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Climate Change and Poverty in Vietnam

Background Paper

Modeling the Impacts of Climate Change on Future Vietnamese Households

A Micro-Simulation Approach

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Abstract

The impacts of climate change on poverty depend on the magnitude of climate change, but also on demographic and socioeconomic trends. An analysis of hundreds of baseline scenarios for future economic development in the absence of climate change in Vietnam shows that the main determinant of the eradication of extreme poverty by 2030 is the income of unskilled agriculture workers, followed by redistribution policies. Results from sector analyses of climate change impacts—in agriculture, health, and natural disasters—are introduced in each of the hundreds scenarios. By 2030 climate change is found to have a significant impact on poverty in Vietnam in about a quarter of the scenarios, with 400,000 to more than a million people living in extreme poverty just because of climate change impacts. Those scenarios in which climate change pushes the most people into poverty are scenarios with slow structural change away from agriculture, low productivity growth in agriculture, high population growth, and low redistribution levels. Conversely, in scenarios with rapid, inclusive, and climate-informed development, climate change has no impact on extreme poverty, although it still has an impact on the income of the bottom 40 percent.

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Modeling the Impacts of climate Change on Future Vietnamese Households: A Micro-Simulation Approach

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Vietnam has experienced during the past decades unprecedented changes in its economy, land use, demographics, and natural environment. It had made significant progress in poverty reduction, but in 2010 around 20 percent of Vietnam's population still lived in extreme poverty – about 27 percent in rural areas (World Bank, 2012).

In the next 15 years, new challenges linked to climate change could slow down poverty eradication in Vietnam. The country is particularly sensitive to climate hazards, weather variability and water-borne diseases, and all of these shocks are likely to be exacerbated by climate change.

Assessing the impact of climate change on poverty remains however a daunting task. In particular, socioeconomic trends in Vietnam will determine the future impacts of climate change on poor people and on poverty rates as much as climate change itself (Hallegatte, Przyluski, and Vogt-Schilb 2011). The impacts of climate change on poor people will be very different depending on where they live, which sector they work in, and the kind of social protection they benefit from (will the majority of poor people still live in rural areas? Will their income depend on agriculture and ecosystems or will they be more diversified?). It is not hard to imagine that if most workers work outside or without air conditioning, the impact of temperature increase on labor productivity will be stronger than if there is fast structural change away from agriculture and towards services and industry, with fast penetration of air conditioning. Similarly, a poorer household will have a larger share of its consumption dedicated to food and will therefore be more vulnerable to climate-related food price fluctuations than a richer household.

Assessing the future impacts of climate change in Vietnam therefore requires an exploration of future socioeconomic development pathways for the country, in addition to future changes in climate and environmental conditions. To do so, we first assume that there is no climate change, and we explore possible counterfactual scenarios of future development and poverty eradication. Second, we introduce climate change into the picture and look at how it changes the prospect for poverty eradication.

It is impossible to forecast future socioeconomic development. Past experience suggests we are simply not able to anticipate structural shifts, economic crises, technical breakthroughs, and geopolitical changes (Kalra et al. 2014). In this paper, we *predict* neither future socioeconomic change nor the impact of climate change on poverty. Instead, we follow the approach that is the basis of all IPCC reports, namely we analyze a set of *socioeconomic scenarios* and we explore how climate change would affect development in *each* of these scenarios. These scenarios do not correspond to particularly likely futures. Instead, they are possible and internally consistent futures, chosen to cover a broad range of possible futures to allow for an exploration of possible climate change impacts. People sometimes refer to these scenarios as "what-if" scenarios, as they can help answer questions such as "*what* would climate change impact be *if* socioeconomic development followed a given trend." The goals are to better understand how the impact of climate change on poverty depends on socioeconomic development, to estimate the potential impacts in "bad" scenarios, and to explore possible policy options to minimize the risk that such bad scenarios actually occur.

We start by analyzing the drivers of future poverty, and we explore the range of possible futures regarding these drivers to create hundreds of socioeconomic scenarios for Vietnam. This analysis combines household surveys (from the I2D2 database) and micro-simulation techniques (Olivieri et al. 2014; Bussolo et al. 2008; Bourguignon, Ferreira, and Lustig 2005) and is performed in a framework inspired from robust decision-making techniques, in which all uncertain parameters are varied systematically to the full range of possible outcomes. We combine assumptions on future demographic changes (How will fertility change over time? How will education levels change?); structural changes (How fast will developing countries grow their manufacturing sector? How will the economies shift to more services?); productivity and economic growth (How fast will productivity grow in each economic sector?); and policies (What will be the level of pensions? How much redistribution will occur?). The range of possible futures of these parameters is determined based on historical evidence, and on the socioeconomic scenarios currently developed for the analysis of climate change, the Shared Socio-Economic Pathways (SSPs) (Kriegler et al., n.d.; O'Neill et al. 2013). These sets of assumptions are used to generate hundreds of scenarios for the future socioeconomic development of Vietnam.

Then, we select two representative scenarios, one optimistic and one pessimistic in terms of poverty reduction and changes in inequality. Finally, we introduce quantified estimates of the impacts of climate change on agriculture incomes and food prices, on natural hazards, and on malaria, diarrhea and stunting into these two scenarios. Here again the impacts of climate change are uncertain. We thus consider again two cases, one high impact and one low impact, and investigate the potential impact of unmitigated climate change on the number of poor people living in extreme poverty in 2030 in the four cases (optimistic and pessimistic regarding socioeconomic trends, and optimistic and pessimistic regarding climate change impacts).

The results are unequivocal: the impact of climate change on poverty is conditioned by overall development progress. In particular, the impacts of climate change are lower in scenarios with high structural change away from agriculture, high productivity growth in the agriculture sector and high levels of social protection. In scenarios where these conditions are not met, climate change could bring up to 1 million additional people in extreme poverty by 2030.

Even without climate change, very different futures can be imagined for poverty and development in Vietnam

We explore a wide range of uncertainties on future structural change, productivity growth or demographic changes and create a large number (several hundreds or thousands) of scenarios for future income growth and income distribution in Vietnam (Table 1). We then analyze the resulting space of possible future poverty and income distribution using several indicators like the income of the bottom 20%, the number of people living in extreme poverty, the income share of the bottom 40%, or GDP growth.

