of investment and can have a negative impact on Germany’s export industry through corresponding ties. This reduced purchasing power in other countries means economic risks are predominantly expected

outside Europe. There may by all means even be comparative benefits in European countries. It is also anticipated that the impacts arising from an altered demand structure for goods from Germany in other parts of the world will create opportunities. This particularly relates to increased demand from regions of the world that are severely affected by climate change for investment in climate adaptations and damage containment, as well as changes in demand for low-carbon consumer goods and investment in emission-lowering technologies. Where the latter is concerned, economic risks for Germany cannot be excluded if it does not invest in its competitiveness in these new technologies at the right time.

Interviews with company representatives from various industries make it clear that only certain companies and sectors already have expertise about international impact chains and how global climate change can affect German companies and households. Companies from the wholesale and retail (coffee) sectors and the insurance industry that are involved in foreign trade are undoubtedly among those who are more acutely aware of the issue. In other sectors, however, there is little knowledge of the possible risks and opportunities in the supply chains. Even the transport sector (especially shipping) seems only to be moderately aware of the issue. Companies who are already expecting opportunities to arise from changing demand structures abroad for German products as a result of the effects of global climate change (such as manufacturers of adaptation products, e.g. water technologies), are already somewhat more aware of the issue at hand.

5 Quantitative model analysis and main findings

In the Impact CHAIN project, we applied a macroeconomic model to quantitatively assessing the impacts of climate change that are transferred to Germany through international trade flows. . . This allows depicting the sector-specific impacts of climate change in the source countries and analysing economic repercussions on Germany. The aim of the model-based impact assessment is to provide an overview of the potential impacts of global climate change on Germany's foreign trade and the economy as a whole. As part of the project, impacts were examined in greater detail where modelled results for all countries and various climate scenarios had previously been validated in international comparison projects. The following areas or impact chains were assessed:

- ▶ Sea level rise
- ▶ Heat-related changes in labour productivity
- ▶ Changes in agricultural yields
- ▶ Changes in GDP and purchasing power

These impacts affect both Germany's imports and exports and can be more or less pronounced depending on the sector of the economy (from agriculture to industry to services). The timescale of the analysis is a 30 year period around 2050 (in order to reflect a climate period). Two socio-economic scenarios (SSP2 and SSP3) as well as two emission scenarios (RCP4.5 and RCP8.5) were assessed. The Shared Socioeconomic Pathway 2 (SSP2) is referred to as a 'middle of the road' scenario because it depicts medium challenges for mitigation and adaptation. SSP3, on the other hand, represents a fragmented world with large challenges for mitigation and adaptation (O'Neill et al. 2014). The Representative Concentration Pathway (RCP) 4.5 corresponds to an emissions scenario with an average global temperature rise of 1.8°C by the end of the 21st century relative to 1986-2005 or 2.4°C relative to pre-industrial times. RCP 8.5 is characterised by higher greenhouse gas emissions with an average global temperature rise of around 3.7°C relative to 1986-2005, or 4.3°C relative to pre-industrial times (Collins et al. 2013).

The COIN-INT model is a global multi-regional and multi-sectoral Computable General Equilibrium model (CGE). Multi-regional, global CGE models are based on a consistent set of input-output tables and international trade data, consumer data and public budget data. They allow for a detailed evaluation of the impacts of climate change on sectors, private households and the public budget; in other words, it allows for an overall economic evaluation (see e.g. OECD 2015). There is a representative household for each region that is endowed with production factors such as labour, capital and natural resources (land, fossil resources). These factors and resources are supplied to the markets and generate income for the private household (factor incomes and resource rents). Income is moreover generated for the public household through taxation on production and consumption. The income is distributed across consumption based on specific consumption functions (differentiated between a private and a public budget) and investments (= final demand). Every business sector combines factors and intermediate goods and services (i.e. outputs from other sectors) based on sector-specific production functions. Some sectors are reliant on land or other natural resources in their production processes (e.g. land for the agricultural sector, or fossil resources for the oil and gas sector). We rely on the Armington assumption with regard to international trade. This means that imports and goods produced domestically are imperfect substitutes and can therefore only be substituted to a certain extent according to sector-specific elasticities (Hertel et al. 2007). Changes in trade flows are consequently triggered by regional import demand and by adjustments in relative international prices (terms of trade). Furthermore, the trade balance is

(nominally) fixed, which means the ratio of trade balance to GDP is kept constant at the ratio of the reference year.

The model describes the economy as a steady state of annual monetary flows between agents and sectors, in which all markets are cleared (= general equilibrium). In order to quantify the impacts of climate change on a macroeconomic level, this equilibrium is disrupted (e.g. by altered production conditions), which leads to quantity and price adjustments, until a new equilibrium is reached where all markets are cleared again. Then, the initial equilibrium is compared to the newly established equilibrium and the sectoral and macroeconomic effects of international climate impacts become visible. As the underlying input-output structure implies that all sectors in all regions are interconnected either on the supply or demand side, direct effects in one sector or region may spill over to other sectors and other regions. While there are some studies that have already investigated certain climate change impacts on Germany's foreign trade, this is the first study that analyses the consequences of global climate change for Germany within a consistent macroeconomic framework. The results of the study provide an initial impression of how Germany's foreign trade and thus its domestic economy could be affected by various climatic impacts by the middle of the century. Although the present study provides concrete figures about the impacts, any interpretation should focus on the effects and their interdependencies rather than on the absolute magnitude.

