THE ECONOMIC IMPACT OF SEA LEVEL RISE

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Sea level rise has a range of impacts on the coast, including permanent inundation, increased flood risk, wetland loss, and saltwater intrusion. Enhanced protection of the coast would alleviate some of these impacts (e.g., flood risk), but may ameliorate others (e.g., wetland loss).

The bulk of the literature on the economic impact of sea level rise has used the so-called direct cost method to estimate the total welfare loss. This method is conceptually straightforward. One starts with estimates of the physical impacts, estimates the price, multiplies the two, and adds the results across impacts, space and time.

While conceptually straightforward, there are practical difficulties. The price of permanent inundation, for instance, is the average value of land. Although beach front property is considerably more expensive than property further inland, sea level rise would shift the coastline. Beach front property would get lost, but adjacent property would become beach front and thus appreciate in value. The appropriate value of land is therefore the average value of land. But where would one get an estimate of the average value? Some countries have a well-developed market for land and a robust administration that collects and reports such data. Most countries, however, lack either or both.

Figure 1 shows one attempt to fill the data gap. It assumes that land value is a function of income density ($/yr/ha) – the product of per capita income ($/p/yr) and population density (p/ha). The income density elasticity of land value is estimated using data for the states of the USA. The US average land value is used as the basis for extrapolation to the rest of the world. Figure 1 contrasts this estimate to two other, equally crude attempts which agree on the broad picture but disagree on the details.

There are different issues with the cost of coastal protection. Dikes, seawalls, groins, etc are often built in the same way around the world, and often by the same small group of multinational companies. While estimates are available for the cost of raising a kilometer of dike by one meter, say, the analysis is complicated by the fact that different places would opt for different types of coastal protection.

Wetlands impose yet another challenge. There is a market price for land and for coastal protection. There is no market for wetlands. One therefore has to rely on non-market valuation techniques. Brander et al. conduct a meta-analysis of wetland values. Figure 2 reproduces some of their results, which confirm expectations. Wetlands are more valuable in places where there are many people and where there are rich people; larger wetlands are less valuable, per hectare, than smaller wetlands. At the same time, Figure 2 reveals a large range of wetland values. This is partly because wetlands are very heterogeneous, and partly because non-market valuation is difficult and prone to measurement error.

One cannot study the impacts of sea level rise (or any other aspect of climate change for that matter) without adaptation. Some forms of adaptation are trivial. Sunbathers are unlikely to return to a beach, or the beach that their grandfather used to frequent, if it would be washed away. There is no risk that sea level rise would drown them. Coastal protection, on the other hand, is typically regarded as a collective or public good.

One could take one of two approaches to model and protect coastal protection. One could study the type and design standard of coastal protection as it is. This is hampered by poor data. Attempts to gather data on the design standard of dikes and seawalls have led nowhere, even for data-rich and well-organized places like the European Union. Instead, one could study the frequency of floods. Data are available – cf. Figure 3 – but while multiple regression analysis reveals certain patterns – richer, more egalitarian, more authoritarian countries are less vulnerable to natural disasters – a substantial part of the variance cannot be explained.

The second approach to modeling coastal protection is to consider optimal adaptation. This approach circumvents the problem of collecting data on how people adapt, but it creates a counterfactual set of data on how people should adapt. There are a few studies that compare actual and optimal coastal protection. These studies suggest that decisions about coastal protection are typically not based on a cost-benefit analysis. Nonetheless, optimal adaptation is the method most prevalent in the literature.

Figure 4 shows some results for direct cost estimates. Figure 4 displays the fifty most vulnerable countries in 2100 – that is, the countries with the highest total cost relatively to their gross domestic product. While sea level rise would cost more than 0.5% of GDP in a handful of countries, the relative cost is much smaller than that in the vast majority of countries. The main reason for this result is that the absolute cost of coastal protection is stable over time, and therefore falls relative to the value of land and the size of the economy. As a result, a greater share of the coastline is protected and the relative costs of sea level rise fall. Exceptionally vulnerable are countries with a coast that is long relative to the hinterland – that is, small islands – and poor countries in river deltas.