Consistently with our goal of exploring the largest possible uncertainty, the range of income growth in our scenarios is much larger than the one explored in other scenario exercises, such as the SSPs (Figure 1). All the hypotheses that were made on the input parameters appear however possible (or at least, non-impossible) and based on historical data (see Rozenberg and Hallegatte, 2015).

Table 1 Initial shares and scenario ranges for economic structure, and growth rates, in Vietnam.

		Vietnam
Share of adults in the labor force (%)	2012	81
	Min 2030	68
	Max 2030	91
Share of workers in the agriculture sector (%)	2012	45
	Min 2030	15
	Max 2030	48
Share of workers in the manufacture sector (%)	2012	24
	Min 2030	12
	Max 2030	34
Productivity growth rate for unskilled workers (%)	Min	1
	Max	6

Besides, the “Vietnam 2035” exercise suggests that the desired growth rate in Vietnam for the next 15 to 20 years should be around 7-8% per year, which is outside of the SSP range.

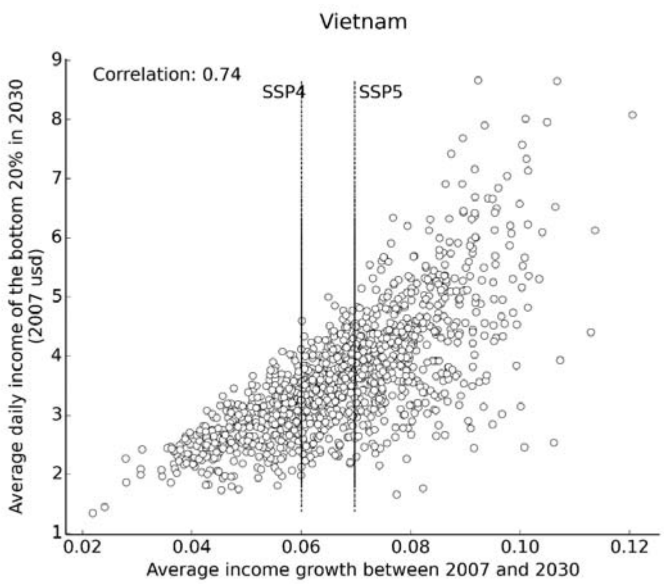

Figure 1 Uncertainty range on total income growth coming out of the experiment, and SSP growth for Vietnam in SSP4 and SSP5, represented by the two vertical lines.

Analysis of variance

To understand what input parameters matter for the reduction of poverty and inequalities, we perform two simple analyses of variance for the income of the bottom 20% and for the difference in income growth between the bottom 40% and the average income in Vietnam. The analysis of variance partitions the observed variance in a variable into components attributable to different sources of variation. In other words, we are explaining the variance of the outputs of our micro-simulation (income of the bottom 20% and inequalities) model by the variance of the inputs (the twelve sources of uncertainty identified previously).

In Vietnam, the most important driver for poverty reduction by 2030 is the income growth rate of unskilled agriculture workers, followed by redistribution. They are then followed by income growth rate of unskilled manufacture workers, population growth rate and the share of workers in agriculture.

The drivers of inequalities are different. They unsurprisingly depend mainly on redistribution and then on the skill premium for services workers (inequalities increase with this skill premium).

Scenario discovery

We then select a group of "optimistic" scenarios (in green in Figure 2 in the case of Vietnam) and a group of "pessimistic" scenarios (in purple in Figure 2). The scenarios are selected in terms of poverty and inequality only: optimistic scenarios are the ones above the median for both the average income of the bottom 20% and for difference in growth rates between the income of the bottom 40% and average income. Similarly, pessimistic scenarios are the ones below the median for both indicators.

Box 1. It is possible to inform decision-making, even in a context of deep uncertainty

We do not attribute probabilities or likelihood to our scenarios. These scenarios thus cannot be used as forecasts or predictions of the future of poverty or as inputs into a probabilistic cost-benefit analysis. That said, they can still be an important input into decision-making. Indeed, decisions often are not based on average or expected values or on the most likely outputs, but instead on the consequences of relatively low-probability outcomes. For instance, insurers and reinsurers are often regulated based on the 200-year losses (that is, the losses that have a 0.5 percent chance of occurring every year). And we buy insurance to protect ourselves against low-probability events that could have a large impact on our well-being.

Moreover, in a situation of deep uncertainty, it is often impossible to attribute probabilities to possible outcomes (Kalra et al. 2014). For example, we know that conflicts, such as those in North Africa and the Middle-East, could continue over decades, slowing down growth and poverty reduction. But they also could subside, allowing for rapid progress. While these two scenarios are obviously possible, it is impossible to attribute probabilities to them in any reliable way. The same deep uncertainty surrounds the future of technologies and most political and socioeconomic trends. In such a context, exploring scenarios without attributing probabilities to them is commonplace. Since the 1990s, the IPCC and climate community have used such long-term socioeconomic scenarios (the Special Report on Emissions Scenarios (SRES) and now the Shared Socio-Economic Pathways (SSPs)) to link policy decisions to their possible outcomes (Edenhofer and Minx 2014). Similarly, the UK government performs national risk assessments using "reasonable worst case scenarios" (for example, regarding pandemics, natural disasters, technological accidents or terrorism), which are considered plausible enough to deserve attention, even though their probability is unknown (World Bank, 2013, chapter 2).

While these scenarios cannot be used to perform a full cost-benefit analysis, they make it possible to elicit trade-offs and to support decision-making. For instance, they help identify dangerous vulnerabilities that can be removed through short-term interventions (Kalra et al. 2014). In our case here, our two scenarios help us explore and quantify how poverty reduction can reduce the vulnerability to climate change.

We then use a scenario discovery algorithm[1] (Bryant and Lempert 2010) to identify a combination of input drivers that is most likely to put the scenario in the optimistic or pessimistic group. In other words, we identify the range of parameter values (or "box") that are found in a group of scenarios and that are not found outside of the group.