Based on the impact chains that were assessed, the following conclusions can be drawn:

- ▶ **The three modelled impact chains, 'Sea Level Rise (including adaptations)', 'Changes in Labour Productivity' and 'Changes in Agricultural Yields', show negative economic effects across the world.** Southeast Asia, China, India, Africa and oil-exporting countries are particularly severely affected with GDP losses in 2050 of up to -4% in Southeast Asia and welfare losses⁴ of up to -8% in India, relative to a scenario without climate change. Overall economic losses are to a large extent driven by heat-related labour productivity losses. Based on the underlying agricultural models, decreases in agricultural yields cause comparably smaller losses. According to the climate and biophysical models, some regions may even see positive effects. As a result of rising sea levels, negative effects occur in every model region.. These effects are however relatively small due to the assumption of active adaptation measures (reinforcement of protective structures).
- ▶ **Germany's foreign trade flows are subject to shifting effects on both the imports and export side.** On the imports side, trade with other EU regions is strengthened, while trade with regions outside the EU decreases. These effects can be traced back to the fact that EU regions are less severely affected by the direct impacts of climate change compared with the rest of the world. Shifts in the sectoral structure of German imports can be observed particularly in sectors such as machinery and electronic equipment, the foodstuffs, textiles and timber industries as well as the chemical industry, refined crude oil products, processed iron and steel. Due to climate change these sectors will by 2050 increasingly source their materials from other EU countries (overall +0.4%) and to a lesser degree from regions outside the EU (overall -1.4%).. Overall, Germany's imports will decrease by -0.4%. On the exports side, Germany may be able to slightly increase its foreign trade volume. This leads to a small increase in export surpluses as Germany's economy is less negatively affected by the

⁴ Household purchasing power was used in the model to measure welfare.

direct impacts of climate change and is able to preserve its structural competitive advantages in the industrial sector. With respect to its sectoral structure, Germany's exports in sectors such as machinery and electronic equipment, the foodstuffs, textiles and timber industries as well as the chemical industry are slightly higher (overall +0.1%) in a scenario with climate change as compared to the level in a scenario without climate change.

- ▶ **The overall effect on the German economy is negative.** The global consequences of climate change cause a decrease in Germany's GDP of the order of between 0.01% and 0.35% p.a., and welfare losses of between 0.11% and 0.36% p.a. (in 2050, depending on climatic and socio-economic developments and relative to a scenario without climate change). Thus, the German economy will be impaired by the impacts of climate change that occur beyond Germany's borders, even if less profoundly than other regions of the world. Generally speaking, household purchasing power (as a measure of welfare) will decline more strongly than GDP. This is because expenditure on repair activities and restoration up to the initial situation contribute positively to GDP, but do not increase the welfare of society.
- ▶ **The economic costs of global climate change for Germany largely arise in regions outside the EU, which then spill over to Germany through international trade.** If we assume (in a hypothetical scenario) that climate change only occurs in regions outside the EU and compare the results with a scenario in which climate change occurs all over the world, the differences in the impacts on Germany's GDP and welfare are only marginal and remain negative overall. It can thus be concluded that the negative indirect consequences for Germany's economy for the three modelled impact chains are largely driven by impacts outside the EU. Based on the modelling, climate change that occurs within the EU has considerably less influence on the German economy than indirect effects that originate in regions outside the EU.
- ▶ **Adaptation has a strong influence on economic effects.** It became clear that adaptation has a pronounced positive influence on indicators such as GDP and welfare. In the scenario without adaptation, the most severely affected non-European regions experienced negative effects for both indicators that were two to three times stronger than in the scenario with adaptation. In such a case, Germany's foreign trade would react with an even greater shift from non-EU to EU trade partners. The welfare effect without any assumed adaptation to cope with sea level rise is considerably higher for Germany than with adaptation (-0.3% compared with -0.1%).
- ▶ **Impacts may escalate significantly by the end of the century.** While the economic effects up to the end of the century (2100) were not quantified, the biophysical impacts for the three impact chains are expected to rise significantly by the end of the century. Especially the effects of sea level rise see a dramatic increase in the second half of the century.. The same applies for the heat-related decline in labour productivity. The effects of climate-change induced changes in agricultural yields are more pronounced in the second half of the century too, although the various models produced differing effect directions for some regions. This is due to, among other things, uncertainty regarding regional changes in precipitation.

As part of this research project, a scenario analysis for Germany showed that the impacts of climate change beyond Europe's boundaries will affect Germany's national economy more profoundly through global trade than the impacts of climate change that arise within Europe. This result can be traced back to the fact that, in comparison with the rest of the world, EU regions are less severely affected by the direct consequences of climate change for the considered impact chains. Similar assessments for the United Kingdom, Switzerland and Austria confirm the conclusion of this study for Germany that the consequences of climate change through foreign trade alone are at least just as important as the economic impacts of climate change within national borders.

