Chapter 13

The macroeconomics of climate change and adaptation in Viet Nam

acronyms?

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Abstract

We propose an economy-wide assessment of the social and economic effects of climate impacts on the Vietnamese economy as a whole using an integrated macroeconomic framework. Our integrated assessment framework involves the following steps. First, we apply a monetary valuation of direct damages by sector (agriculture, energy and health) by using the key quantitative results from the Chapters 3, 4, 5, 6. Mainly, we focus on the impacts on rice yields, hydropower supply and electricity demand, infectious diseases and mortality, labor productivity and total factor productivity. Then, we construct the sectoral damage functions which represent the losses in each sector conditional on Viet Nam mean surface temperature (VNMST) change. Summing across sectoral direct impacts as a function of VNMST change 2020–2099 relative to 1997–2019, we find that expected annual GDP loss reaches 6% relative to the baseline scenario at +1°C of warming. Integrating these sectoral damage functions within a stock-flow consistent model of the Vietnamese economy, by 2050, average losses range between 0.7 and 10.4% under RCP 4.5 and between 1.7 and 12.2% under RCP 8.5. In addition, we estimate the annual GDP losses due to typhoons in the period 1992–2013 at 2.4%. Uncertainties remain about the future impacts of typhoons combined with climate change scenarios. Finally, because export-oriented activity clearly supports the country's growth, we specifically account for the potential international damage spillovers that may be incurred by changing trade patterns. Evidence is given that climate change through international spillover damages is expected to reduce Viet Nam's long-run growth rate over the next 40 years.

Tóm tắt

Chúng tôi đề xuất một đánh giá các tác động kinh tế và xã hội của biến đổi khí hậu trên toàn bộ nền kinh tế Việt Nam bằng cách sử dụng một khung vĩ mô tích hợp. Khung đánh giá tích hợp của chúng tôi được xây dựng theo các bước sau. Thứ nhất, chúng tôi áp dụng lượng giá bằng tiền đối với thiệt hại trực tiếp theo ngành (nông nghiệp, năng lượng, y tế và năng suất lao động) bằng cách sử dụng các kết quả định lượng chính từ các chương 3, 4, 5, 6. Chúng tôi tập trung vào một số ảnh hưởng tới sản lượng lúa, thuỷ điện, tiêu dùng điện, các bệnh truyền nhiễm, tử vong, năng suất lao động và năng suất nhân tố tổng hợp. Sau đó, chúng tôi xây dựng các hàm thiệt hại theo ngành tương ứng với sự thay đổi nhiệt độ bề mặt trung bình của Việt Nam (VNMST). Bằng cách cộng tổng các tác động ngành trực tiếp theo sự thay đổi của VNMST trong giai đoạn 2020–2099 so với giai đoạn 1997–2019, chúng tôi tìm ra rằng thiệt hại GDP ước tính hằng năm có thể đạt tới 6% so với kịch bản gốc khi nhiệt độ tăng lên 1°C. Sau khi tích hợp các hàm thiệt hại này vào mô hình kinh tế vĩ mô trữ lượng-lưu lượng nhất quán của kinh tế Việt Nam để đánh giá tác động liên ngành và tổng hợp của biến đổi khí hậu, đến năm 2050, thiệt hại trung bình có thể đạt từ 0.7 đến 10.4% với kịch bản RCP 4.5 và từ 1.7 đến 12.2% với kịch bản RCP 8.5. Thêm vào đó, chúng tôi tiến hành ước lượng thiệt hại hằng năm GDP do bão trong giai đoạn 1992–2013 là khoảng 2.4%. Hiện nay, rất khó dự đoán các cơn bão trong tương lai với các kịch bản khí hậu khác nhau. Cuối cùng, do đặc điểm tăng trưởng của Việt Nam chủ yếu dựa vào các hoạt động xuất khẩu, chúng tôi đặc biệt nghiên cứu các tác động ảnh hưởng từ quốc tế có thể thay đổi cấu trúc thương mại của nước ta. Bằng chứng cho thấy biến đổi khí hậu thông qua các tác động ảnh hưởng từ quốc tế sẽ có thể làm giảm tốc độ tăng trưởng lâu dài của Việt Nam trong vòng 40 năm tới.

Résumé

Nous proposons une évaluation des effets sociaux et économiques du changement climatique en utilisant un cadre macroéconomique intégré. Notre cadre d'évaluation comprend les étapes suivantes. Tout d'abord, nous appliquons une évaluation monétaire des dommages directs par secteur (agriculture, énergie et santé) en utilisant les principaux résultats quantitatifs des chapitres 3, 4, 5 et 6. Nous nous concentrons principalement sur les impacts sur les rendements rizicoles, l'offre et la demande d'électricité, les maladies infectieuses, la mortalité, la productivité du travail et la productivité totale des facteurs. Ensuite, nous construisons des fonctions de dommages sectoriels qui représentent les pertes dans chaque secteur en fonction du changement de la température moyenne de surface du Viet Nam (VNMST). En additionnant les impacts directs sectoriels en fonction du changement de la VNMST entre 2020 et 2099 par rapport à 1997–2019, nous constatons que la perte annuelle de PIB atteint 6% par rapport au scénario de référence à +1°C de réchauffement. En intégrant ces fonctions de dommages sectoriels dans un modèle cohérent stock-flux de l'économie vietnamienne, d'ici 2050, les pertes moyennes se situent entre 0,7 et 10,4% sous RCP 4,5 et entre 1,7 et 12,2% sous RCP 8,5. En outre, nous estimons à 2,4% les pertes annuelles de PIB dues aux typhons pour la période 1992–2013. Des incertitudes subsistent quant aux impacts futurs des typhons combinés aux scénarios de changement climatique. Enfin, étant donné que l'activité particulièrement orientée vers l'exportation du Viet Nam soutient clairement la croissance du pays, nous tenons compte spécifiquement des retombées potentielles des dommages internationaux qui peuvent être encourus par la modification de la structure des échanges. Le changement climatique, par le biais des dommages internationaux, devrait réduire le taux de croissance à long terme du Viet Nam au cours des 40 prochaines années.).

1. Introduction

In previous chapters, we have presented updated and more spatially-disaggregated climate scenarios, different types of sectoral analysis, and an in-depth look at national adaptation strategies and local adaptation dynamics. Indeed, we have investigated how climate change might affect health [Chapter 3], the agricultural sector [Chapter 4], the energy sector [Chapter 5] and households [Chapter 6], while also considering the complex dynamics of climate and more local environmental impacts in the Mekong region (Chapters 7, 8, 9). Yet it remains essential to understand the cross-sectoral and cumulative effects of climate change, not only within Viet Nam, but also in relation with its main trade partners. In this chapter, we propose a new economy-wide assessment of the social and economic effects of climate change on the Vietnamese economy as a whole, using an integrated macroeconomic framework.

In addition, existing studies on the evaluation of the impacts of climate change in Viet Nam are usually focused on specific sectors or specific regions, as shown in the different meta-analysis and sectoral assessments in the second part of this report. Few studies seek to assess the economy-wide effect of climate change. UNU-WIDER and CIEM (2012) are to our knowledge the most recent study to evaluate climate impacts on economic growth and welfare in a dynamic CGE model, via three principal mechanisms: crop yields, hydropower production and regional road networks. This latest study provides insights into the potential macroeconomic effects of different climate scenarios from the previous IPCC report.

Contrary to standard CGE models, the macroeconomic model that we have specifically developed combines real side variables with financial balance sheet effects. Indeed, over the last three decades, the Vietnamese economy has been integrated into the world economy and undergone an important financialization process. Increased integration with other countries has contributed to income growth, but also to economic vulnerability in the context of rising trade tensions. The global financial crisis of 2008, the ensuing Vietnamese banking crisis of 2011, along with the recent COVID-19 pandemic — all mostly macroeconomic shocks coming from the financial side — have had significant impacts in real terms as well. They have thus revealed the critical need to pay more attention to the integration of the financial sector (*i.e* money, debt, and assets/liabilities) and the real economy within a single framework, to gain a proper understanding of the dynamics at hand. This more coherent approach is key for any comprehensive macroeconomic analysis and forecast in the short term, and necessary to public policies for a sound development process and macroeconomic stability in the longer term.

Furthermore, Viet Nam is a very open economy, whose international position might also be affected (for better or for worse) by differentiated climate impacts across key trading partners. Within this chapter, we will investigate them independently by using the theory of Balance-of-Payments-Constrained Growth (BPCG).

Beyond this introduction, this chapter has five other sections. Section 2 highlights the integrated framework that has been built within this project to assess climate impacts and adaptation. It should be borne in mind that this platform remains open to incorporate further studies on specific impacts of climate change on specific sectors. We thus do not pretend to offer an exhaustive assessment of the economic costs of climate change through to 2050, but rather to build transparent empirical scenarios of what could happen in very specific and contingent circumstances. Section 3 thus builds an aggregate damage function based on different sectoral assessments. Section 4 integrates this assessment into the stock-flow coherent macroeconomic model of Viet-Nam. Section 5 treats the specific case of the relative climate impacts of Viet Nam with respect to its main trade partners, which can act as a constraint on the long-term equilibrium growth rate of the Vietnamese economy. Section 6 concludes with some more policy-oriented recommendations and avenues for further research.

2. Towards an integrated framework to assess climate impacts and adaptation

Our methodological approach in this chapter builds on the integrated assessment approach of Hsiang *et al.* (2017) who have attempted to assess the economic cost of climate change in the US via a combination of multiple climate scenarios, quantitative meta-analysis of sectoral and social impacts based on existing studies, and aggregation and integration within a macroeconomic model.

Our integrated assessment framework involves the following steps:

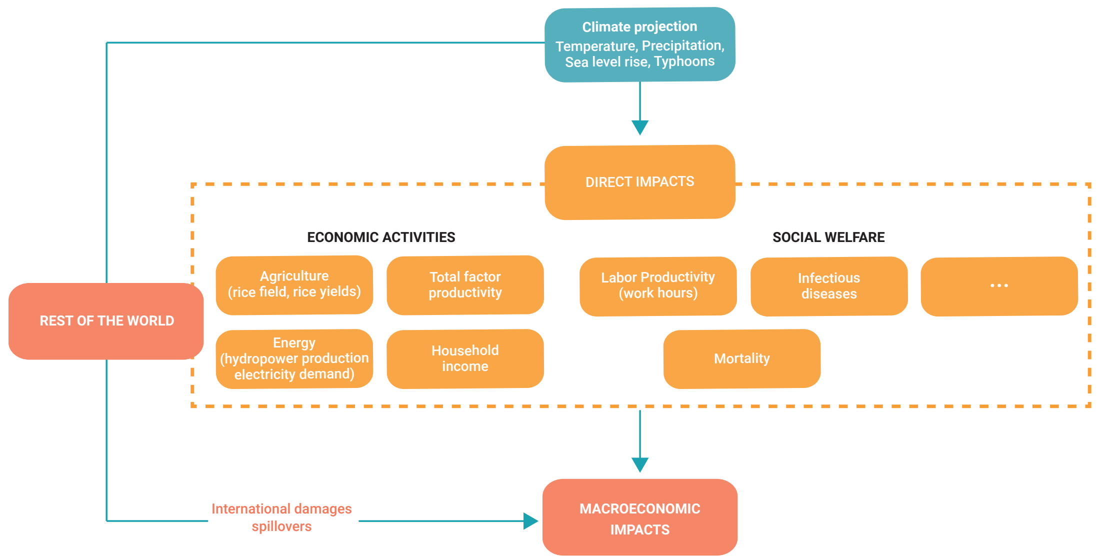
▸ Valuation of direct damage by sector: in order to aggregate over each individual sector to obtain a total economic response to climate forcing, we first apply a monetary valuation to each individual sector, namely agriculture, energy, health, labor productivity, and total factor productivity. We use the key quantitative results from Chapters 3, 4, 5, 6. The choice of studies as well as the valuation for specific sectors is discussed below. For all direct damage, values are presented as a proportion of Vietnamese Gross Domestic Product.