Optimistic scenarios in Vietnam are mostly scenarios with high redistribution level, relatively high pension levels, low population growth and high education (SSP5 demography), and relatively high productivity growth for unskilled agricultural workers.

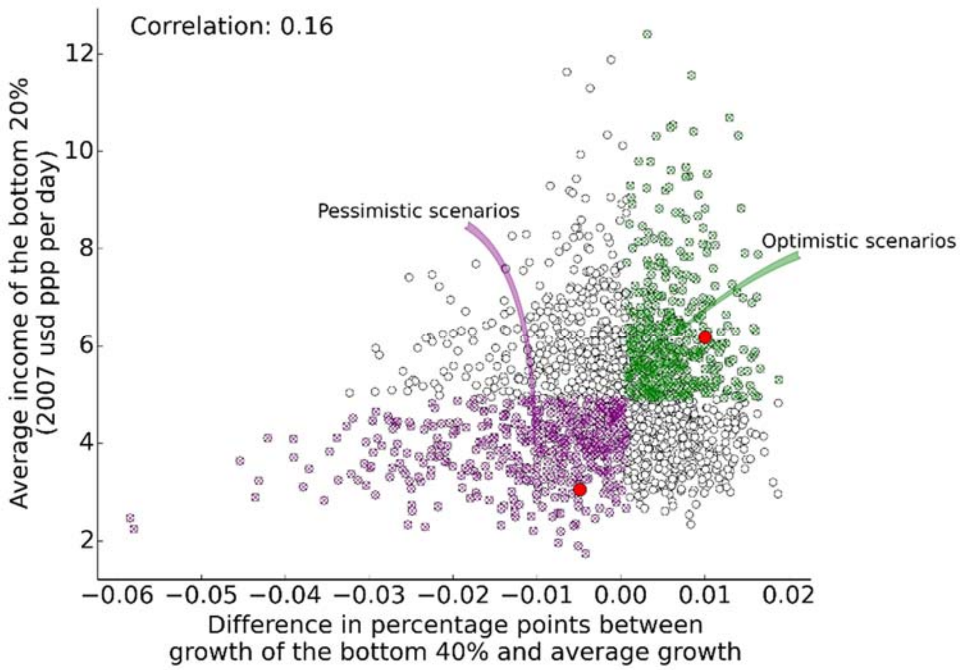

Figure 2 Selection of the optimistic and pessimistic groups and of the two representative scenarios in Vietnam (two red dots).

Pessimistic scenarios are characterized by relatively low redistribution level, high population growth and low education (SSP4 demography), and low productivity growth for unskilled agricultural workers. The details are in Table 1. The other parameters (e.g., structural change or change in productivity in service or manufacturing) play only a secondary role.

Interestingly, the parameters that matter the most for poverty eradication and reduction of inequalities are not the same as the ones that drive GDP growth. For instance, even though structural change is a strong driver of GDP growth (McMillan and Rodrik 2011), in our scenarios it is not sufficient to lift everyone out of extreme poverty, and parallel efforts are required on education, agriculture productivity growth and redistribution.

[1] Here we use the EMA work bench developed at Delft University: http://simulation.tbm.tudelft.nl/ema-workbench/contents.html.

Table 2: sets of conditions (box) that characterize the scenarios in the optimistic group (defined as in Figure 2) for Vietnam. Density is the probability of a scenario in the box to be in the optimistic group. Coverage is the probability of a scenario in the optimistic group to match the box.

Optimistic box 78% density 40% coverage	- High redistribution (tax for cash transfers >8% of total consumption) - Relatively high pensions (tax >5% of total consumption) - Low population growth, high education (SSP5) - Productivity growth for unskilled agriculture workers >2% per year

Table 3: sets of conditions (box) that characterize the scenarios in the pessimistic group (defined as in Figure 2) for Vietnam. Density is the probability of a scenario in the box to be in the pessimistic group. Coverage is the probability of a scenario in the pessimistic group to match the box.

Pessimistic box 47% density 59% coverage	- Relatively low redistribution tax for cash transfers <15% of total consumption) - High population growth, low education (SSP4) - Productivity growth for unskilled agriculture workers <5% per year

If we assume that demography is a given factor, the two main levers to eradicate extreme poverty as fast as possible are agriculture productivity growth and redistribution. Below we explore what is feasible in Vietnam.

Redistribution

Along with agricultural productivity growth, relatively high redistribution is the main lever to reduce poverty in Vietnam in our model. In the model, it is represented by a flat tax on consumption, which is redistributed to the entire population (except children) as a basic income (i.e. the same amount for each individual). We also model redistribution to the elderly as a tax on income from workers only, redistributed as a cash transfer to people older than 60 years. We apply these transfers to households' consumption after pre-existing tax and transfers. They can be seen, therefore, as additional transfers in addition to current ones.

According to the most recent data in the ASPIRE database, 6.3% of Vietnam GDP is used for social transfers (cash transfers only) and people from the first quintile get about 10 times less transfers per capita (in absolute terms) than people from the last quintile. The way we model cash transfers is more favorable to the poor since each person receives the same transfer in absolute terms.

Our results suggest that, to be in the optimistic scenarios in terms of poverty reduction and shared prosperity, Vietnam needs to use 8% of GDP for universal social transfers, assuming that it is financed by a flat tax and people from all quintiles get the same amount. To deal with an aging population while reducing poverty, Vietnam will also need to use at least 5% of workers' income to finance pensions.

Agriculture productivity growth

If high redistribution is too costly, productivity growth for unskilled agricultural workers is another important driver of poverty reduction, even in scenarios in which the share of workers in agriculture is drastically reduced. It is indeed within the sets of conditions for either an optimistic or pessimistic future scenario, combined with population and redistribution.

In a future with high redistribution, low population growth and skilled workers, poverty is low if agriculture productivity growth is higher than 2% per year (Table 2) for unskilled workers. Total agricultural productivity growth depends also on the skill premium in the agriculture sector and lies between 5% and 10% per year in these scenarios.