6 Regional and sectoral strategic directions in trade and climate policy

Figure 5 illustrates the losses in GDP and welfare in the model regions differentiated with respect to EU and non-EU by 2050, compared with the reference development without climate change, based on the modelling of the three considered impact chains.

Figure 5: Changes in GDP and welfare by 2050



Changes in GDP and welfare by the year 2050 as a result of the interaction of the impact chains sea level rise, labour productivity change and changes in agricultural yields, for RCP4.5 in comparison with the base scenario (SSP2); climate model used: HadGEM2-ES; climate period 2050 (Ø2036-2065); see Table 1 in appendix for region abbreviations
 Source: Wegener Center, University of Graz

The negative economic effects in the EU regions are significantly lower than in regions outside the EU, where declines in GDP and welfare can become quite extreme. This result suggests that one element of a strategy to increase resilience to the indirect consequences of global climate change consists of focussing Germany’s trade relations on the EU area.

For regions outside the EU, particularly in China, India, South and Southeast Asia, the Middle East and Africa (including Tunisia), the three impact chains included in the model analysis induce sharp declines in GDP and welfare. The purchasing power in these regions declines considerably compared with the reference scenario, with extensive indirect consequences for Germany as a trading partner.

However, the transnational impacts of global climate change cannot be cushioned by a general reduction in international trade relations. Such a strategy could also lead to a significant decline in welfare for Germany. Global trade and the division of labour in the production of goods and

services are built on the relative strengths of every country. They also create an interconnectedness that is vital for a global social and political stability.

The resilience of the German economy can be improved through greater diversification, in other words by restructuring global trade relations. This must be accompanied by targeted support for adaptation measures in the severely affected regions of the world that are important to Germany with regard to supplier and sales markets and which cannot be replaced easily. This includes emerging countries in South and Southeast Asia as well as China. These observations and an analysis of all three impact chains (allowing for the assumed adaptation measures with regard to sea level rise) would be followed by a targeted regional combination of trade and climate-policy measures aimed at minimising the negative transnational effects on welfare and GDP in Germany:

1a) A strategic reinforcement of German trade with regions of the world that cause minimal spillover effects (esp. EU, Turkey, North America).

1b) A wider diversification of international supply chains in order to reduce dependency on individual (vulnerable) countries,

while simultaneously

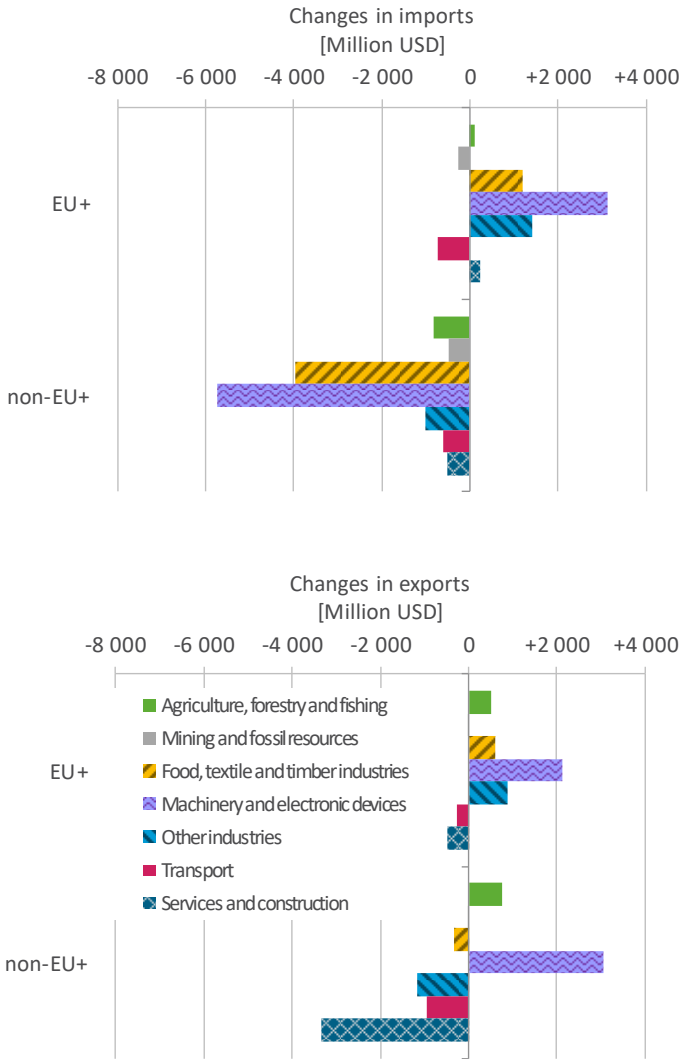
2) Strategically supporting adaptation measures in regions of the world that cause particularly strong negative transnational spillover effects on trade through climate change (esp. China, India, Southeast Asia) in the context of a German “foreign climate policy”. As the main contributors to global warming, industrialised nations have a key responsibility in supporting climate change mitigation and adaptation in the more severely affected regions of the world.

Conclusions from the region-by-region assessment

The aim should be a combination of strengthening trade with selected regions – a “strategic diversification of trade” – and targeted support for climate change adaptation in emerging countries.