Direct costs are conceptually straightforward albeit uncertain in practice. Direct costs, however, are only an approximation of the true impact of sea level rise on welfare. Particularly, a loss of land would reduce production in agriculture, which would drive up food prices and leave less money for other consumption. Coastal protection would increase the demand for construction and for investment funds. In order to fully appreciate the economic implications of sea level rise, one would need to use a computable general equilibrium model.

Figure 5 shows the results of such an analysis. In the scenario, it is assumed that there is no additional coastal protection. The analysis is done for assumptions that may reflect the economy of 2050, and sea level is assumed to rise by 25 cm. Two shocks are considered. First, only land is lost. Second, both land and the capital on that land are lost. In the first shock, people anticipate sea level rise and fully depreciate their houses, factories, roads etc before they are washed away by the waves. In the second shock, there is no anticipation of sea level rise. Economic activity falls if productive assets are lost to the sea. Developed economies respond little to a reduction in the availability of land but more strongly to a loss of capital; less developed economies respond in the opposite way. This reflects the relative land- and capital-intensity of production.

Figure 6 shows results from the same model and analysis, now assuming that all vulnerable and inhabited coasts are fully protected. Two mechanisms explain the pattern in Figure 6. First, coastal protection stimulates the economic activity through an increased demand for construction. (This also illustrates that GDP is a poor indicator for welfare.) Second, the increase in the demand for investment and hence savings suppresses consumption. Therefore, the impact of coastal protection is net positive in regions that have a lot of coast to protect (Australia, Canada, Russia) and it is net negative in regions that finance a lot of international investment (European Union, Japan – the model is calibrated to data from the mid-1990s).

Figure 7 compares direct cost estimates to the true welfare impact (or rather, the Hicksian equivalent variation), considering a scenario without additional coastal protection. Figure 7 reveals that, globally, the direct cost estimate underestimates the true welfare loss, but only by 15% or so. Direct costs are necessarily lower than welfare, because a loss of a productive asset deflates the entire economy and raises production costs everywhere. The direct costs only include the direct implications. Figure 7 further shows that the regional pattern of impacts is different. In some regions, the true welfare loss may be lower than the direct cost estimate. In this case, that is because relatively land-abundant regions (Brazil, Ukraine) can take advantage of land loss elsewhere and increase their agricultural production and export.

Although sea level rise is one of the better understood impacts of climate change, the above review suggests that current impact estimates leave much to be desired. There is a paucity of high-quality data. Partly, this is because not much of an effort has been made (e.g., land values). Partly, this is because good data is expensive to collect (e.g., wetland values). Partly, this is because most of the impact will take place in the future and studies necessarily rely on extrapolation. Two big uncertainties are the value of wetlands and the nature and intensity of coastal protection. Two unquantified unknowns the impact of saltwater intrusion and the effect of change in the frequency, direction, and intensity of storms.