Such growth rates are comparable to the average growth rates of productivity growth in China (4.7%), Malaysia (4.9%) or Mongolia (7%) over the past ten years, but are higher than what Vietnam has been able to achieve in the recent past (2.4% per year on average between 2002 and 2012).

On the other end, in order to avoid being in the most pessimistic cases if redistribution is low, population growth is high and the share of skilled workers is lower, agricultural productivity growth has to be higher than 5% per year for unskilled workers (Table 3). This threshold correspond to a minimum growth rates of 3 to 9% per year for total agriculture growth, depending on the skill premium.

In a nutshell, to have good chances to reduce poverty, Vietnam must see an agricultural productivity growth of at least 4-5% per year on average over the next 15 years, with at least 2-3 % income growth per year for unskilled workers.

Choice of two representative scenarios

To analyze the impacts of climate change, we first choose two scenarios among the hundreds that were run, one optimistic and one pessimistic. To select one representative scenario in each group, we select only scenarios that correspond to the boxes (i.e. the combinations of drivers most representative of the scenarios in each group) and apply the following additional criteria. For the pessimistic scenario we selected a scenario with a total income growth that is close to GDP growth in the SSP4 (the SSP scenario in which poverty and inequality remain high) and minimized structure change (to represent stagnation). For the optimistic scenario, we tried to be in line with the “Vietnam 2035” scenarios so we aimed at 7-8% annual growth for total income, while minimizing the share of workers in agriculture and maximizing the share of workers in industry, and making sure that skill premiums are not too different between sectors.

Prosperity scenario.

This scenario is optimistic in that it assumes that extreme poverty is eradicated in Vietnam in 2030 (no one lives with less than 1.25usd per day in Vietnam, and only 5 million people live with less than 4usd per day); [2] that population growth is slow (population follows the SSP5 trend), education levels and labor productivity increase rapidly; and that the productivity gap with developed countries decreases quickly (GDP grows at 7.6% per year on average by 2030, and the participation in the labor force increases by 17% in 2030 with regards to 2007). It also assumes that there is fast globalization and technology transfers between countries, allowing rapid structural changes in Vietnam and the reduction of the share of

[2] These simulations are performed using 2005 PPP exchange rate and the $1.25 extreme poverty line, but results are not expected to change significantly under the $1.90 poverty line and using 2011 PPP.

unskilled jobs in agriculture in favor of the industry and service sectors (the share of agriculture is divided by two in the total number of jobs, and the share of industry increases by 40%. Productivity growth reaches 4.6% per year in the agriculture sector, where most of the poorest people work, and 6% in the rest of the economy). Governance is good, and fiscal systems are efficient, allowing for high levels of redistribution. Even the most vulnerable populations have access to universal health coverage, water and sanitation, and efficient safety nets. And agricultural workers have enough market power to receive a large share of agricultural price increases if price shocks occur.

Poverty scenario.

This scenario is pessimistic in that it assumes high population growth (population follows the SSP4 trend with low education levels), low economic growth, and greater inequalities in Vietnam in 2030. In this scenario 2.7 million people still live in extreme poverty in 2030, and 44 million people live with less than 4usd per day. The share of agriculture in total jobs only decreases by 15% and participation does not increase. Productivity growth in agriculture is only 1.8% per year whereas it is 5% per year in the services sector. There is no industrialization in this scenario, with a constant share of jobs in industry and a slow productivity growth (only 1%) for the industry sector.

These two scenarios are counterfactual *reference* scenarios, which do not include climate change. In a second stage, we add climate change impacts into each of these scenarios. We do not attribute probabilities or likelihood to our scenarios, as we are not interested in forecasting the future of poverty. Instead, we want to explore how the impacts of climate change on poverty are different in different development scenarios, with and without climate change, to inform decision-making on poverty reduction and climate policies (Box 1).

The effect of climate change on poverty is a combination of many sectoral impacts

For each of the two selected socioeconomic scenarios (*prosperity* and *poverty*) we introduce climate change impacts on food prices and production, natural disasters, and health, drawing on the results from chapters 2 to 4 in *Shockwaves* (Figure 3). In the projections of all households modeled in our scenarios, we adjust the income and prices to reflect the impact of climate change on their ability to consume, and derive the impact on poverty. The impacts are estimated using sectoral models (such as crops and agricultural trade models) and include adaptive behaviors (such as changing agricultural practices or trade patterns).

With a 2030 horizon, impacts barely depend on emissions between 2015 and 2030 because these affect the magnitude of climate change only over the longer term, beyond 2050. Regardless of socioeconomic trends and climate policies, the mean temperature increase between 2015 and 2035 is between 0.5 and 1.2°C—and the magnitude depends on the response of the climate system (IPCC 2013). The impacts of such a change in climate are highly uncertain and depend on how global climate change translates into local changes, on the ability of ecosystems to adapt, on the responsiveness of physical systems such coastal zones, and on spontaneous adaptation in various sectors (such as adoption of new agricultural practices or improved hygiene habits).

To account for this uncertainty, we define a *low-impact* and a *high-impact* scenario that represent the uncertainty on the magnitude of the physical and biological impacts of climate change. For agriculture, for instance, the difference between the low-impact and the high-impact scenario comes from the uncertainty in the global climate system, crop responses, and trade models that are used. For health, one difference across low-impact and high-impact scenarios comes from the uncertainty on the additional number of cases of dengue and malaria due to climate change and on the cost of treatment.

There are several limits to our approach. First, we follow a bottom-up approach and sum the sectoral impacts, assuming they do not interact. We do not focus on the macroeconomic impact of climate change and its effects on overall economic growth – and thus on the secondary impact on poverty reduction, a limitation considering the evidence that overall growth is a major driver of poverty reduction (Dollar and Kraay 2002; Dollar, Kleineberg, and Kraay 2013). We do so because previous research suggests that the macroeconomic impact of climate change is likely to remain limited by 2030, and because we hypothesize that the main channel from climate change impacts to poverty is the direct impacts, which are largely invisible in macroeconomic models (chapter 1 of the *Shock Waves* report). Second, we only consider a subset of impacts, even within our three sectors – for instance, we do not include the loss of ecosystem services and the nutritional quality of food.