Figure 6 shows how the sectoral structure of Germany’s imports and exports, again differentiated with respect to regions within the EU and outside the EU, will change by 2050 compared with the reference development without climate change..

Figure 6: Changes in Germany’s imports and exports by 2050 as a result of the interaction of the impact chains of sea level rise, labour productivity change and changes in agricultural yields



Changes in Germany’s imports (top chart) and exports (bottom chart) of US\$ 2011 by the year 2050 as a result of the interaction of the impact chains sea level rise, labour productivity change and changes in agricultural yields for RCP4.5 in comparison with the base scenario (SSP2); climate model used: HadGEM2-ES; climate period 2050 (Ø2036-2065); see Table 2 in appendix for a detailed description of the sector groups
 Source: Wegener Center, University of Graz

The overall picture suggests that Germany’s imports are affected more severely than its exports. Depending on the sector, this can negatively affect the production chains of German companies to varying degrees. For imports, Germany would as a result of climate change increasingly obtain its import goods from the EU area and less so from regions outside the EU. For exports, the demand abroad for services and construction work would diminish considerably, whereas Germany would see a greater demand both within the EU and in non-EU countries for machinery and electronic equipment (engineering services). It will be particularly important to preserve Germany’s technological competitiveness in these sectors in order to minimise the losses in welfare and to maintain production in Germany.

The results show that Germany is tangibly exposed to global climate change. This affects the international export markets for German companies, and especially imports of important

intermediate goods for production processes within Germany. The results of the study may prompt economic operators to review their strategies towards trade links and, wherever possible, seek to diversify the risks stemming from intermediate services that are exposed to the impacts of climate change. They may also reduce significant dependencies on individual materials from countries hit hardest by climate change. As a consequence, the degree of globalisation in the production of goods in Germany is likely to decrease slightly - in other words more intermediate services would come from the EU and fewer from the rest of the world.

The analysis of the three impact chains would be closely followed by a targeted sectoral combination of trade and climate policy measures aimed at minimising the negative transnational effects on welfare and GDP in Germany:

1) Support and strategic strengthening of the trade framework for machinery and electronic products, a traditional strength of German foreign trade, in the event of insufficient focus among businesses on the long-term challenges of climate change in technology development,

while simultaneously

2) Strategically supporting adaptation measures aimed at stabilising the demand for services, construction and other industrial goods (excluding the machinery and electronics sector) in non-EU countries.

Conclusions from the sector-by-sector assessment

The objective should be a combination of “strengthening strengths” (in sectoral trade policy) and “reducing industry sales losses” (by supporting climate change adaptation and the adaptation capacity of non-EU countries).

7 Direct recommendations

The following recommendations for adaptation measures can be derived from the analysis and the incorporation of the Impact CHAIN project into the challenges that climate change presents for Germany. The analysis reveals that the international impacts of climate change pose relevant challenges for Germany's trade activities. Firstly, this means that companies involved in the trade of intermediate and/or export goods are faced with challenges. Some of the recommendations relate to company level. The extent to which the challenges create a need for government action depends on whether the challenges can be interpreted as market failures, or whether the required speed of adaptation and the necessary planning horizon exceed the timescales that businesses normally work to. If, in the event of a market failure, better results are to be expected following government intervention, then government intervention is advisable (with a focus on the federal level). These recommendations for the state sector will be laid out below.

The recommendations are essentially divided into measures that predominantly concern the public sector (a) and those that target businesses (b). For the latter, a distinction will be made between measures that businesses should implement on their own initiative (b1) and those that are still aimed at companies but which should be implemented through governmental support (b2). Policy recommendations that should be developed on an international level in order to inform Germany's contribution to negotiating processes (c) will also be presented.

a) National policy

- ▶ Based on the analysis, the main recommendation of this study is **to combine trade and climate policy measures in a targeted manner**. The transnational impacts of global climate change cannot be absorbed, however, by a general reduction in international trade relations. Such a strategy would also lead to a significant decline in welfare in Germany. Global trade and the division of labour in the production of goods and services are built on the relative strengths of every country. They also lead to an interconnectedness that is vital for global social and political stability. Active and **varied trade relations** are therefore still a means of risk diversification. It is consequently recommended not simply to reduce the amount of trade but to diversify it. Foreexample, to source certain intermediate services from more than just a single country wherever possible and to be mindful at all times to also incorporate potential substitutive goods. This increases the responsiveness of German businesses in sourcing intermediate services from the rest of the world if a product is no longer available or a region is no longer able to act as a supplier due to climate change and if delays are otherwise imminent.

The assorted measures described below should as a matter of principle be implemented on the basis of social welfare considerations and should not primarily focus on the impacts on trade balances. It is not a question of consciously reducing global trade or, conversely, striving to achieve maximum connectivity between countries, but of a healthy and resilient diversification in light of gradual changes to the climate and increasing weather extremes.

- ▶ The quantitative analysis of the financial impacts shows that Europe in general and Germany in particular will be less negatively affected in comparison with some non-European regions. Climate change will result in a displacement effect of trade from non-EU to EU countries and an improvement in Germany's competitiveness (in terms of trade). It is therefore

recommended to strengthen the EU+ further in the future and to **expand economic relations** with the EU+ (e.g. customs agreements with Turkey or other comparatively less vulnerable countries in the region). It would be ideal from an economic viewpoint to combine these efforts with achieving climate change mitigation goals and Sustainable Development Goals (SDGs).