▸ Sectoral damage function calculation: constructing sectoral damage functions requires that losses in each sector be represented as conditional on Viet Nam mean surface temperature (VNMST) change. We estimate summaries of these relationships by regressing the impact value (for all realizations) on these temperatures. As in Hsiang *et al.* (2017), we consider that the results are not weighted, because the likelihood of states of the world is not relevant to the description of the damage function.

▸ Aggregate national-level damage function:
– Summing sectoral damage functions across the spectrum of possible temperature increases to obtain cumulative direct impacts;
– Applying the direct damage impacts to the stock-flow coherent macroeconomic model of Viet Nam, in order to assess the intersectoral and aggregate effects.

Independently of this framework, we assess the impact of typhoons on Vietnamese GDP, using night-time light data to get a better spatial approximation of their economic costs. Because we could not work on the impacts of climate change on the increased frequency of

[Figure 13.1]
An open integrated framework to assess climate damage in Viet Nam



The integrated framework used in this report allows for the measure of direct impacts on key socio-economic variables and their macroeconomic effect. It remains open to additional sectoral impacts, more detailed specifications of climate scenarios (including uncertain future tipping points), as well as probabilistic assessments considering different sources of uncertainties.

typhoons under different climate scenarios, we did not integrate typhoon impacts into the general framework at this stage, although this will be done in future developments of the model. We also assess the impact of international spillover impacts independently of this framework, as this assessment involves a refined representation of Viet Nam's trading partners as well as their own climate impacts, that would have been too complex to integrate within the already-complex SFC model used for the general assessment of climate impacts.

We thus end up with three parallel evaluations of climate impacts, mainly the direct climate impacts on socio-economic variables in the face of temperature increase, changing precipitation patterns and sea-level rise; the climate impacts on GDP due to typhoons; and the relative climate impacts on growth due the changing external position of Viet Nam, in different climate scenarios. This chapter thus builds an open platform to progressively incorporate different aspects of climate change impacts on Viet Nam in more detail. It should be noted that the empirical assessment of climate damage costs is a very difficult and sometimes hazardous exercise [Keen *et al.*, 2021]. This specific application to Viet Nam tries to be as transparent as possible with regard to the inevitable unknowns and uncertainties surrounding these types of assessments.

3. Direct climate damages

Total damage in each sector, and sometimes daily projections from the relevant chapters (mainly Chapters 3, 4, 5 and 6), are valued in monetary terms, aggregated nationally, and completed with a meta-analysis of selected studies. For the meta-analysis, climate models and scenarios may be different from the simulations developed in Chapter 1 of the report. We have included them nonetheless in order to build a theoretical response function, which will then be applied to the complete set of Chapter 1 scenarios. Indeed, each of these aggregate outcomes can be indexed against the change in average temperature in the corresponding climate realization across the four Representative Concentration Pathways (RCP), or their equivalent in the previous form, or the most recent one from the incoming Intergovernmental Panel on Climate Change (IPCC) report. Values are presented as a proportion of Vietnamese GDP. As such, the relative weighting of each sector follows the weighting anticipated by the Vietnamese government up to 2050 and defined in the baseline scenario (see the next section on the macroeconomic model). By being expressed as a percentage change, this direct damage would scale with the expansion of the economy while holding the structure of the economy unchanged compared to the baseline.

3.1 Agriculture

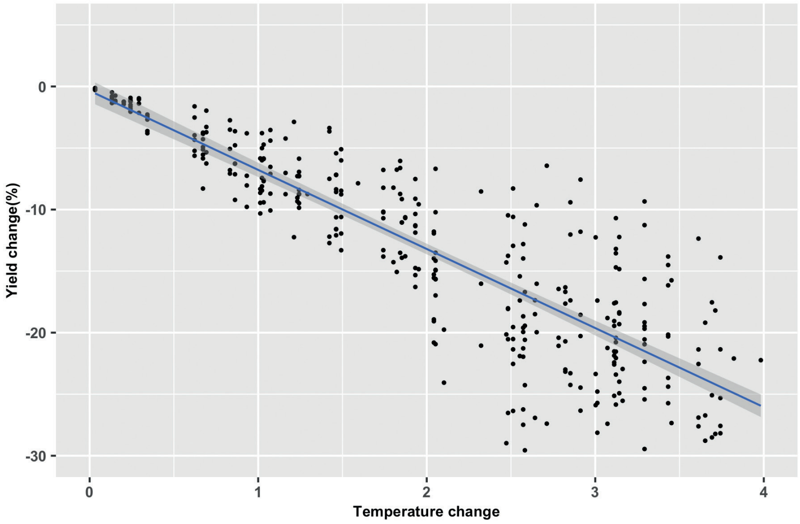
Since the entire Vietnamese population depends on agriculture for food, and agricultural labor still accounts for a significant proportion of total labor (33% in 2020), agriculture remains one of the most important sectors. Climate change has important impacts on the agricultural sector via both direct (temperature, precipitation, sea level rise, etc.) and indirect mechanisms (water resource, saline intrusion, drought, floods, impacts on labor productivity, etc.). Despite the expected restructuring of agriculture from predominantly rice production towards higher-value products – such as coffee, rubber, fishing, etc., rice is still one of the most important crops in Viet Nam (see Chapter 4 of this report). In addition, Viet Nam is one of the largest exporters of rice (top 5 rice exporting countries in 2020).

In our study, agricultural yield impacts are represented as changes in rice yields. We base our analysis purely on a meta-analysis of a set of key existing studies to develop the sector-specific damage functions for agriculture, namely Yu *et al.* (2010), Li *et al.* (2017), Kontgis *et al.* (2019), Deb *et al.* (2015), Shrestha *et al.* (2016) (see Chapter 4 for a more detailed assessment of these references). Then, we assume that a given change in rice output results in a proportional change in the value of that agricultural sector's gross output in the baseline scenario. In this sense, we do not consider possible endogenous adaptation strategies at this stage and estimate an upper threshold for the corresponding damage function. However, we may also under-estimate damage since non-linear tipping points of the climate system are not accounted for, even if we complete this assessment by taking sea-level rise into account in the case of rice. With these limitations in mind, the direct impact of climate change on rice could affect yields by up to 30% beyond a 2°C increase in temperature relative to 1997–2019.

3.2 Energy

The energy sector is a crucial component in any development dynamics, but is affected

[Figure 13.2]
Rice damage function



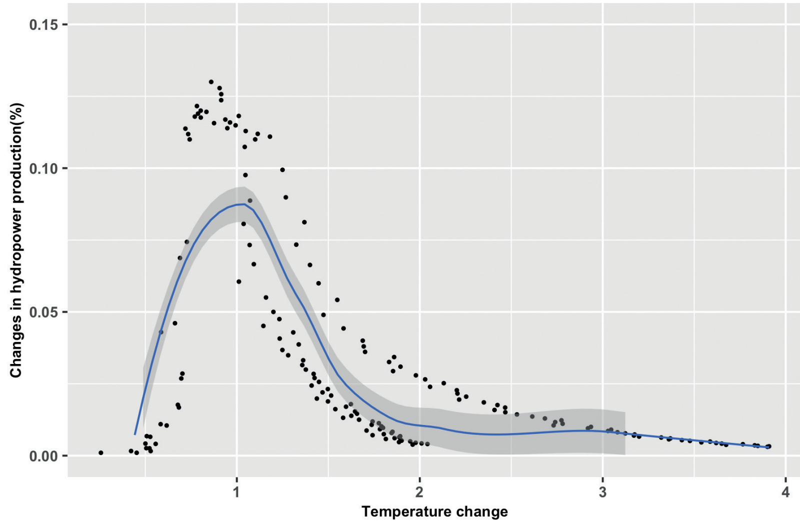
Average yield change over the period 2020–2099 as a function of VNMST change 2020–2099 relative to 1997–2019. Dots indicate the distribution of direct damages corresponding to VNMST change in each combination of climate models and scenario projection. Black line represents the linear regression of damage values on VNMST change.

by climate change both in terms of energy supply and demand [Auffhammer & Mansur, 2014; Yalew *et al.*,2020]. The direct costs and benefits of climate-driven change in energy were assessed in Chapter 6, including the forecasted development of the Viet Nam Power Development Plan 8 (PDP8).

On the supply side, changes in precipitation and temperature can affect energy production capacity, the transmission systems, or the infrastructure itself [World Bank, 2011; Ciscar & Dowling, 2014; Perera *et al.*,2020]. In this report, given the current dominant role of hydropower in total Vietnamese electricity production (37.7% in 2019) despite a planned reduction to 18% by 2030 and to 9% by 2045 (PDP8), we study the climate impact on hydropower production. Figure 13.4 shows that the case of hydropower is more complex, as it induces an initial surplus of production (with a maximum at a 1°C increase of temperature) because of increased precipitation. Beyond a 2°C increase however, there is not much change compared to a baseline without further climate change. It should be noted here, as suggested in Chapter 5, that we do not consider other impacts on energy supply and demand due to lack of data, and that we cannot consider the impact of the multiple use of water from the hydropower sector.