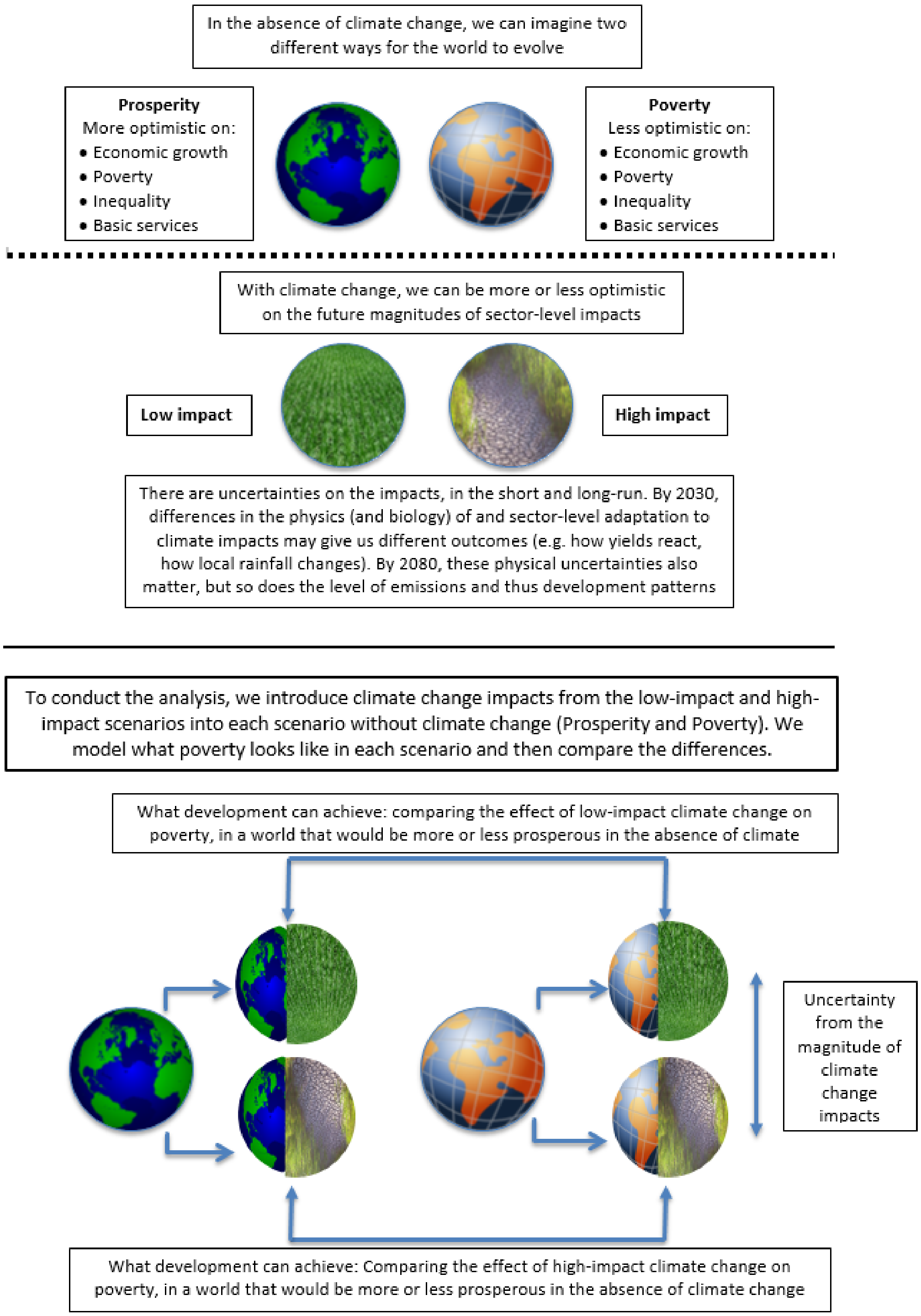

*Figure 3. **Our model for estimating the number of people in poverty due to climate change.** A schematic to represent the modeling undertaken to estimate the impact of climate change on extreme poverty in 2030 under different scenarios of future development, and thus in worlds with different levels of exposure and vulnerability.*

Food prices and food production

Impacts of climate change on agriculture affect poverty in two ways, first through prices and consumption, and second through farmers' incomes. Higher food prices reduce households' available income – especially for the poor, who spend a large share of their income on food products. In our scenarios, the impact depends on the fraction of food expenditure in total expenditure, and this fraction decreases as households get richer. Food price changes also affect farmers' incomes. However, this channel is complex since lower yields (which are expected in many areas due to climate change) mean that higher food prices do not necessarily translate into higher farmer revenues: the net effect depends on the balance between changes in prices and quantities produced.

Table 4 Low-impact and high-impact changes in the agriculture sector due to climate change (RCP8.5) in 2030 in the East Asia region. Source: GLOBIOM model (IIASA). Bold numbers highlight negative impacts, either for consumers (with higher prices) or farmers (with lower revenues).

(a) Low-impact climate change in East Asia

SSP	Socio-economic scenario	Price difference (minimum across all GCMs)	Corresponding production difference	Corresponding agriculture revenue difference
SSP4	Poverty	**0.37%**	-0.74%	**-0.38%**
SSP5	Prosperity	-0.13%	-0.75%	**-0.88%**

(b) High-impact climate change in East Asia

SSP	Socio-economic scenario	Price difference (minimum across all GCMs)	Corresponding production difference	Corresponding agriculture revenue difference
SSP4	Poverty	**3.4%**	-3.2%	0.05%
SSP5	Prosperity	**1.9%**	-3.0%	**-1.17%**

Using the data from our analysis of food prices and production, we change the income of all workers in the agricultural sector, according to the combination of changes in prices and in the quantities that are produced in the East Asia region (see Table and Rozenberg and Hallegatte, 2015, for details). We also rescale the (real) income of all households, accounting for the change in food prices and the share of food in household budget (which decreases with income). The impact of the agriculture channel on poverty depends on the number of farmers in Vietnam, the income of these farmers, and the income of the entire population (which affects the share of food in consumption).