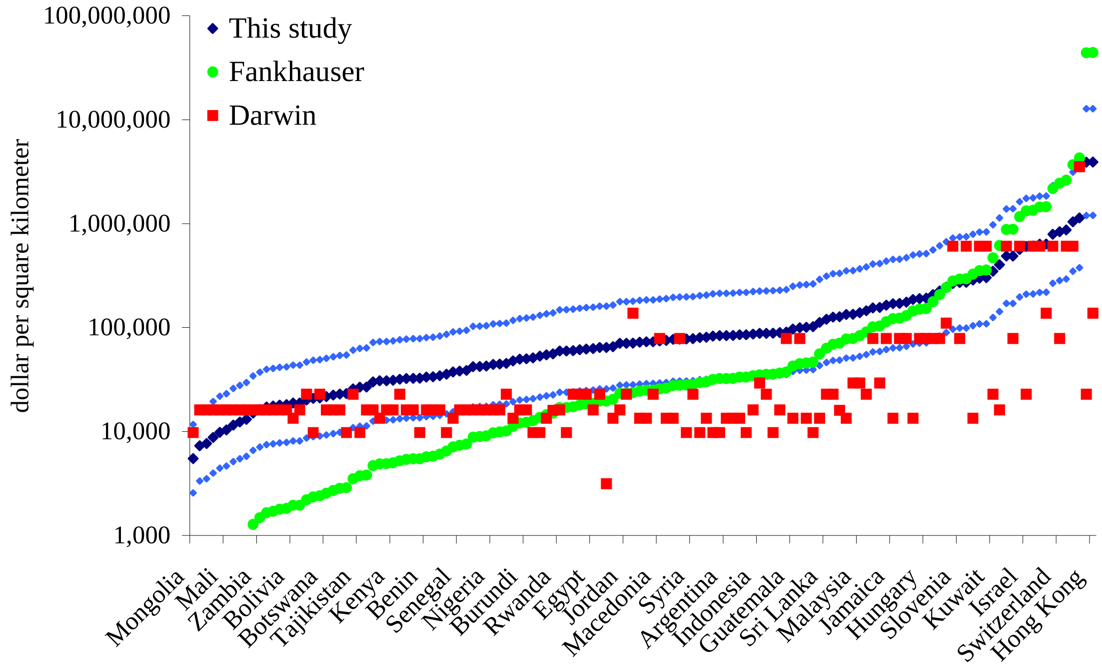

Figure 1. Three alternative estimates of the national average value of agricultural land.