- ▶ Once the risks have been identified, it is vital to break down the significance of those risks into individual sectors/companies. Standardising the risk assessment is seen as a matter of national government policy. This involves identifying and **publicising financial climate risks**. One task of the G20's FSB Task Force⁵ will be to promote the voluntary publication of companies' climate risks in regular company reporting. This disclosure is of increasing interest to insurance firms, investors and other capital market players too. The European Commission presented precise rules for "sustainable financial products" in March 2018 (DG FISMA 2018). These rules are an important supporting political instrument in creating a regulatory framework for increased transparency and better measurability in this fast-growing segment of the capital market.
- ▶ On a national level it is recommended to focus on the **opportunities** that arise and to make positive use of new trade benefits that emerge, principally with regard to exports (terms of trade). Lühr et al. (2014, 42) used company surveys to identify the following strategic pathways for businesses: 1) climate-proof product development in conjunction with research institutions and universities, 2) new and adapted existing technical regulations and standards to improve "climate robustness"⁶ and 3) the raising of awareness of climate change among customers. Government funded climate change information platforms, or rather connections with proven platforms managed by the EU and other bodies (e.g. Climate-ADAPT, Climate-KIC) can make an important contribution.
- ▶ The analysis shows that the regions of Southeast Asia, China, India, Africa and oil-exporting countries are particularly adversely affected by the impacts of climate change. It is therefore appropriate to **support targeted adaptation measures in emerging countries** in order to strengthen the resilience of imports and exports. As the main contributors to global warming, industrialised nations have a key responsibility in supporting climate change mitigation and adaptation in the more severely affected parts of the world. Environmental regulations, or rather climate policies, can be suitable instruments for aligning international climate and trade agreements (cf. Dröge and Schernuit 2018, Schloeman et al., 2016). Climate and environmental regulations covering the allocation of funds by development banks, which are today already widespread, (cf. Di Leva, 2015) can provide orientation on this matter. If Germany can retain its current competitiveness in high value-creating goods (e.g. in the high-tech sector), any negative international impacts of climate change through trade channels can be absorbed. This competitive edge depends on, for example, the scope of research and development, entrepreneurial frameworks, the quality of education and the

⁵ The Task Force on Climate-Related Financial Disclosures (TCFD) was set up in 2015 by the Financial Stability Board (FSB) of the G20 in order to develop a consistent climate-related publication of financial risks, which will then be used by companies when they make information available to investors, credit providers, insurers and other interest groups. Cf. <https://www.fsb-tcfd.org/>.

⁶ The current ISO 1409x standards, the ISO Guide 84 and other projects on a European level (CEN) could be the connecting factors for adaptive management. Cf. i.a. <https://www.iso.org/committee/546318.html>

innovative capacity of the companies involved. Should Germany's competitiveness in this field diminish in the future, the risks of global climate change would be considerably greater for Germany and there would be fewer opportunities.

- ▶ On a national level, it is recommended to **expand support for exports** based on their existing strengths. In the event of a market failure (information asymmetry, short-term vision of companies in investment planning, system risks), the export sectors that can already hold their ground and will continue to do so, such as the machinery and electronic devices sector, should be strengthened. Whether public sector support through industrial policies is needed is still to be discussed. Given that the timescales of the foreseeable challenges exceed the planning horizons for businesses to a certain extent, it may be more meaningful to raise awareness in individual technology sectors, perhaps as far as providing temporary R&D support, and to encourage networking between applied sciences and businesses. Government initiatives that promote climate services should be developed further towards potential adaptation strategies for transnational effects. It would also be important for projects that are not obviously climate-sensitive to make more allowances for climatic risks (e.g. more frequent extreme weather events, temperature rises etc.). It would moreover be advisable, for example, to promote specific investments that focus on adaptation along with export credit guarantees. There must be binding requirements for export promotion in every sector. These must in turn be adopted by the administration as a result of political discussions. Collaboration between environmental and economics departments appears to be vital. As part of the German Strategy for Adaptation to Climate Change (DAS), efforts among business circles to incorporate the issue of climate change in the promotion of foreign trade could be communicated more proactively.
- ▶ We recommend that measures are formulated step-by-step based on increasingly robust results. It will be vital to have regular **monitoring of the data situation concerning the development of companies that are reliant on imports but strong on exports in areas of the world that will be potentially the hardest hit by climate change**. It is also very important for the state sector to **actively follow** any further **scientific advances** and the **latest research** in this relatively new field of research and adapt its strategy to the latest findings.

b1) Recommendations for businesses

- ▶ Where climate change is concerned, it is recommended to strengthen **strategic risk management** as well as **operational risk management**. The issue must be present on a strategic level, which also means that a Risk Manager, for example, should be taught about the issue. It does not appear to be expedient to only raise awareness in sustainability departments. On a strategic level, measures to disclose financial climate risks should be supported and the costs thereof borne by the private sector (e.g. TCFD or CDP). One specific private sector initiative related to the topic is the CDP Supply Chain Report of 2017, which promotes the public disclosure of climate risks (with regard to international interconnectedness).