Our results show that in Vietnam, in the *poverty* scenario, the number of people living below the extreme poverty line in 2030 increases by 400,000 people because of climate change impacts on agriculture (in the high-impact scenario). And the number of people living with less than 4usd per day increases by 700,000 people (Figure 4). Those numbers are possibly an underestimation of actual impacts because both climate scenarios (low and high impact) assume that there is CO2 fertilization, which remains uncertain.

In the *prosperity* scenario, even though prices increase by 2% in the high impact scenario and agriculture revenue decreases by 1.17%, the impact on poverty is nearly inexistent, because households are less vulnerable to food price increases and there are fewer unskilled farmers.

Natural disasters

To account for climate change impacts on natural disasters by 2030, we assume that the fraction of the population that will be annually affected[3] by a disaster (about 10% of the population in Vietnam today) increases by 40 percent in the low impact case and by 120 percent in the high impact case, which is in the range reported by (Bouwer, 2013; IPCC, 2014, 2012) for the expected rise in economic losses. Ultimately, these numbers will depend on the effectiveness and timeliness of adaptation to new climate conditions.

In the low-impact case, we assume that affected people lose 20 percent of their annual income if they are poor and 10 percent if they are non-poor; in the high-impact case, the losses would be 30 percent for the poor and 15 percent for the non-poor.[4] These numbers are in line with post-disaster household surveys, even though much higher values are often observed (Patankar 2015; Patankar and Patwardhan 2014; Noy and Patel 2014; Carter et al. 2007). We also assume that natural disasters affect income only during one year, which is a conservative estimate that is valid for small disasters, but not for large scale events like Typhoon Yolanda in the Philippines or Hurricane Katrina in the United States.[5]

Our results show that for natural disasters, in the high impact scenario, the number of poor people rises by 130,000 people in the *poverty* scenario, and the number of people below 4usd per day rises by 83,000 people. Here again, disasters have nearly no impact on poverty in the *prosperity* scenario (Figure 4).

Health and high temperatures

We now include a set of additional impacts of climate change on health (malaria, diarrhea, and stunting), based on the literature reviewed in chapter 4 in *Shock Waves*.

For *stunting*, we include the additional share of children estimated to be stunted because of climate change in 2030. Today in Vietnam 25 to 40% of children under 5 in the three poorest quintiles get stunted. To factor in development, we use data from the Demographic and Health Surveys (DHS) by wealth quintile to explore the relationship between household income and stunting. We find that the prevalence of stunting drops for families whose income is above $8,000 per year. We calculate the fraction of the stunted individuals in the families with income below $8,000, so that stunting prevalence is consistent with data for the current situation. Then, we increase this fraction using projections from (Hales et al. 2014) to account for climate change. We assume that stunted individuals have lifelong earnings reduced by 5 percent (low-impact scenario) and 15 percent (high-impact scenario), regardless of employment sector and skill level.

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[3] We use the fraction of people who lose income. We cannot use data on the number of "affected persons" because the usual definition of *affected* is much broader and includes people who do not lose income because of the disasters.

[4] Because the analysis proposed in chapter 3 does not include all countries, we assume that poor and non-poor people are equally exposed to natural disasters.

[5] Note that the impact of droughts on children through stunting is accounted for in the health impact category.

For *malaria*, we increase the number of malaria cases in 2030 following (Caminade et al. 2014). As with stunting, we calculate the fraction of people who are affected by malaria, based on current prevalence, and we vary this fraction using estimates of future change due to climate change in various regions. Then, based on the literature reviewed in chapter 4, we assume that these people are affected between 0.1 and 2 times per year, and lose income through the cost of treatment (between $0.7 and $6 per occurrence) and lost days of work (by the sick or caregivers, between 1 and 5 days per occurrence). Note that we consider only the monetary expenses due to the disease and do not model non-monetary effects (like the cost of life or loss in well-being from being sick), which would be important in a multidimensional analysis of poverty.

In Vietnam, (Caminade et al. 2014) actually project a decrease of malaria because of climate change. So we increase the income of people who would have been affected by Malaria in the absence of climate change.

For *diarrhea*, we start from data on the number of cases per country today, the cost of treatment (between $2 and $4 per episode), and the number of days out of work (between 3 and 7 days for the sick and caregivers) (Hutton, Haller, and others 2004). We also assume that the prevalence of diarrhea will increase by 10 percent by 2030 because of climate change, using results from (Kolstad and Johansson 2010). In Vietnam, the number of cases per year is around 80% of the population, so it is increased to nearly 90% of the population in our scenarios.

To account for development, we use DHS data to explore the relationship between household income and exposure to diarrhea. We find a threshold at $15,600 per year, and we assume that only households with income below this level are affected by impact of climate change on diarrhea.

Further, we assume that fast progress in access to water and sanitation in the *prosperity* scenario would halve the number of cases, which is consistent with a recent assessment in India (Andres et al. 2014). Of course, this assumes that the new water and sanitation infrastructure can continue to perform well in 2030 and beyond – in other words, that development has been climate-informed. For that to occur, the uncertainty in climate projections would need to be accounted for in the design phase, as would the extra funds needed to invest in more resilient infrastructure (possibly factoring in safety margins and retrofit options) (Kalra et al. 2014).

We find that with high climate change impacts, in Vietnam, in the high-impact case, 350,000 people would be pushed into poverty in 2030 in the *poverty* scenario and 200,000 would be pushed below 4usd per day (Figure 4). However, in the *prosperity* scenario and in the low-impact case, impacts are very small because of the positive impact of malaria (actually, the average income of the bottom 40% slightly increases in the low-impact case, see Table 5).

As for the impact of high temperatures on labor productivity (also based on results presented in chapter 4 in *Shock Waves*), we assume that in hot countries, people working outside or without air conditioning will lose between 1 and 3 percent in labor productivity due to this change of climate, compared with a baseline with no climate change. To assess the number of people affected, we estimate the shares of people working outside or without air conditioning in the two socioeconomic scenarios. Our results show that the temperature impacts of climate change are severe in the *poverty* scenario: 270,000 people would be pushed into poverty in 2030 in the *poverty* scenario, and 700,000 would be pushed below 4usd per day.