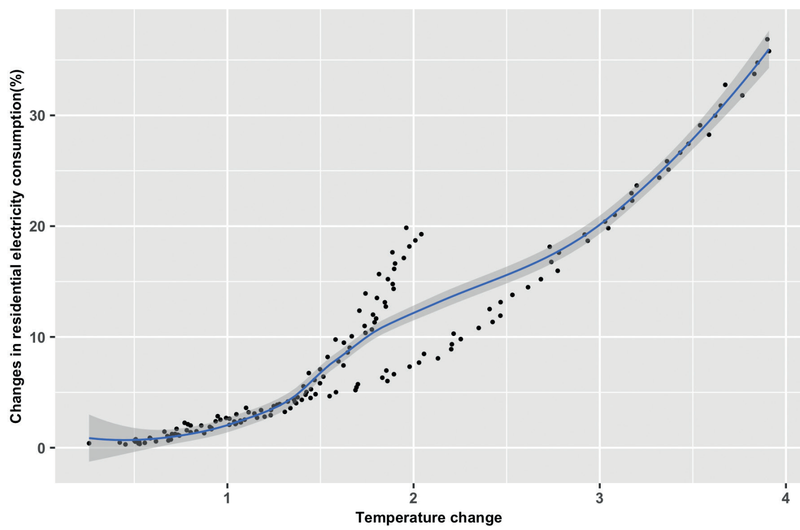
On the demand side, the rising temperature and weather extremes in recent years have strongly affected residential electricity demand (27% of total end-use consumption in 2016). The main use of electricity in households is for air conditioners, refrigerators, and electric fans. In Chapter 5, we project changes in residential and commercial

[Figure 13.3]
Hydropower production damage function



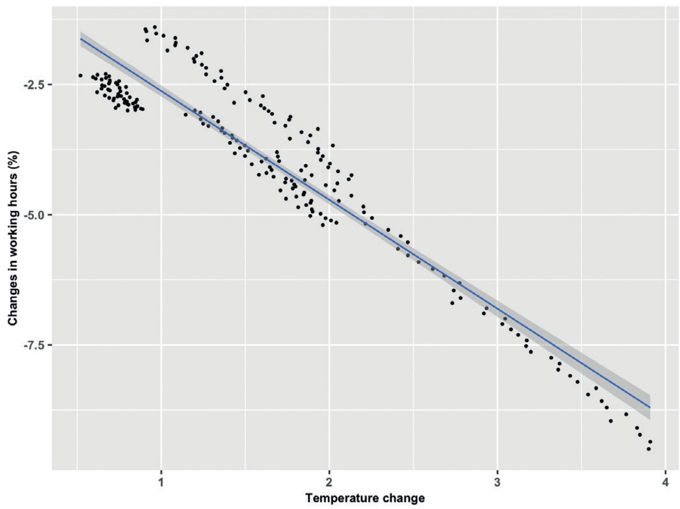
Average change in hydropower production over the period 2020–2099, as a function of VNMST change 2020–2099 relative to 1997–2019. Dots indicate the distribution of direct damages corresponding to VNMST change in each combination of climate models and scenario projection. Black line represents the polynomial regression of damage values on VNMST change.

[Figure 13.4]
Electricity demand damage function



Average residential electricity demand changes over the period 2020–2099 as a function of VNMST change 2020–2099 relative to 1997–2019. Dots indicate the distribution of direct damages corresponding to VNMST change in each combination of climate models and scenario projection. Black line represents the non-linear regression of damage values on VNMST change.

[Figure 13.5]
Labor productivity damage function



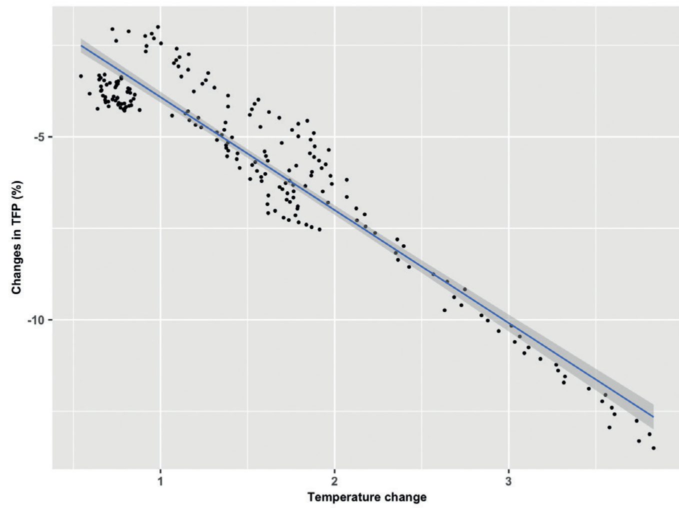
Average working hours lost over the period 2020–2099 as a function of VNMST change 2020–2099 relative to 1997–2019. Dots indicate the distribution of direct damages corresponding to VNMST change in each combination of climate models and scenario projection. Black line represents the linear regression of damage values on VNMST change.

electricity demand, residential and commercial total energy expenditure, and electricity generating capacity. The response functions are derived from the outputs of LEAP in 2040, under a range of temperature scenarios from Chapter 1. These responses are then mapped to regional changes in climate variables in each period (2020–2039, 2040–2059 and 2080–2099). Beyond a 2°C increase in temperature, electricity demand could increase by as much as 12%, and by more than 20% above a 3°C increase.

3.3 Labor productivity

Several studies show that heat stress can have negative impacts on human health as well as worker productivity [Orlov *et al.*, 2020; ILO, 2019; ILO, 2016; Kjellstrom, 2009]. Kjellstrom *et al.* (2012) describe how in the case of South-East Asia, heat stress reduces work capacity leading to lower economic output. Dao *et al.* (2013) found that in Da Nang, the rise in temperature has particularly affected the working conditions of low-income outdoor workers. Opitz-Stapleton (2014) demonstrates the heat stress induced by climate change will increase the occupational heat exposure of workers. Kjellstrom *et al.* (2014) emphasize that in 2030, heat loss could represent 5.7% of Viet Nam's GDP. In our case, we consider the results of Chapter 6 to quantify an impact function in terms of working hours lost. A 1°C rise in temperature is associated with a decrease of 2.5% in working hours. The value of labor productivity impact is calculated by multiplying the equivalent number of workers which is proportional with the working hours lost by GDP per worker.

[Figure 13.6]
Total factor productivity damage function

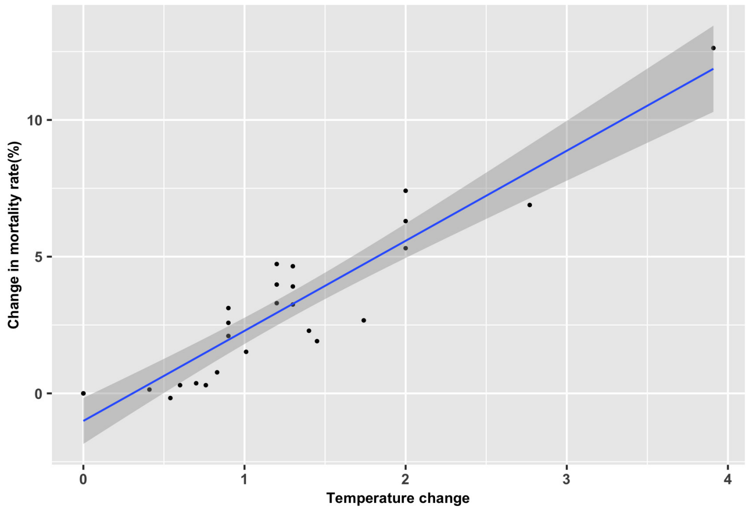


Change in TFP over the period 2020–2099 as a function of VNMST change 2020–2099 relative to 1997–2019. Dots indicate the distribution of direct damages corresponding to VNMST change in each combination of climate models and scenario projection. Black line represents the linear regression of damage values on VNMST change.

3.4 Total factor productivity

The total factor productivity (TFP) plays an important role for the long-run economic growth. In Viet Nam, according to GSO data, TFP has contributed 43.5% to the national economic growth in 2018. In addition, the approved National Assembly's resolution for Viet Nam's socio-economic development indicates that the TFP is expected to contribute 45–47% of GDP growth during coming years. Several studies in the recent literature found a negative impact of climate change on total factor productivity. Letta & Tol (2016), by using macro TFP data from the Penn World Tables, examine the relationship between annual temperature shocks and TFP growth rates in the period 1960–2006. They found only a negative relationship in poor countries but indistinguishable from zero in rich countries. Dietz & Stern (2015) marginally change the DICE model of William Nordhaus and test the macroeconomic impacts when TFP is hit. Moore & Diaz (2015) test a modified DICE model, calibrated on Dell *et al.* (2012) and obtain increased impacts. Another theoretical study of Moyer *et al.* (2014) also has hypothesized a future impact of global warming on TFP growth. Chapter 6 in the report found that an increase in temperature would reduce the total factor productivity. Specifically, an increase of average temperature of 1°C leads to a 3.6 per cent decline in the TFP. The value of total factor productivity impact is calculated through their impact on GDP growth which is then translated to the changes in GDP level.

[Figure 13.7]
Mortality damage function



Change in mortality rate over the period 2020–2099 as a function of VNMST change 2020–2099 relative to 1997–2019. Dots indicate the distribution of direct damages corresponding to VNMST change in each combination of climate models and scenario projection. Black line represents the linear regression of damage values on VNMST change.

3.5 Health

Most studies show negative impacts of climate change on health outcomes (*e.g.* physical health, mortality, infectious diseases, mental health, dietary outcomes) [Rocque *et al.* (2021)]. In this report, Chapter 3 investigates the effects of climate variability (temperature, rainfall, wind speed, heatwaves) on infectious diseases (*i.e.*, water-borne, airborne, and vector-borne) and on mortality. They found that the effect of a heat wave on the mortality rate is more significant and of greater magnitude compared with a cold wave. There is also a strong impact of temperature on vector-borne and water-borne disease. The effect of weather changes on the incidence of major diseases differs by climate region. Provinces located in the South and Southern Central Coast appear to have a higher sensitivity to infections at 15°C–18°C temperature.

Mortality

Regarding the effect on mortality, Gasparrini *et al.* (2017) investigate the projections of temperature-related excess mortality under climate change scenarios, assuming no adaptation or population changes. This study shows the negative impacts of climate change, which potentially produces an increase in mortality in most regions. Guo *et al.* (2018) projected excess mortality in relation to heatwaves in the future under each RCP scenario, with or without adaptation and with three population change scenarios (high variant, median variant, and low variant). They found that if there is no adaptation, heatwave-related excess mortality is expected to increase the most in tropical and subtropical countries/regions. WHO (2014) shows climate change-attributable heat-related deaths by world region. They find that the relative increase in excess

deaths from 2030 to 2050 is large in some regions, including South-East Asia. In addition, the countries with high populations and pre-existing disease burdens will be more vulnerable to the health impacts of climate change. Another study by Vicedo-Cabrera *et al.* (2018) suggests that the Paris Agreement's commitment to hold warming below 2°C could prevent an increase in temperature-related mortality. Based on these above studies, we obtain the damage function represented in the Figure 13.7.

To value mortality damage in monetary terms, several methods exist and we do not necessarily want to engage in a theoretical decision about them, as this should be the choice of policy-makers. As a practical solution, despite the problems on both theoretical issues of interpretation and difficult problems of measurement of the Value of Statistical Life [Ashenfelter, 2006], we use the Value of Statistical Life (VSL) from a study of Ohno *et al.* (2012) on measurement of Value of Statistical Life by Evaluating Diarrhoea Mortality Risk due to Water Pollution in Viet Nam. VSL has been calculated as 65,726–209,660 US$ for Viet Nam. Concerning the impact channel in the macroeconomic model, it is possible to consider an impact on population growth, which in turn affects aggregate demand, the labor supply and thus economic growth.

Infectious diseases

Climate change increases the risk of many infectious diseases. Chapter 3 investigates the effect of infectious diseases on the macro-economy through loss in labor productivity. The results suggest a negative influence of infectious diseases on labor productivity, which is represented as the average hourly wage of workers. Specifically, a 1% increase in disease infections leads to a decrease in the average hourly wage of approximately 0.049%. Based on the projection of changes in the number of infections under RCP4.5 and RCP8.5 of Chapter 3, we develop the damage function of infectious diseases [Figure 13.8]. The average provincial incidence of infection will increase by 29% by 2050 under both RCP4.5 and RCP8.5 without adaptation, and by 36% by 2100 under RCP8.5 without adaptation.