- ▶ On an operational level, the recommended measures comprise activities that should be covered as part of business risk management. These include, for example, systematically analysing risks and risk management systems, **diversification** of sourcing and sales markets or promoting the **substitution** of intermediate goods. Furthermore, the **diversification** of supply chains or business cooperation in the procurement of intermediate inputs from abroad are instruments that can increase resilience and should continue to be promoted.
- ▶ **Insurance solutions** (e.g. climate risk insurance, development of business interruption insurance, technology insurance) will also gain importance and should be promoted and supported within a political framework. The Federal Environment Agency's "Climate Risk Management 2050"⁷ network and the "Climate Check"⁸ initiative sponsored by the Federal Ministry for Economic Affairs and Energy are current examples of the support given to companies with drawing up risk strategies that cover the entire national and international value creation chain.
- ▶ As with the national measures, business measures should also be oriented to support the **resilience of sourcing markets**. The coffee industry can be seen as a pioneer in this regard. It aims to increase the resilience of coffee plants to the effects of climate change through its *coffee&climate* industry initiative and thereby sustain or boost the quality and quantity of coffee production. Such initiatives could also be adapted by other industries.
- ▶ Just like within the national measures, businesses should try to make the most of the opportunities that arise from changing sales conditions. Numerous examples from the construction, engineering, chemical and pharmaceutical industries are provided by Luhr et al. (2014): levee construction and coastal protection measures (e.g. installation of flood walls and sheet piles, groynes and floodgates) offer an attractive market potential for specialised companies in Germany as well as forward-looking technologies for wastewater treatment. In the conditions created by increasing water scarcity, water-saving agricultural machinery (e.g. drip irrigation systems) and transportation vehicles with a low draught offer market opportunities for the engineering industry.. Heat-resistant and drought-resistant seeds as well as new materials for insulating facades and roofs open up new global sales opportunities for the chemical industry and reduce the heat and water-induced losses in labour productivity.

b2) Government-supported measures focussing on companies

- ▶ In general, raising awareness of the issue of climate change should be promoted at a company level. It is worthwhile to illustrate its effects. The issue is still not widely embraced in many sectors. It is expedient to draw on examples of best practice here (e.g. from the

⁷ <https://www.umweltbundesamt.de/service/termine/netzwerk-klimarisikomanagement-2050-umgang>

⁸ <https://www.bmwi.de/Redaktion/DE/Downloads/klimacheck-tool.html>

coffee industry or the insurance sector). Different approaches will be required, however, for smaller and medium-sized companies and for large companies..

- ▶ It is also recommended to expand the **scientific data basis** for this issue and to better identify the global risks for companies. There are, for example, initial computer models that project the future cultivation conditions for coffee. These are valuable first steps in raising awareness among various stakeholders and should be developed further. Action is also required in modelling the business impacts for German companies. It is also vital to continue assessing trade data for supply chains. So that companies can align their practices accordingly, highlighting risks and trade options would be conceivable through comparative analysis (best in class approach). Such analysis can be supported by, for example, the EU-funded Climate-KIC initiative (EIT 2019) and by business associations.
- ▶ In principle, the **identification and illustration of climate risks** for private entities (households and companies) can be seen as a systemic risk that transcends businesses and is thus a government responsibility (Renn 2014). Private companies have little incentive to make this information available because elements of market failure are present on the market: a) differences between time frames that are relevant to businesses (survive on the market) and the climate change related time spans of economic activities; b) problems with merit goods - private actors expect less of themselves than would be desirable from an economic viewpoint; c) danger of free riding, which is why companies do not process information that could then be used free of charge by other parties. These aspects of market failure make government action advisable. The public sector could then make this information available to companies and households under the heading of climate change adaptation services.
- ▶ **Sectoral efforts on the part of companies** should be boosted. Projects such as those carried out as part of the *coffee&climate* initiative should be expanded. The state is just as important a stakeholder in such activities as the private sector and should act as a partner when confronting this issue. Strong cooperation between private and state actors as well as long-term commitments are critical to this.
- ▶ An assessment should be carried out of how **governmental export risk guarantees** based on the OECD's (TAD/ECG(2012)5) "Common Approaches on Environment and Officially Supported Export Credits" can be organised in a suitable way to incorporate aspects of exposure to climate change. The promotion of exports by the government is based on nuanced reporting obligations for state credit providers and credit insurers (such as Hermes) with regard to the environmental and social compatibility of the funded projects, for example those listed in TAD/ECG(2015)15/FINAL. To date these have primarily referred to the recipient countries complying with standards (Paragraph 26 of the Common Approaches), as well as in principle to adherence with the international standards of the World Bank, of multilateral development banks (such as the DEG) and with further internationally recognised standards set out by the EU (paragraphs 20, 21 and 24 of the Common Approaches). If these standards were to be expanded to take into account the global welfare impacts caused by transnational effects, it would accordingly be possible and could also be made mandatory to promote exports in a targeted manner.