Total impacts

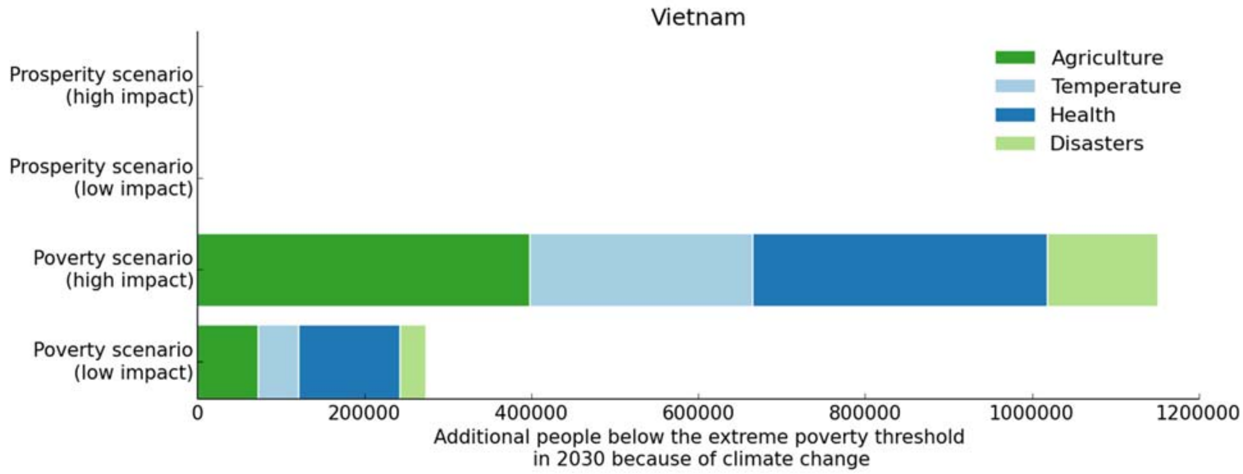
So how do these sectoral results add up in terms of climate change's effect on future poverty trends? We definitely find that a large effect on poverty is possible, even though our analysis is partial and does not include many other possible impacts (for example through tourism, energy prices, foreign direct investment, or remittances) and looks only at the short-term (during which there will be small changes in climate conditions compared with what unabated climate change could bring over the long-term). Indeed, our overall results show that between 0 (in the *prosperity* scenario with low impact) and 1.2 million (in the *poverty* scenario with high impact) additional people would be in poverty because of climate change.

Note that the large range of estimates in our results – 0 to 1.2 million – may incorrectly suggest that we cannot say anything about the future impact of climate change on poverty. The reason for this rather wide range is not just scientific uncertainty on climate change and its impacts. Instead, it is predominantly policy choices – particularly those concerning development patterns and poverty reduction policies between now and 2030. While emission reduction policies cannot do much regarding the climate change that will happen between now and 2030 (since that is mostly the result of past emissions), development choices can affect what the impact of that climate change will be.

In the *prosperity* scenario, the lower impact of climate change on poverty comes from a reduced vulnerability of Vietnam to climate change compared to the *poverty* scenario. This reduced vulnerability, in turn, stems from several channels.

- People are richer and fewer households live with a daily income close to the poverty line. Better-off people are less exposed to health shocks (such as stunting and diarrhea) and are less likely to be pushed into poverty when hit by a shock.
- The global population is smaller in the *prosperity* scenario in 2030, by 2 percent globally, 4 percent in the developing world, and 10 to 20 percent in most African countries. This difference in population makes it easier for global food production to meet demand, thereby mitigating the impact of climate change on global food prices. The *prosperity* scenario also assumes more technology transfers to developing countries, which further mitigates agricultural losses.
- There is more structural change (involving shifts from unskilled agricultural jobs to skilled manufacturing and service jobs), so fewer workers are vulnerable to the negative impacts of climate change on yields. In the *prosperity* scenario, a more balanced economy and better governance mean that farmers capture a larger share of the income benefits from higher food prices.

(a)



(b)

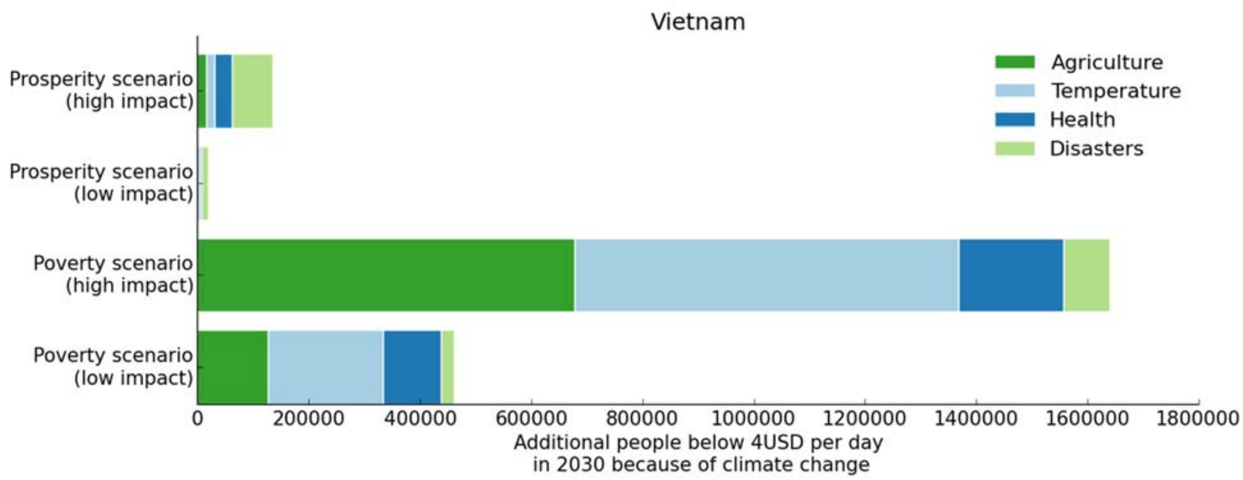


Figure 4 Climate change impacts on the number of people living below the extreme poverty threshold (panel a) and with less than 4usd per day (panel b) in 2030 in Vietnam

Up to 2030, climate change remains a secondary driver of global poverty compared to development: the difference across reference scenarios due to socioeconomic trends and policies (that is, the difference between the *poverty* and *prosperity* scenarios in the absence of climate change) is 2.7 million people.