3.6 Typhoons and sea level rise impacts

We know from Chapters 4 and 9 that sea-level rise in the Mekong Delta will induce a loss in rice production due to salinization [Nguyen *et al.*, 2018]. In the particular case of the Mekong Delta (see Chapter 9), sea-level rise dynamics are due to a combination of climate change and subsidence dynamics from human-induced and natural causes [Minderhoud, 2020]. In our chapter, we use the Ministry of Natural Resources and Environment (MONRE) flood maps for three scenarios of sea level rise in 2050: 30cm (RCP2.6/RCP4.5), 60 cm (RCP6.0) and 90 cm (RCP8.5). We then include rice fields lost by submersion [Table 13.1] in the macroeconomic model.

Given its location in the Northwestern Pacific Basin, the most active tropical cyclone zone on earth, and its extensive coastline, Viet Nam is prone to meteorological disasters, particularly storms and typhoons. With one-minute sustained wind speeds that can reach more than 64 knots, typhoons are intense storms accompanied by heavy rainfall. When they make landfall, typhoons cause flooding and trigger landslides. With additional climate change, typhoons have more impact because of sea-level rise. In order to assess this aspect, we have selected past typhoons above

130 knots, which are supposed to re-occur every century in the current climate while generating an important storm surge. Sea-level rise tends to make this type of storm surge more frequent. We use the calculation of the economic impact [Box 13.1] of this particular type of typhoon to assess the associated GDP losses in affected grid cells.

[Table 13.1]

Rice submersion assessment

Province	Rice planted areas (k.ha)	Rice planted areas lost (%) - Scenario		
		30 cm	60 cm	90 cm
Quang Ninh	21	49%	55%	58%
Thai Binh	82	11%	23%	66%
Hai Phong	38	3%	8%	53%
Nam Dinh	76	8%	29%	68%
Ninh Binh	42	1%	7%	21%
Quang Binh	30	21%	33%	58%
Phu Yen	25.3	0%	0.70%	1.10%
Ninh Thuan	16	0%	0%	0.20%

[Box 13.1]

Assessing typhoon impacts on GDP using satellite imagery

Global damage caused by typhoons has steadily increased in recent decades [OFDA, 2010], due to a combination of accelerated economic development [Takagi, 2019] and ongoing climate change [Stocker *et al.*, 2013]. The economic impacts of typhoons have notably been estimated at the global scale [Felbermayr *et al.*, 2018], in the US [Strobl, 2009], China [Elliott *et al.*, 2015], and the Philippines [Blanc and Strobl, 2016], among others.

We estimate the GDP impact of typhoons in Viet Nam using satellite data as a proxy for localized GDP. We avoid using ex-post collected data on damage, deaths, and/or the affected area such as EM-DAT [Noy and Vu, 2010; Thomas *et al.*, 2010; Trung, 2015; Arouri *et al.*, 2015], which suffers serious drawbacks: reliability, endogeneity, and sample selection bias. In the end, the higher the affected country's GDP per capita, the more likely a disaster with a given natural intensity will be reported. When it comes to developing economies such as Viet Nam, this leads to the under-inclusion of events and their spatial extents, while overestimating the impact.

Night-time light imagery was adopted to investigate economic activity as early as Croft (1978). It is indeed a good proxy for economic activity both at the country [Chen and Nordhaus, 2011; Henderson *et al.*, 2012] and subnational levels [Hodler and Raschky, 2014; Donaldson and Storeygard, 2016]. A large volume of literature studying the consequences of extreme events has already applied night-time light luminosity [Strobl, 2012; Bertinelli and Strobl, 2013; Elliott *et al.*, 2015; Felbermayr, 2018], although never in Viet Nam.

As stated in Noy (2009), heterogeneity in institutional and socioeconomic characteristics results in different ex-post disaster impacts.

The International Best Track Archive for Climate Stewardship (IBTrACS) Version ibtracs.WP.list.v04r00 provides information on 6-hourly central locations of the Western North Pacific's storms, with their respective maximum sustained wind speed in conjunction with details such as direction, forward velocity, central pressure, etc. It is worth noting that interpolated 3-hourly data are also available. Some measurements across different World Meteorological Organization (WMO) Regional Specialized Meteorological Centres (RSMC) cannot be directly compared due to varying units. Therefore, we use data from different agencies when appropriate.

Typhoons are tropical cyclones that reach a 1-minute sustained wind of 64 knots according to international standards. As weaker storms may also be devastating due to the associated extreme rainfall, the results of this study should be treated as the lower bound of damage caused by tropical cyclones. We consider wind speed data from the U.S. Department of Defense Joint Typhoon Warning Center (JTWC), which are given with a 1-min averaging period. We use RSMC Tokyo wind radii at a 30-knot threshold to define if a pixel is affected by a typhoon. Figure 13.8 illustrates all the typhoons used for analysis.

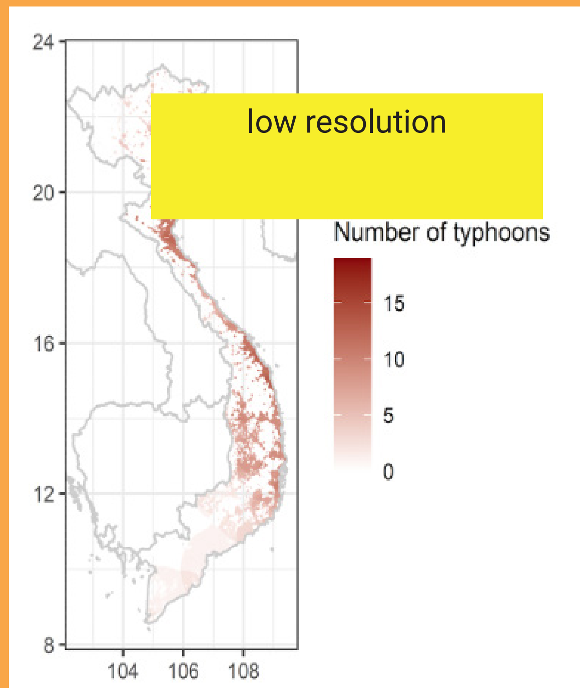
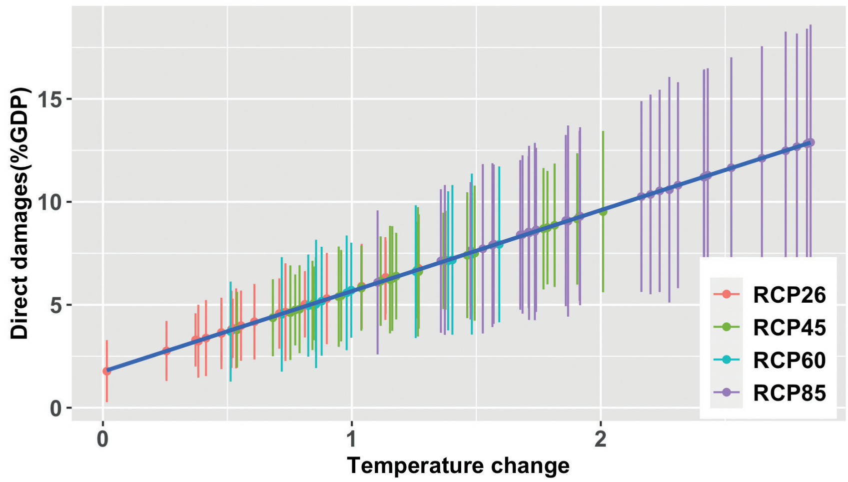


Figure 13.8 Typhoon impacts during 1992–2013

Night-time light data come from the Defense Meteorological Satellite Program (DMSP) and have been processed for the general public by the National Oceanic and Atmospheric Administration (NOAA), with records dating back to 1992 [Elvidge, 2001] and up to 2013. Only pixels in mainland Viet Nam and sizable islands are used for analysis. This is since lights at sea may be affected by typhoons differently and come from mobile and temporary sources such as oil rigs, fishing boats, etc. On average, for pixels with a large value of nightlight intensity, being stricken once in a year leads to a reduction of local economic activities of 4.6%. Given that a 1% change in NL is approximately equivalent to a 0.633% change in GDP, this corresponds to 2.4% GDP loss annually due to typhoon impacts in Viet Nam between 1993–2013.

[Figure 13.9]
Estimates of total direct damage under RCPs



Total direct damage to the Vietnamese economy summed across different sectors as a function of VNMST change 2020–2099 relative to 1997–2019. Dots indicate the distribution of direct damages corresponding to VNMST change in each combination of climate models and scenario projection. Black line represents the linear regression of damage values on VNMST change.

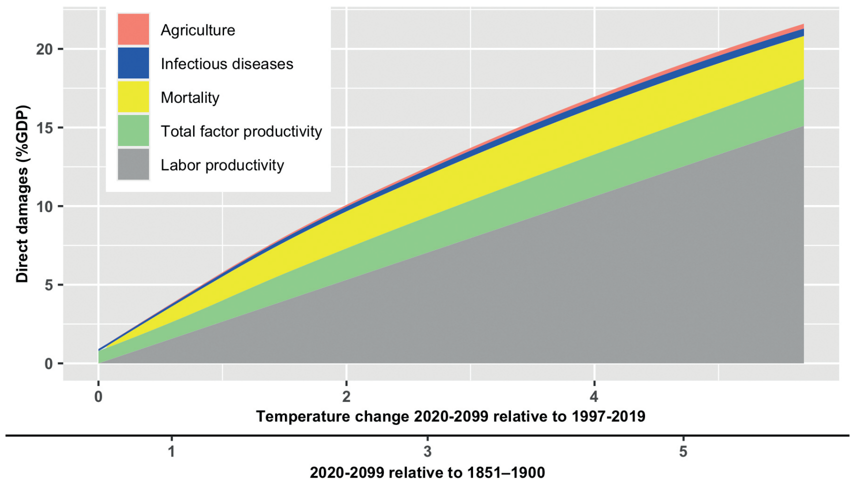
Aggregate direct damage function

Based on the sectoral damage functions described above, we can build an aggregate damage function for the Vietnamese economy by applying the different functions to the climate scenarios of Chapter 1. Figure 13.9 gives us a hint of the aggregate direct damage in different RCPs, considering the uncertainty from the different climate scenarios (but not from the socio-economic side). It shows that direct damage can reach up to a 12% loss in annual GDP relative to the baseline scenario in the case of a temperature increase above 2.5°C. Remaining below a temperature increase of 1°C allows for a minimal loss of up to 6% of GDP compared to the baseline scenario.

It should be noted that this assessment takes into account some uncertainty on the climate side, but not on the socio-economic side, where strong non-linearities in the reaction to non-marginal climate changes might emerge. Some important impacts have not been taken into account, such as typhoon impacts, which we show independently because their dynamics in relation to climate scenarios is not yet clear.

Figure 13.10 shows a break-down of total direct damage into its sectoral components, using the mean value of climate scenarios. We found that the greatest direct damage from the increasing of VNMST is the impact of labor productivity. The economic damage on agriculture is relatively small mainly due to the Vietnamese economic restructuring in the coming years. Indeed, the agriculture share of GDP by 2045–2050 tends to decline.