- ▶ **In the future, overarching monitoring** of transnational climate risks should be carried out through channels of influence (not only for trade channels) and be made available to companies on climate change information platforms which are provided by the government.
- ▶ **Fundamentally**, each government strategy for adapting to climate change with the goal of reducing the vulnerability of value creation chains to extreme weather events should follow a **bottom-up approach, i.e. with shared responsibility among the actors in the private sector**. “Soft” measures such as information dissemination, raising awareness, education, incorporation in job profiles and training courses, standards for business risk management etc. should be implemented before “hard” regulatory interventions or risk bearing by the state sector. The efforts of KOMPASS (UBA) and KLIMACHECK (BMW) in the field of corporate supply chain management, as well as the varied initiatives provided by private intermediaries such as Price-Waterhouse-Cooper 2015, FM Global 2017 and HSBC Global Research 2018 from the climate change services sector, offer some starting points for such an approach in Germany.

c) Policy approaches at the international level

The protection and preservation of international value chains is a recognised goal of the United Nations Framework Convention on Climate Change (UNFCCC). Important agreements reached by the UNFCCC include the Bali Action Plan and the Cancun Agreements on climate adaptation (FCCC/CP/2010/7/Add.1). The latter was adopted almost verbatim in Article 7 of the Paris Climate Agreement, in which it is stated:

“Parties recognize that adaptation is a global challenge faced by all with local, subnational, national, regional and international dimensions.”

This provision gives rise to the obligation for all the signatories of the Paris Agreement, including the European Union (EU) and its member states to develop goals and goal achievement reports in line with Art. 7.10 PA and submit them to the UN in so-called adaptation communications (Schwarze 2017). This in turn necessitates a transition to a collaborative EU adaptation policy, which would include joint strategies to reduce the negative transnational effects of climate change for the community. Brussels’ abstention on these matters up to now will come to an end after 2020 with an obligation to develop a uniform reporting system for climate resilience. A coordinated effort must be made by the member states to implement the UN’s Sendai Framework for Disaster Risk Reduction (Foreign Office 2015). In this respect, the Paris Agreement and the Sendai Framework strengthen each other in the implementation of a strategy to avoid transnational effects. The impacts of climate change on international value chains will also be addressed in other international political contexts. The 2030 Agenda for Sustainable Development with its 17 Sustainable Development Goals (SDGs) explicitly calls for a climate-friendly and resilient restructuring of economic systems in industrialised and developing countries in SDG 13, for example. The G7 and G20 gave their political backing to this focus at their summit meetings in Elmau (2015) and Hangzhou (2016).

All of the international agreements previously mentioned share the conviction that adaptation policies in industrialised countries must not be implemented at the cost of developing countries. Article 7.6 expressly highlights the principles of supporting developing countries and international cooperation. Strategies to combat negative transnational effects must therefore be justified from the perspective of international welfare or must give consideration to compensation payments for developing countries. In any case, they must not be governed purely

by national considerations. The latter would considerably limit the room for the implementation of necessary measures as part of an integrated climate and trade policy strategy. The legal and economic form of the restrictions should be examined in more detail.

The specific measures that the German government has already passed as part of its close financial links with developing and emerging countries are set out in the government's response to a request presented by The Greens in 2016 (document 18/9282). This document also references more than 100 Technology Needs Assessments, or TNAs, that were drafted by 79 countries as part of the UN's Technology Mechanism and assisted by the Federal Republic of Germany. The Federal Ministry for Economic Affairs and Energy, as the relevant national authority, assessed "Technologies and Services for Climate Mitigation and Climate Adaptation in Germany", prioritised by "areas of need" and compiled in the form of "profiles". There is no profile among them with measures that aim to protect exchange relationships and value chains or improve their dynamic resilience. The dominant sectors in the field of climate adaptation are agriculture and water management, which accounted for a total of two thirds (66%) of all the identified technology needs (NDE 2017). The prevailing technological orientation of the TNAs as well as the sole non-EU perspective of the UNFCCC's list of measures leave little room for action to safeguard international value chains. If the EU accepts its obligations arising from Article 7 of the Paris Agreement, however, this framework is too narrow. We are therefore faced with new political challenges that give new weight to the findings of this study and the other studies on the transnational impacts of climate change, and which can justify the need for a dedicated policy chapter in the EU Adaptation Strategy and the German Strategy for Adaptation to Climate Change (DAS).

Many opportunities for shaping international trade agreements come to the fore against this backdrop. Chapters on sustainable development are now included as standard in bilateral and multilateral free trade agreements (FTAs) signed by EU member states and the European Union. These provide a concrete connecting element for incorporating the risks of transnational climate impacts. The application and enforceability of environmentally relevant provisions in the sustainability chapters can, for example, be strengthened by dovetailing them with the trade regulations in the respective agreement or by enforcing the consultation and complaints mechanisms stipulated in the sustainability chapters. The trade agreement with Japan – which came into force on 1 February 2019 – for example, is the first FTA that makes reference to implementing the Paris Agreement (Art. 16.4) and gives consideration to a transition to climate-resilient development:⁹

The Parties reaffirm their commitments to effectively implement the UNFCCC and the Paris Agreement, done at Paris on 12 December 2015 by the Conference of the Parties to the UNFCCC at its 21st session. The Parties shall cooperate to promote the positive contribution of trade to the transition to low greenhouse gas emissions and climate-resilient development. The Parties commit to working together to take actions to address climate change towards achieving the ultimate objective of the UNFCCC and the purpose of the Paris Agreement.