Shared prosperity

When looking at impacts on the income of the bottom 40% and on GDP (Table 5), the story is somewhat different. First, most of the uncertainty comes from the uncertainty on climate impacts and not on development choices. Even though the impact on the bottom 40% is still higher in the poverty scenario (4.3% loss) than in the prosperity scenario (2.5% loss), the difference between the high impact case and low impact case is higher than the difference between poverty and prosperity. And for GDP, impacts are around 2% in the high impact case and around 0.6% in the low impact case, in both the poverty and prosperity scenarios.

Note that these impacts on GDP come from a bottom-up approach and do not replace macro perspectives. For instance, our household approach misses the richest households (who are often absent from the surveys) and not capture general equilibrium effects. However, it brings complementary and new information to traditional macroeconomic approaches. Aggregate numbers can indeed be misleading because they can the impacts of climate change on poverty. They also hide the fact that rapid and inclusive development can dramatically reduce the impacts of climate change on poor people while having limited effect on climate impacts on total income.

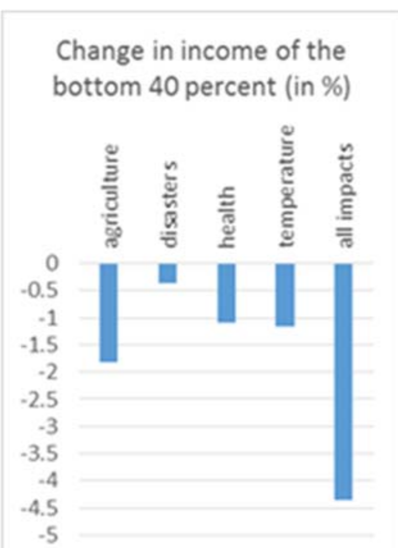
Table 5 Climate change impacts on the average income of the bottom 40% (panel a) and GDP (panel b) in Vietnam in 2030.

(a) Difference in the income of the bottom 40% in % (low-impact/high impact)

	Agriculture	Disasters	Health	Temperature	Total
Poverty scenario	-0.42/-1.8	-0.07/-0.37	-0.42/-1.1	-0.39/-1.2	-1.2/-4.3
Prosperity scenario	-0.12/-0.96	-0.06/-0.19	-0.09/-0.1	-0.43/-1.3	-0.52/-2.5

(b) Difference in GDP in % (low-impact/high impact)

	Agriculture	Disasters	Health	Temperature	Total
Poverty scenario	-0.12/-0.82	-0.07/-0.25	-0.11/-0.29	-0.31/-0.94	-0.61/-2.3
Prosperity scenario	-0.1/-0.77	-0.08/-0.26	-0.06/-0.17	-0.41/-1.2	-0.65/-2.4



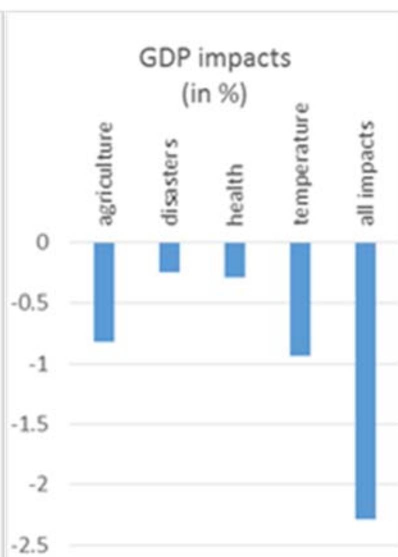


Figure 5 Impacts on shared prosperity and GDP in the poverty/high impact scenario

Coming back to the hundreds of scenarios: which socioeconomic conditions lead to the highest climate change impacts?

Finally, in order to check the sensitivity of our climate change impact results to socioeconomic conditions, we run the high impact scenario in the hundreds of baselines previously run. We find that with the high impact scenario, climate change leads to between a few hundreds to 1.2 million additional people in extreme poverty depending on the baseline. These numbers show that our two representative scenarios where the extremes in terms of sensitivity to climate change. Among the hundreds of scenarios, 25% of them have more than 400 000 additional people in extreme poverty because of climate change.

We then run the scenario discovery again, in order to explain the common characteristics of the scenarios that have more than 400,000 additional people into poverty because of climate change. We find that 70% of those scenarios have a high population growth (SSP4 scenario), a low productivity growth for unskilled agriculture workers (less than 3% per year), a relatively high share of jobs in agriculture (more than 33%) and low redistribution levels (less than 12% of GDP). These criteria are very similar to the criteria that led to high poverty and high inequalities in the baseline scenarios, so it is not surprising that we chose one of the worst scenarios in terms of impacts when we chose the pessimistic baseline scenario. These results show that in Vietnam, since the drivers of poverty are also the drivers of climate change impacts on poverty, poverty reduction efforts are a good adaptation policy.

What messages should we take away from all of these results?

First, the quantitative impacts of climate change on poverty in Vietnam are uncertain, but could be significant, even over the relatively short-term. It is true that our analysis does not cover all climate change impacts (like those on ecosystem services), yet we still find that more than 1 million people may be pushed into poverty because of climate change impacts in Vietnam.

Second, most of the uncertainty surrounding these impacts comes from development choices made between now and 2030 in Vietnam, and can therefore be actively reduced by implementing the right policies. The quantitative impacts of climate change on poverty are much smaller if socioeconomic trends and policies ensure that development is rapid, inclusive, and climate-informed, than if extreme poverty persists even without climate change. Development policies supporting high growth, in particular in agriculture, structural changes, expansion of social protection like health insurance, expansion of access to clean water and sanitation, and education, are good adaptation policies that will ensure climate change does not hurt poor people by 2030 in Vietnam.

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