[Figure 13.10]
Estimates of total direct damages by sectors



Total direct damage to the Vietnamese economy by different sectors as a function of VNMST change 2020–2099 relative to 1997–2019 (contemporary climate) and relative to 1851–1900 (pre-industrial climate). The temperature of the pre-industrial period is estimated from observation dataset and HadCRUT5 (with a coarse resolution of 5°x5°).

The macroeconomic simulations we propose in this chapter try to tackle the complexities of a rapidly developing economy such as Viet Nam. At this stage, they do not capture international trade effects. This is the reason why we have completed them with a specific exercise of simulation of the relative impacts of climate change on Viet Nam's trade partners with the hypothesis that the Thirlwall law is verified. This gives us a hint over the reallocation effect of activities at the international level. These results need to be confirmed by a full integration into the main macroeconomic model. At this stage also, we do have not capture reflected the effect on migrations, both within and outside Viet Nam, either. In the end, we have deliberately admitted that impacts and adaptation strategies are also a question of governance [Chapter 12] and cooperation [Chapter 8], especially for the Mekong region [Chapter 7], which might even involve historically grounded-based perceptions of the natural environment and a social memory of past climate events [Chapter 2]. Although prospective scenarios provide useful and transparent tools for informed strategic discussions, they must be put in context, which is the purpose of the resolutely trans-disciplinary approach of this project.

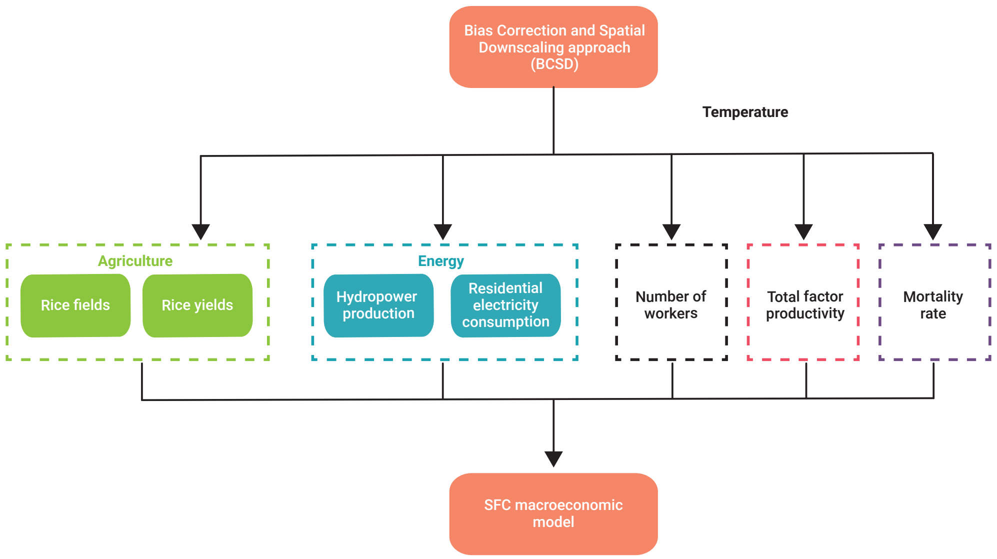
4. Macroeconomic impacts

In this part, we develop the different steps necessary to evaluate macroeconomic climate damage at the national level [Figure 13.11]. Indeed, given the complex relations between sectors in the economy, climate impacts cannot be summarized by the sum over the direct impacts. As soon as they affect a specific sector or economic agent, they disturb the whole set of relations within societies, leading to reallocations in the forms of production. Thus, these estimated damage functions build on the work done in the second part of the report at the sectoral level. In our case, several climate impact channels are considered: how climate change might affect health (from Chapter 3), the agricultural sector (from Chapter 4), the energy sector (from Chapter 5) or labor productivity and total factor productivity (from Chapter 6), while also considering the complex dynamics of climate impacts in the Mekong region (Chapters 7, 8, 9). They will then be implemented within the GEMMES Viet Nam macroeconomic model in order to assess the macroeconomic effects of different climate change scenarios.

4.1 An empirical stock-flow consistent macroeconomic model for Viet Nam

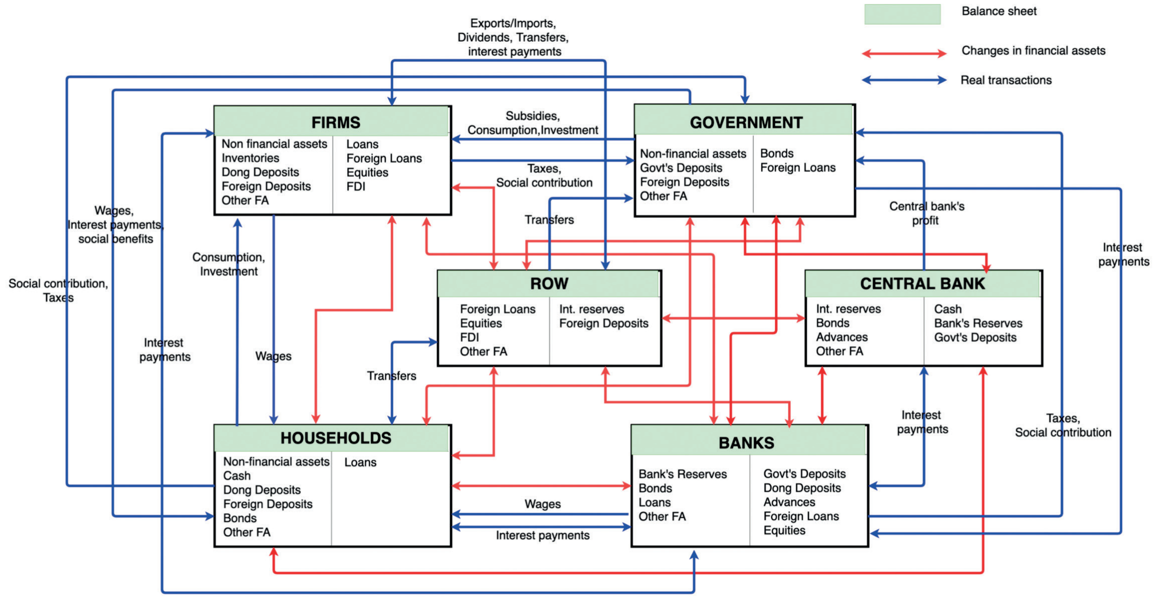
Vietnamese government institutions, research institutes and universities use different types of macroeconomic models for forecasting and

[Figure 13.11]
Macroeconomic impacts framework



Macroeconomic impacts from climate change scenarios via different channels in the macroeconomic model.

[Figure 13.12]
Circular flow of the economy and balance sheet structure



Transactions of the real economy (in blue) and financial flows (in red) between sectors. Balance sheet structure of each sector with assets on the left and liabilities on the right of each institutional sectoral account.

modelling the Vietnamese economy, as well as policy analysis. They include input-output (I-O) models, regression-based econometric models, time series models and Computable General Equilibrium (CGE) – an accounting-based macroeconomic modelling approach. However, overall, there is a lack of attention paid to the financial sector/system in these models. Stock-flow consistent (SFC) models, although marginalized during the period of the so-called great moderation, assume that financial and real variables should be integrated together within the same framework and analysed as a whole in the same model. They are therefore best-suited to address the challenges posed by the recent crisis. The SFC literature has emerged from the post-Keynesian school [Godley and Lavoie, 2007], itself a product of discussion around James Tobin (1969). The SFC approach relies on two main basic principles: accounting consistencies (i) flow consistency, (ii) stock consistency, (iii) stock-flow coherence, and (iv) quadruple entry) and post-Keynesian closure/behavioural specifications, which explain how economic agents determine and finance their expenditure, and allocate their wealth among different non-financial and financial assets (See Figure 13.12). In this chapter, we thus use the first empirical stock-flow coherent model for the Vietnamese economy[1].

1. The model is fully described in an incoming AFD Working Paper. This chapter only highlights its key characteristics and presents the main results of the climate impact simulations.

Our model is multi-sectoral in order to assess the cross-sectoral effects of different types of climate impacts. Although a few studies have tried to integrate the SFC approach with the I-O approach, notably to address environmental issues [Jackson *et al.*, 2014], or energy issues [Berg & Hartley & Richters, 2015], it is among the first empirical multi-sectoral models of this sort.

The macroeconomic specificities of a developing economy experiencing massive structural change with a plurality of possible futures play a key role in assessing prospective climate impacts. Indeed, despite rapid economic growth and transformation, much of Viet Nam's population still depends on agriculture. At the same time, a rapidly expanding energy sector puts key infrastructure at risk of being stranded by changing climates and climate policies, while adaptation pathways are facing the difficulties of rapid structural change. We thus need to make some hypotheses on the future structural transformations experienced by Viet Nam by mid-century. We also use key macroeconomic features from the simple open-economy model of Yilmaz and Godin (2019), and more generic features from the seminal book by Godley & Lavoie (2007).

We assume that there is one single good, domestically produced or imported, that can be used for intermediate consumption, final consumption, export and investment purposes. It is itself produced using agricultural, energy and industrial services, and financial and government production. Firms decide to produce based on adaptive expectations. They invest and accumulate physical capital by using retained profits, borrowing from banks or abroad, issuing equities or attracting foreign direct investment. Climate change affects the agricultural and energy sectors via rice yields, electricity demand and the hydropower sector. They also affect firms' productivity in general via an impact on total factor productivity.

The State Bank of Viet Nam (SBV) determines the refinancing rate as a monetary policy tool, provides advances to the commercial banks and manages international reserves. The SBV does not directly purchase government bonds but indirectly from commercial banks (mainly in repos contract) if commercial banks are in need of liquidity. However, we simplify in our model that the central bank buys the bulk of remaining government bonds. We assume that all the central bank's profits are transferred to the government. In 2016, Viet Nam changed its exchange mechanism by daily determining the central exchange rate and allowing commercial banks to transact within bands of ±3% of this rate. For the sake of simplicity and following IMF (2019), we consider the exchange rate as the result of supply and demand of foreign exchange, with an active intervention of the central bank to the foreign exchange market through reserve stock to respond to the evolution of the exchange rate.

Commercial banks provide credits to firms and households, but they also impose credit rationing on firm and household loans, based on loan-to-value (LTV) and debt-to-income (DTI) respectively. They decide both the lending rate and the deposit rate based on a premium over the central bank's interest rate. Commercial banks also hold part of the government's bonds.

Households use their disposable income to consume, invest and accumulate financial assets in the form of deposits, government bonds, firms' equities or other financial assets. Households can also borrow from commercial banks to meet their financing needs. Households are impacted by climate change through different channels: the number of working hours they can dedicate to firms; their productivity decreases if they catch an infectious disease; the aggregate mortality rate of the population.

The government collects taxes, receives other transfers or payments, and then consumes and invests. The public deficit can be financed by issuing bonds or borrowing from abroad. The rest of the world contributes to financing the domestic economy through foreign direct investment, portfolio investment or foreign loans.

The macroeconomic model for Viet Nam is estimated using the data from 1996 to 2019. We check the model's performance in replicating past data. Then, we simulate it to create a baseline scenario broadly aligned with current Vietnamese Green Growth and NDC strategies in 2030, as well as the socio-economic development trends of Viet Nam and the world.