It remains to be seen how the commitment contained in the trade deal regarding greater cooperation on climate adaptation can be implemented programmatically. The FTA does not specify any particular direction. The decisive factor will be how the various platforms and committees that the FTA created – including the Committee on Trade and Sustainable Development (Art. 16.13) – position themselves in the future. It would be possible and sensible to work on developing "blueprints" for a climate-related trade policy agenda. Bilateral cooperations in this context could cover, for example, the fields of science, technology transfer

⁹ Council Decision on the conclusion of the Economic Partnership Agreement between the European Union and Japan, Official Journal of the European Union L 330/1 of 27 December 2018

and services. An action plan for the liberalization of adaptation technologies and related services could be developed based on the work of the Committee on Trade and Sustainable Development¹⁰. Individual measures could include simplified procedures for the approval of equipment, automatic licensing of vehicles and issuing visas for the free movement of installation and training teams. Germany can and should insist – both directly as a contracting partner and indirectly through its influence within the EU – that climate adaptation-related trading instruments are discussed, drafted and finally implemented together with the respective partner states within the FTA structure.¹¹

Moreover, there are numerous international initiatives and institutions in the private sector that deal with the economic impacts of climate change, such as the World Business Council for Sustainable Development (WBCSD: <https://www.wbcsd.org/>) and the UN Global Compact (<https://www.unglobalcompact.org/>). The impacts of climate change are also discussed in various international forums focussing on the development of financial markets. The G20's Green Finance Study Group, for example, analysed the impacts of an increase in extreme weather events on the risks for financial portfolios. The UNEP Finance Initiative is analysing the opportunities for supporting value chain management for businesses in vulnerable economic networks in a similar manner (<http://www.unepfi.org/climate-change/climate-change/>). Both focus more concertedly on the industrialised and emerging countries of the G20 than the UN technology mechanisms.

This mixture of wide-ranging political and private sector initiatives contains important starting points for international mobilisation and support for business-based value chain management in vulnerable economic contexts. Creating and updating these framework conditions through international policy are important prerequisites for the otherwise autonomous initiatives of the international private sector. In order to develop the political frameworks further, it is important to continuously monitor the political working structures of international organisations such as the G20's Green Finance Study Group.

¹⁰The Environmental Goods Agreement was negotiated and discussed in such a manner with the aim of facilitating trade, including tariff reductions for green technologies.

¹¹ For more detail, see Griffin et al. 2019: Climate change and trade agreements: Friends or foes? The Economist Intelligence Unit 2019; Conway et al. 2016: Fostering Action Through Trade-Related Policy Instruments (Luxembourg 2016).

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9 Annex

Table 1: Regions in the COIN-INT model

Region group	Model region	Abbreviation
Europa (EU+)	Germany	DEU
	Austria	AUT
	Italy	ITA
	France	FRA
	Benelux	BLX
	Great Britain and Ireland	UKI
	Central EU 27 and Switzerland	CEU
	Northern EU 27+ Liechtenstein, Norway and Iceland	NEU
	Mediterranean EU 27	MEU
	Southeast EU 27 + rest of Europe	SEE
Outside Europe (non-EU+)	North America	NAM
	Remaining industrialised countries	ROI
	Eurasian countries	ERA
	Emerging countries in Latin America	ECL
	Emerging countries in Asia and Israel	ECA
	Turkey	TUR
	China	CHN
	India	IND
	Countries with a focus on the textile industry in Southeast Asia, Tunisia	SEAT
	Countries with a focus on electronic devices in Southeast Asia	SEAE
	Rest of Latin America	LAM
	Oil-exporting countries in the Middle East, Africa and Venezuela	OIE
	Rest of South and Southeast Asia (less developed countries)	RSEA
	Africa	AFR

Data base: GTAP v9 (Aguiar, Narayanan and McDougall 2016)

Table 2: Sectors in the COIN-INT model

Sector group	Model sectors	Abbreviation
Agriculture, forestry, fishery	Agricultural products: plant-based	AGC
	Agricultural products: animal-based	AGL
	Forestry and fishery	FOF

Sector group	Model sectors	Abbreviation
Mining and fossil resources	Coal	COA
	Crude oil and natural gas	OAG
	Rest of mining industry	OMN
Food, textile and timber industries	Food and fodder, drinks and tobacco products	FBT
	Textile industry	TWL
	Timber and paper industry, printing houses	WOP
Machinery and electronic devices	Manufacture of machines, data processing devices, electronic and optical products	OME
	Electronic devices	ELE
	Engines and vehicles, other modes of transport	MVT
	Electricity	ELY
	Other production	OMF
Other industries	Refined oil products	P_C
	Chemical industry	CRP
	Production of other non-metallic mineral products, precious metals and non-ferrous metals	NMF
	Production of iron and steel, as well as casting and processing of metal products	ISM
Transport	Water transport	WAT
	Air transport	AIT
	Overland transport	LAT
Services and construction	Other private and public services	SER
	Construction industry	CRE

Data base: GTAP v9 (Aguiar, Narayanan and McDougall 2016)