4.2 Baseline scenario

Firstly, the agricultural contribution to GDP is projected to fall during the period 2020–2050[2]. The rate of population growth is taken from the United Nations population projections for Viet Nam. It represents a downward trend. The capital depreciation rates are projected to remain constant at their current value [IMF, 2018]. Due to the large share of informal and self-employment in the Vietnamese economy and the low level of unemployment in the past, we assume that the unemployment rate will remain constant at the 2019 value [IMF, 2018]. The ratio of public investment to GDP, and public current expenditures to GDP are respectively 6.8% and 5.9%, taken from Viet Nam's Debt Sustainability Analysis (DSA) (IMF, 2018).

2. Projections are taken from the GDP growth baseline projection of Vietnam Green Growth Strategy.

[Table 13.2]
Main assumptions for exogenous variables

Variables	Projections
Sectoral contribution to GDP	Agriculture (8.7%), Industry (45.6%), Services (45.7%) in 2045
Population	United Nations projections (109 million in 2050)
Unemployment rate	2% (Value in 2019)
Capital depreciation	Value in 2019
Public expenditures	5.9% GDP
Public investment	6.8% GDP
Growth rate of world GDP	SSP's projections (SSP5)
Imports of trading partners	OECD's projections
US interest rate	FED's forecasts for interest rate

Several variables reflect the dynamics of the rest of the world. For the growth rate of world GDP, we take the quantitative projections of the so-called Shared Socioeconomic Pathways (SSP5) to facilitate the integrated analysis of future climate impacts and adaptation policies in the second step of the simulation exercise of the model. The demand for real imports by trading partners is based on the OECD's projections.

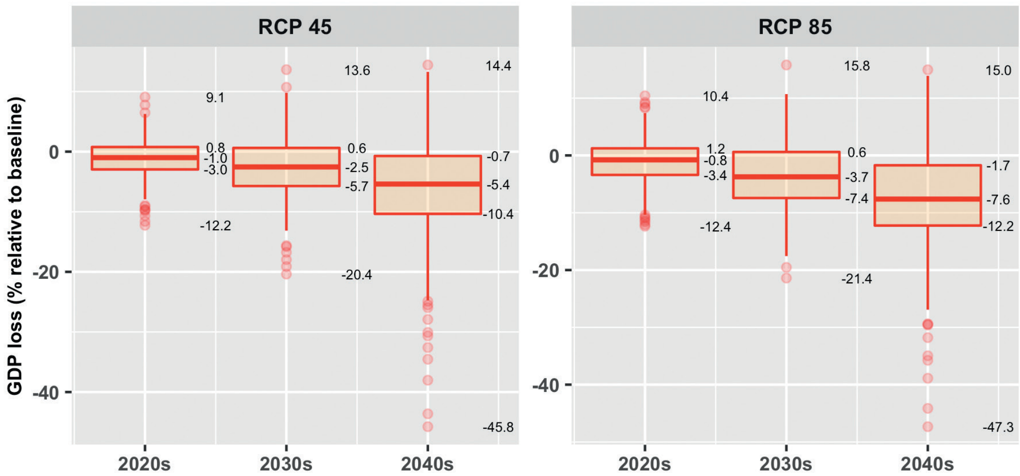
Regarding the financial side of the model, we follow the most recent behaviour of key variables. We follow the projection of the Federal Reserve's interest rate forecasts for the short term and the longer term.

4.3 Climate impacts at the macroeconomic level

Figure 13.13 shows the damages within the macroeconomic model by decade (2020s, 2030s, 2040s) in the simulation where all sectoral damages (agriculture, energy, labor productivity, total factor productivity, mortality) are integrated simultaneously. By the 2040s, averaged losses ranged between 0.7 and 10.4% under RCP 4.5 and between 1.7 and 12.2 % under RCP 8.5.

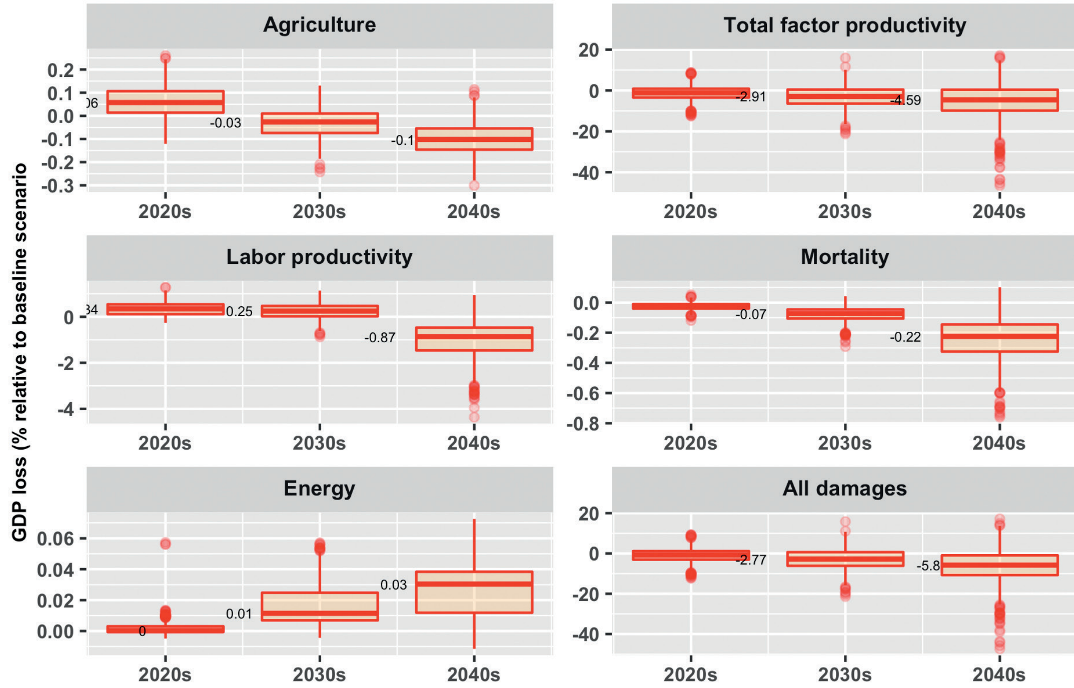
Then, we consider the climate impacts when the model is integrated with damages only in the specified sector [Figure 13.14]. We also compare macroeconomic adjusted losses with direct damage losses. Figure 13.15 shows

[Figure 13.13]
Macroeconomic damage as a percentage of GDP loss relative to baseline scenario



Boxes = interquartile range (25th (Q1) and 75th (Q3) percentile); Black line = median value; Dots = outliers (maximum = Q3 + 1.5 * interquantile range (IQR: 25th to the 75th percentile), minimum = Q1 + 1.5 * interquantile range (IQR: 25th to the 75th percentile). Damage functions (agriculture, energy, labor productivity, total factor productivity, mortality) are taken into account.

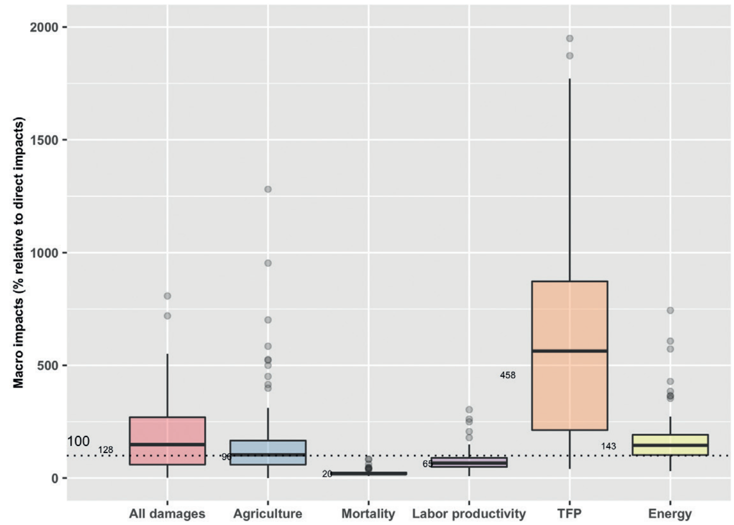
[Figure 13.14]
Macroeconomic damage as a percentage of GDP loss relative to baseline scenario by sector



Boxes = interquartile range (25th (Q1) and 75th (Q3) percentile); Black line = median value; Dots = outliers. Agriculture, Energy, Labor productivity, Total factor productivity and Mortality are integrated in the specified sector and GDP losses when all sectors are considered simultaneously.

that the direct damages of one sector in the macroeconomic model can be larger or smaller than the corresponding direct damages valuation, depending on the sector. The case of mortality, it is much smaller in the macroeconomic model due to the way of valuation of mortality by using VSL. In the case of TFP, the macro impact is much larger due to the role of TFP in the model, which contributes to the production decision, the investment decision. Overall, the macroeconomic impacts losses are larger than direct damages by around 30%.

[Figure 13.15]
Distributions of GDP loss in the macroeconomic model compared with direct damages



Boxes = interquartile range (25th and 75th percentile); Black line = median value; Dots = outliers.

5. Viet Nam's external climate constraint under the Thirlwall's law stability condition

Viet Nam is one of the most open economies in the world, with trade in merchandise reaching 196% of GDP in 2018. Yet the country may both export to and import from climate-sensitive countries. In the long term, there will be a differentiated impact on countries' export and import growth rates, and this impact varies over time and across different groups of exporting and importing countries. If we consider the fact that the country is highly open, this implies that climate change may indirectly impact Viet Nam's economy through changing trade patterns. Because export-oriented activity clearly supports the country's growth, we need to address climate-related challenges by taking into account potential "international spillover damages". Ultimately, climate change is a global externality, meaning that Viet Nam could be further affected by climate damage incurred by its trading partners, and that an adjustment in trade patterns could increase the burden of climate impacts. By ignoring such "international spillover damages", the Vietnamese government may misjudge the climate shock on the domestic economy.

Accordingly, the present section aims to measure the consequences of climate change on Viet Nam's patterns of trade and the related competitive position. In that respect, the theory of Balance-of-Payments-Constrained Growth (BPCG) is a particularly well-suited approach to our purpose. Originally proposed by

Thirlwall (1979), this theory broadly appeals to external demand-side constraints in explaining long-term growth. It allows us to analyse how, and through which transmission channels, the changing geography of international trade resulting from climate damage would impact the evolution of Viet Nam's external constraints and growth rates in the long term.

Our analysis on the projected costs of climate change is measured in comparison with a baseline scenario absent climate considerations. Because of cross-country linkages through bilateral trade, there are two channels through which "international damage spillovers" occur. First, we can easily trace the dynamics of partners' growth in the two alternative scenarios (with and without climate damage) to project future trends in Viet Nam's volume of exports. Second, since the domestic impact of climate change may be heterogeneous across countries, there will be a differentiated impact on export and import market shares. Both terms play a critical role in summarising behavioural parameters that are likely to shift relative competitive positions.

5.1 Analytical framework

The impact of climate change is likely to vary considerably across countries at different levels of economic development and trade openness. If climate change had homogeneous impacts across trading partners and Viet Nam, there would be no change in the country's relative competitiveness; but if instead Viet Nam was negatively affected by climate damage while its trading partners were more severely impacted, then the country's relative competitiveness would be improved. Therefore, we need to understand not only the impact of climate change on potential domestic disruptions of economic activity in Viet Nam, but also the projected impacts on trading partners and their positions relative to Viet Nam.

In this context, we propose to examine how trade interrelations are channels through which climate impacts are transmitted into the Vietnamese economy. With projections on the implications of climate change for its main trading partners, these interlinked impacts labelled "international spillover damage" will allow us to measure the effect on Viet Nam's relative competitiveness and long run growth rate. To our knowledge, Gassebner *et al.* (2010) and Oh and Reuveny (2010) were the first to highlight the significant effects of natural disasters on bilateral flows by using a trade gravity analysis. Although research on the trade effect is in its infancy, a multi-country setting is still lacking to assess the indirect effects of climate change. The OECD (2015) and Dellink *et al.* (2017) embraced climate-related issues by providing a DCGE modelling approach to climate damage through to 2060. Specifically, Dellink *et al.* (2017) used the OECD's ENV-Linkages model to explore the long-term impacts of climate change on international trade, diving much deeper into the consequences for competitiveness, specialization, and changes in international trade patterns.

This paper builds on the OECD's ENV-Linkages model simulations to highlight geographic disparities in the indirect consequences of climate change. While an aggregated model of the domestic economy is assumed, a multi-country setting is required to simulate the effects of climate damage on the international geography of trade. Given that domestic growth depends on the growth rate of other countries, it is clear that the relative impact in a country compared to its trading partners matters more for growth predictions than the absolute size of damage.

[Box 13.2]

A multi-country or disaggregated version of Thirlwall's law

Thirlwall's law postulates that the growth rate of an open economy which is consistent with its Balance-of-Payments (BP) equilibrium defines the maximum rate that it can reach in the long run [Thirlwall, 1979]. In its original version, this growth rate is determined by the ratio of the growth rate of aggregate exports (which is, in turn, determined by the exogenously given growth of world income) to the income elasticity of import demand. In practice however, an individual country trades with numerous partner countries and each bilateral trade relation may have different outcomes. Since the economic growth of a country depends on the growth rate of other countries through the BP constraint, this mutual interdependence should be reflected in a model, with multilateral trade relations between the individual country and blocks of countries. Accordingly, our analytical framework relies on Mania *et al.* (2021), who apply a multi-country specification initially developed by Bagnai *et al.* (2016).

Let's assume that a given country *i* has *n* trading partners. Equations (A1) and (A2) feature the conventional demand functions for imports and exports respectively, and equation (A3) sets an equilibrium condition for the BP on the current account as follows:

$$M_{ij} = \left(\frac{P_i}{E_{ij}P_j}\right)^{\psi_{ij}} Y_i^{\pi_{ij}} \qquad \text{(A1)}$$

$$X_{ij} = \left(\frac{E_{ij}P_j}{P_i}\right)^{\eta_{ij}} Y_i^{\varepsilon_{ij}} \qquad \text{(A2)}$$

$$P_i \sum_j X_{ij} = \sum_j E_{ij}P_jM_{ij} \qquad \text{(A3)}$$

where P_i are country *i* export prices, X_{ij} is the real demand of partner *j* for country *i* exports, E_{ij} is the bilateral nominal exchange rate, P_j are export prices in *j*, and M_{ij} are country *i* imports from partner *j*, $\Psi_{ij} > 0$ and $\pi_{ij} > 0$ are respectively the price and income elasticities of country *i* imports from partner *j*, $\eta_{ij} > 0$ and $\epsilon_{ij} > 0$ are respectively the price and income elasticities of country *i* exports to partner *j*.

Taking the growth rates in (A4) we obtain (where dots denote the growth rates):

$$\dot{P}_i + \textstyle\sum_j \nu_{ij}\dot{X}_{ij} = \sum_j \mu_{ij}\left(\dot{E}_{ij} + \dot{P}_j + \dot{M}_{ij}\right) \qquad \text{(A4)}$$

With: $$\nu_{ij} = \frac{X_{ij}}{\sum_j X_{ij}} \qquad \mu_{ij} = \frac{E_{ij}P_jM_{ij}}{\sum_j E_{ij}P_jM_{ij}}$$

v_{ij} and μ_{ij} are respectively the market shares of partner *j* in country *i* total exports (in volume) and in country *i* total imports (in value).

Solving for the growth rate of country *i* and assuming that relative prices are not trending (namely, the ratio of domestic to foreign prices expressed in domestic currency), we obtain a multi-country or disaggregated version of Thirlwall's law:

$$\dot{Y}_{i,BP} = \frac{\sum_{j=1}^{n} \nu_{ij}\,\varepsilon_{ij}\dot{Y}_j}{\sum_{j=1}^{n} \mu_{ij}\,\pi_{ij}} \qquad \text{(A5)}$$

It defines the maximum growth rate (also the BPCG rate) that an economy *i* can reach in the long run. In our disaggregated law, the numerator features a volume effect (a weighted sum of real export growth where export market shares intertwine with the income elasticities to magnify partners' income growth). The denominator instead features an "appetite for imports" (a sum of bilateral income elasticities of imports weighted by the corresponding market shares).

Assuming its heavy reliance on foreign-based determinants, a break-down of Viet Nam's long-term growth into different factors from different sources has been undertaken. In that respect, we apply a multi-country specification of Thirlwall's law (see Box 13.2). The changing geography of international trade can shape the evolution of the BP constraint, as the elasticity ratio is rooted in different patterns of production and trade. Taking into account the BPCG model, a country's long-term predicted growth is based on trading partners' growth on the one hand, and on the country's relative competitiveness on the other. Yet both factors are identified as the two key international spillovers through which country i may be affected by the long-term effect of climate change abroad, namely: the changing volume of exports and market shares in country *i* total exports (in volume) and total imports (in value).

Applied to Viet Nam, our approach consists in evaluating the impact of climate change on the BPCG rate, and assumes no mitigation actions are taken during the period considered. To do this, we use data results from Dellink *et al.* (2017), where two scenarios are projected for 2060: a no-damage baseline which simulates overall change in the world economy without taking into account damage caused by climate, and another scenario where climate impacts are integrated into the model[3]. In the implementation of the BPCG model, we aggregate the 25 regions considered in the OECD's ENV-Linkages model by selecting ten key individual countries or blocks of countries that are Viet Nam's major trading partners. Box 13.3 presents the list of partner areas and the 11th group will cover the rest of the world. In our trade statistics, these ten partner areas accounted in 2017 for 90% and 91% respectively of Viet Nam's exports in volume and imports in value.

Moreover, we rely on Mania *et al.* (2021) who constructed the average growth rates predicted by the BPCG model for Viet Nam over the period from 1990 to 2017. The long-term elasticities of bilateral exports and imports featuring the BP constraint are used here to construct the BPCG rate corresponding to the two scenarios, namely: a no-damage baseline (with $Y_{VN,BP}\,(Baseline)$) and a scenario with climate damage (denoted $Y_{VN,BP}\,(CC)$). The objective here is twofold: first, we compare both predicted rates. If $Y_{VN,BP}\,(Baseline) > Y_{VN,BP}\,(CC)$, this indicates that climate damage will tighten Viet Nam's BP constraint and reflect a deteriorating trade position relative to partners (and *vice-versa*). Second, we examine how, and through which transmission channels, the changing trade patterns resulting from climate damage would impact the evolution of Viet Nam's external constraint in the long run.

Before going into an analysis of our results, it is worth mentioning from Equation A5 that three key elements are of interest in comparing our predicted BPCG rates. On the one hand, climate change will hurt partners' income growth and modify Viet Nam's volume of exports (Y_j); on the other hand, the domestic impact of climate change in each partner *j* over time will have a differentiated impact on Viet Nam's export ($v_{ij}\varepsilon_{ij}$) and import ($\mu_{ij}\pi_{ij}$) competitiveness relative to partner *j*. In our analysis, we consider that change in the country's relative competitiveness arises exclusively through change in the related export and import market shares ($\Delta v_{ij} \Delta\mu_{ij}$), given that long-term income elasticities are unaffected by climate damage (in line with a "business-as-usual" benchmark). In addition,

3. See Dellink *et al.* (2017) for a description of the model and damage that is taken into account.

[Box 13.3]

Viet Nam's trading partner group

CHN	China (including Hong-Kong, SAR)
JPN	Japan
KOR	Rep. of Korea
IND	India
USA	United States of America
RoA	Rest of Asia
OTPP-HI	Other Trans-Pacific Partnership-High Income countries (Australia, Canada, New Zealand)
EU-28	European Union
AFR	Africa
LA	Latin America
RoW	Rest of the World.

the multi-country setting cannot be decomposed in bilateral terms, *i.e.* we cannot define something as a "BoP-constrained-by-partner-*j*-growth rate". However, it allows us to assess separately the contribution of each partner *j*'s variable to changes in the aggregate BP constraint. Therefore, our multi-country version will allow us to break down the overall impact in relation to the evolution of Viet Nam's trade position *vis-à-vis* each partner *j*.

5.2 The impact of climate change on Viet Nam's international trade position

A global assessment

In this subsection, we first compare the average growth rates predicted by our disaggregated law in the two scenarios. Table 13.3 shows our results over the period 2020–2060, and separately for the two sub-periods 2020–2040 and 2040–2060. We observe that $Y_{VN,BP}$ *(Baseline)* > $Y_{VN,BP}$ *(CC)* whatever the time span considered. Thus, climate change leads to a tightening of Viet Nam's BP constraint. This overall impact is reflected in a 0.13 point reduction in the average growth rate over the period 2020–2060 (*i.e.* a 2.5% reduction). Note that the climate-induced impact on Viet Nam's BPCG rate is non-linear, as the decline is deeper in the second sub-period (-3.2% *vs* -2.1%). The gap is not excessively large because, as growth is a cumulative process, the reductions in GDP levels as a result of climate change translate into small reductions in average annual GDP growth rates over the simulation period. In order to capture the scale and implications of this gap, it can be evaluated that if Viet Nam's actual future growth rates matched the BPCG predicted ones, the fractional loss would be 4.84% of GDP in 2060[4].

Viet Nam's competitiveness in relation to its main partners

What is now interesting is to analyse the contribution of each explanatory variable and partner area to the tightening of the BP

4. In 2060, the loss attributed to climate change would be equal to $\left(1-\frac{(1{,}05)^{40}}{(1{,}0513)^{40}}\right)*100$

[Table 13.3]

Viet Nam's BPCG rates by sub-periods, with and without climate damage

	$Y_{VN,BP}$ *(Baseline)*	$Y_{VN,BP}$ *(CC)*	Difference in percentage
2020–2060	5,13%	5,00%	-2.5%
2020–2040	6,17%	6,04%	-2.1%
2040–2060	4,11%	3,98%	-3.2%

constraint between the two scenarios. By decomposing the Equation (A5) down linearly through a Taylor series expansion, it is possible to disaggregate the BP constraint development into three components:

i) A partner growth effect. Climate change will hurt partners' income growth and by modifying Viet Nam's volume of exports, it will subsequently affect the external constraint. A positive sign associated with this component explains the tightening of the BP constraint.

ii) An export market share effect. When climate change increases the relative size of Viet Nam's volume of exports on partner *j* market, it will reflect improvement in the country's relative competitiveness and soften the constraint tightening. This favorable effect is then associated with a negative sign.

iii) An import market share effect. When climate change increases the relative size of Viet Nam's import value from partner *j*, it will reflect deterioration in the country's relative competitiveness on its domestic market. The unfavorable effect explains the tightening of the BP constraint and is therefore associated with a positive sign.

By aggregating over partner areas, we get the decomposition by effect of the overall BP constraint tightening (shown in the last line of Table 13.4), which allows us to gauge the relative importance of the different mechanisms at work. We observe that the deterioration in the BP constraint is accounted for at 34.8% by the negative impact of climate damage on partners' growth (mainly China and the USA), at 37% by a reduction in export market shares (particularly vis-à-vis the USA and EU28) and at 28.1% by Viet Nam's import market shares. Unsurprisingly, all trading partners' growth will be negatively affected by climate change, and this explains Vietam's BP constraint development. But this channel intertwines with the export market share effect to magnify the tightening. When looking at the import market share effect, a contrasting picture emerges between China (whose share in Viet Nam's total imports is diminishing) and India with South Korea (whose growing shares in Vietnimports reflect deterioration in the country's relative competitiveness).

If instead we aggregate over the three effects, we get the decomposition by partner area (reported in the last column of Table 13.4). Another contrasting picture is revealed between China on the one hand, and India and the US on the other hand. Indeed, climate-induced damage leads to improving Viet Nam's competitiveness relative to the former (it should be recalled that China is the country's

[Table 13.4]

A full breakdown of the overall decrease in Viet Nam's BPCG rate by effect and by partner area (in %)

	Partner growth	Export market share	Import market share	Total by area
CHN	12,7	-13,3	-30,6	**-31,3**
JPN	-0,1	6,6	6,6	**13,1**
KOR	0,8	-4,8	22,4	**18,4**
IND	3,2	4,6	25,5	**33,2**
RoA	3,7	-7,0	9,7	**6,4**
USA	6,1	30,7	4,1	**40,9**
OTTP-HI	0,0	-2,2	2,4	**0,2**
EUR28	2,1	21,6	-4,8	**18,8**
AFR	1,1	0,8	-3,8	**-1,9**
LA	2,5	6,4	2,6	**11,5**
RoW	2,7	-6,2	-5,9	**-9,3**
Total by effect	**34,8**	**37,0**	**28,1**	**100,0**

Table 13.4 presents the result of our linear decomposition by effect and by partner area. To get a better understanding of their relative weights, the contributions of each effect and partner area are expressed as a percentage of the overall decrease in the predicted growth rate $Y_{VN,BP}(CC)$.

main trading partner), while the opposite occurs in relation to the US and India.

Putting all the information together by crossing the partner/effect level, we observe that the largest positive effects (*i.e.* main explanations for the overall tightening of Viet Nam's BP constraint) are the export market share effect relative to the US (30.7%) and EU28 (21.6%), and the import market share effect relative to India (25.5%) and South Korea (22.4%). Symmetrically, a sizable negative effect (*i.e.* main explanation in mitigating the overall tightening) is the import (-30.6%) and export (-13.3%) market share effect relative to China. In other words, China contributes to alleviating the impact of climate damage on Viet Nam's long-term growth (-31.3% as shown in the first line, last column) because of a joint increase in the export market share and decrease in the import market share (*i.e.* improvement in Viet Nam's relative competitiveness with respect to this partner). In contrast, because the US is the second leading individual market for Viet Nam's exports, the unfavourable evolution of the bilateral export market share deeply affects the BPCG rate in the climate damage scenario. It reveals that Viet Nam would lose competitiveness vis-à-vis its competitors in the US market.

All in all, our decomposition exercise clearly shows that international damage spillovers may indirectly impact Viet Nam's economy through changing trade patterns. By looking simply at predicted changes in the country's BP constraint, these outcomes result from the composition of very different individual behaviors.

6. Conclusion

6.1 Main results

Our results provide a new economy-wide assessment of the social and economic effects of climate change on the Vietnamese economy as a whole, using an integrated macroeconomic framework and based on empirical analyses of climate impacts and available regional and global climate models. Summing across sectoral direct impacts as a function of VNMST change 2020–2099 relative to 1997–2019, we found that expected annual GDP loss reaches 6% relative to the baseline scenario at +1°C of warming. Integrating sectoral damage function within the stock-flow consistent model of the Vietnamese economy, by 2050, averaged losses ranged between 0.7 and 10.4 % under RCP 4.5 and between 1.7 and 12.2 % under RCP 8.5. In addition, we estimate the annual GDP losses due to typhoons in the period 1992-2013 at 2.4%. Uncertainties remain about the future impacts of typhoons combined with climate change scenarios.

Finally, because export-oriented activity clearly supports the country's growth, we specifically account for the potential international damage spillovers that may be incurred by changing trade patterns. Evidence is given that climate change through international damage spillovers is expected to reduce Viet Nam's long-run growth rate over the next 40 years.

This national estimate is built using the first empirical stock-flow coherent macroeconomic model of the Vietnamese economy. In that sense, growth is demand-driven, while production capacities are affected by the direct impacts of temperature increases on agriculture, energy, labour productivity and health (mortality and infectious diseases), and by the indirect impacts of sea-level rise and typhoons on capital stock and agriculture. This estimate will certainly not be the last, as multiple known sectors of the Vietnamese economy for which no suitable studies exist have been omitted from the analysis so far. We could mention the impacts of climate change on tourism, forestry management, aquaculture and fisheries, the informal sector, and biodiversity losses, to name a few. We will complete the work in some of those directions over the remaining duration of the project. But more generally, the GEMMES Viet Nam architecture is designed to be open to contributions from rigorous future studies, which would quantify climate impacts in these "missing sectors". Our approach therefore allows for updates based on new econometric/sectoral modelling results or climate model projections.

The macroeconomic simulations we propose in this chapter try to tackle the complexities of a rapidly developing economy such as Viet Nam. At this stage, they do not capture international trade effects. This is the reason why we have completed them with a specific exercise of simulation of the relative impacts of climate change on Viet Nam's trade partners with the hypothesis that the Thirlwall law is verified. This gives us a hint over the reallocation effect of activities at the international level. These results need to be confirmed by a full integration into the main macroeconomic model. At this stage also, we do have not capture reflected the effect on migrations, both within and outside Viet Nam, either. In the end, we have deliberately admitted that impacts and adaptation strategies are also a question of governance [Chapter 12] and cooperation [Chapter 8], especially for the Mekong delta region [Chapter 7], which might even involve historically grounded-based perceptions of the natural environment and a social memory of past climate events [Chapter 2]. Although prospective scenarios provide useful and transparent tools for informed strategic discussions, they must be put in context, which is the purpose of the resolutely trans-disciplinary approach of this project.

Integrating adaptation

Adaptation has been only partially treated in this intermediary report, at least in quantitative terms. The different field studies and models from Chapters 10 and 11 have shown how complex and multifaceted adaptation could be on the ground. Chapter 12 has investigated the financial aspect of adaptation projects and underscored the lack of consistent data, as well as the difficulties in tracing adaptation financing throughout the budgeting process. These difficulties make it hard to implement adaptation pathways in an empirically consistent way within a macroeconomic model.

However, because the empirical results that we use describe how populations have responded to climatic conditions in the past, our damage estimates capture numerous forms of adaptation to the extent that populations have previously employed them. In that way, we can already obtain sectoral estimates of specific adaptation strategies or costs, and how much they have allowed to mitigate sectoral damage in the past. This has been done specifically in the case of agriculture and health and will be expanded beyond them in a future stage of the project, although there might well be thresholds of climate changes beyond which certain adaptations might be less effective.

Good adaptation strategies in the future also depend on the incorporation of no-regret situations in the face of unexpected climate situations. In this regard, the full assessment of climate uncertainties calls for dynamic adaptive policy pathways, which would strengthen the resilience of physical assets. A recent study by Dabbla-Norris *et al.* (2021) estimates the costs of both upgrading new projects and retrofitting existing assets for a number of countries in the Asia-Pacific region. Upgrading new investment projects involves choices in design and materials: for example, new roads could incorporate drainage to sustain heavier rainfall, or be built on more-elevated terrain to reduce risk of flooding. Retrofitting existing assets involves modifying existing capital stock exposed to natural hazards, and as such is typically much more expensive. It is thus essential to be able to build this dynamic adaptive policy design to minimize costly retrofitting strategies, especially in the Mekong Delta, as illustrated in Chapters 9 and 10.

Policy implications

Even if not all effects have been accounted for, the loss could possibly reach up to about 12.2% GDP relative to the baseline scenario by 2050 under RCP8.5. This could prevent Viet Nam from achieving her development target which is set at about 7% GDP growth annually during 2021–20230 and become an industrialized country by 2045. This urges Viet Nam to pay more attention to climate change adaptation strategy in order to improve resilience, mitigate possible negative impacts and achieve the country's development targets. Viet Nam is currently quite active in responding to climate change.

The recently revised Environmental Protection Law, unlike the previous version, dedicates a separate article on climate change adaptation with concrete regulations on climate change impact assessment, adaptation activities, monitoring and responsibilities. In the National Adaptation Plan during 2021–2030, a vision to 2050, Viet Nam is preparing for a separate Law on Climate Change. These provide a basic framework for planning, designing and implementing climate adaptation. The macroeconomic simulation results in this chapter suggest some policy recommendations on more effective adaptation:

First, adaptation strategies should be designed in a way to combine both bottom-up and top-down approaches. The bottom-up approach has been widely applied in Viet Nam and has helped to identify the climate change impacts on specific sectors or areas and then formulate the relevant adaptation activities accordingly. The top-down approach on the other hand will allow us to take into account the climate change aggregate effects of multi-sectors and help to prioritize resources for more effective adaptation strategies. Measuring aggregate impacts through an integrated modelling framework in this chapter is an example of such a combination approach and should be followed up and improved overtime.

Second, as pointed out in the chapter, the economic damage of climate change can be significant in some sectors such as agriculture or energy or can impact across sectors through labor productivity or total factor productivity loss. Therefore, climate change adaptation will be more effective if it is mainstreamed into master plans. Viet Nam is at the beginning of master planning for the period of 2021–2030 and vision to 2050. All master plans, ranging from national to sectoral, regional and provincial master plans are currently being drafted. The climate change impacts should be taken into account in these plans. Although this has been regulated in the new Environmental Protection Law, the guidance for this mainstreaming needs to be made available soon to be in line with the master planning process.

Third, agriculture and energy sectors are the sectors which have potential for green house gas mitigation as shown in Viet Nam's NDC. This suggests a possibility to combine between mitigation and adaptation measures of these two sectors in order to better mobilize financial resources.

Fourth, as shown in this chapter, climate change is expected to reduce Viet Nam's long-term growth rate over the next decades through "international spillover damages". In this regard, the Ministry of Industry and Trade of Viet Nam is assigned to prepare a report in 2022 to assess the international trade policies, technical barriers related to climate change and propose response solutions. The "international spillover damages" identified in this chapter should be taken into account carefully in this report in order to lead to relevant measures to mitigate the negative impacts of trade.

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