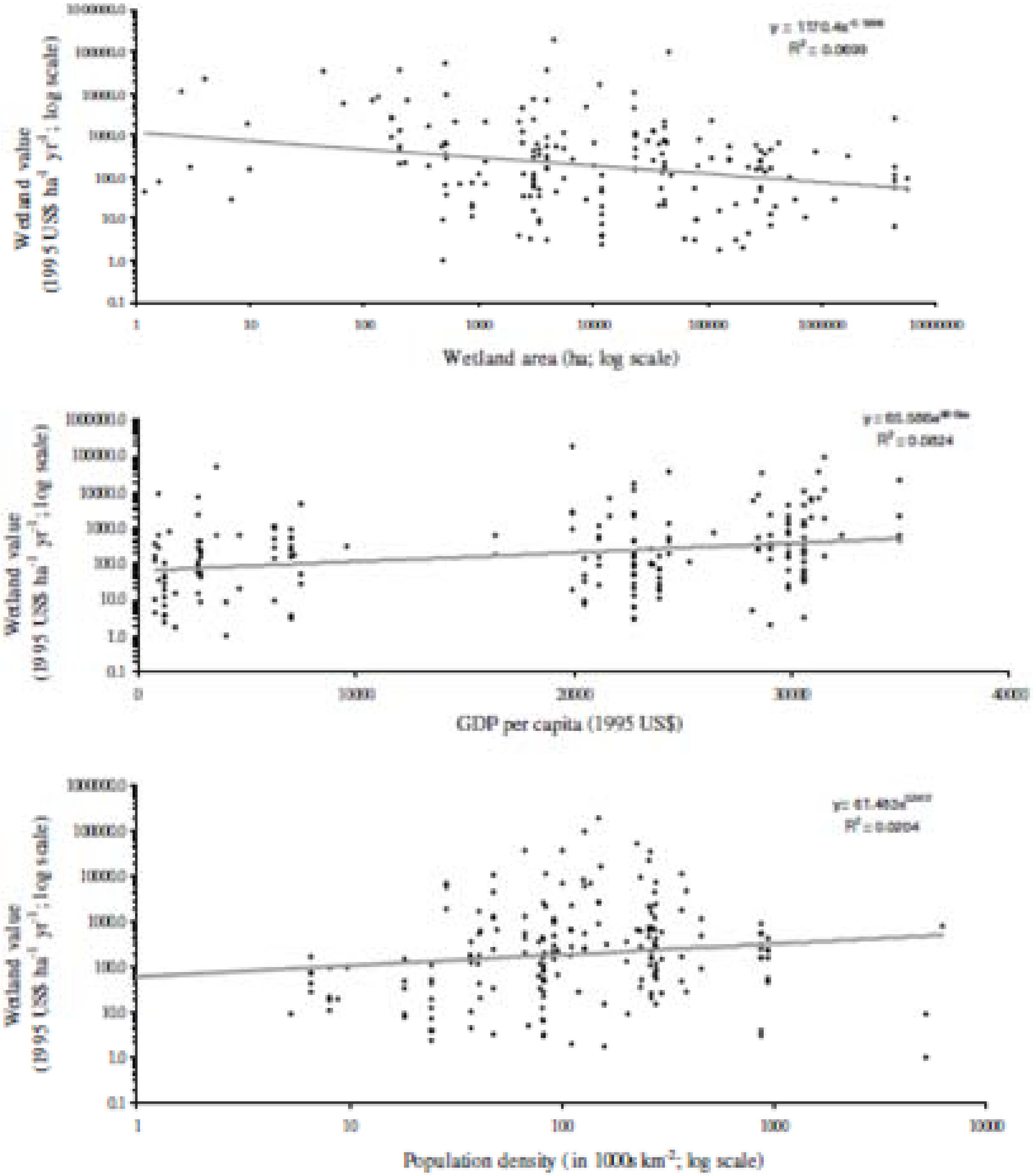

Figure 2. The value of wetlands as a function of wetland area (top panel), per capita income (middle panel) and population density (bottom panel).

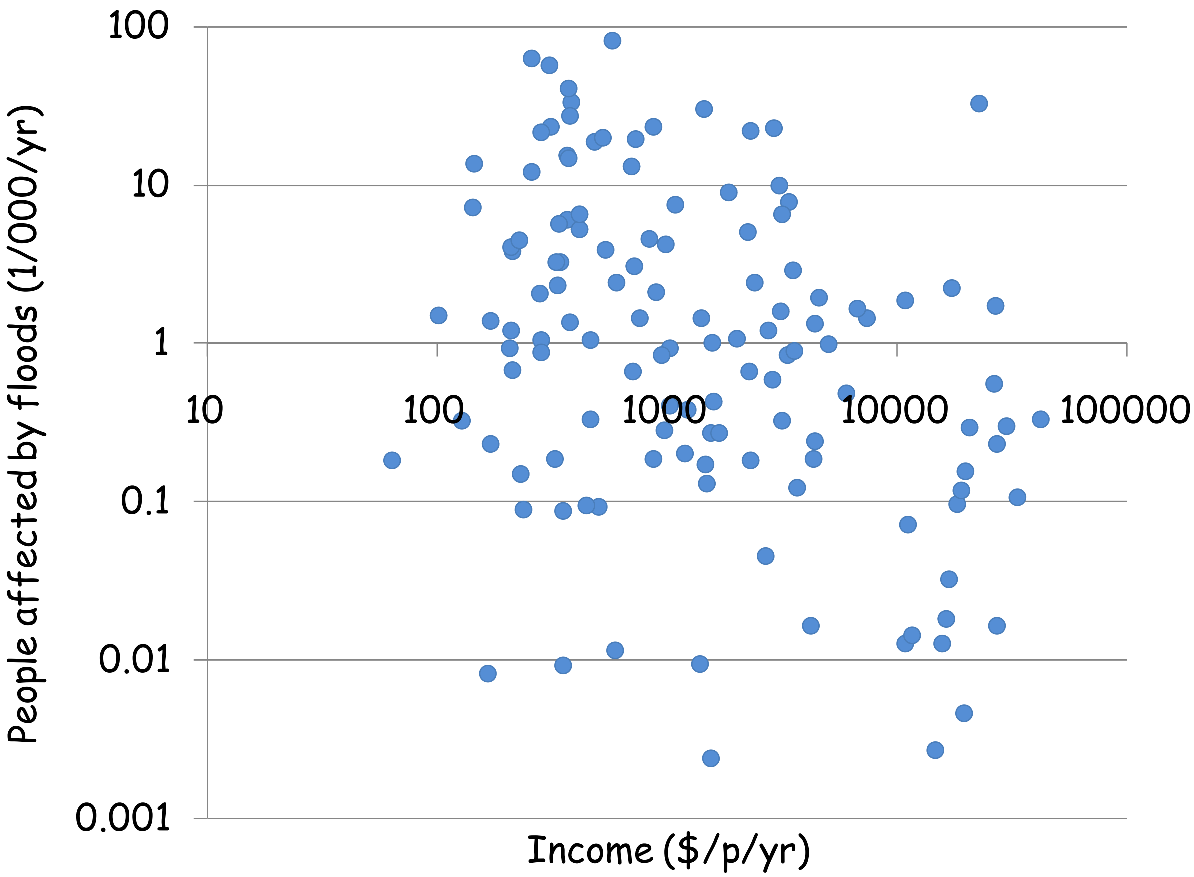

Figure 3. The number of people affected by floods as a function of per capita income.

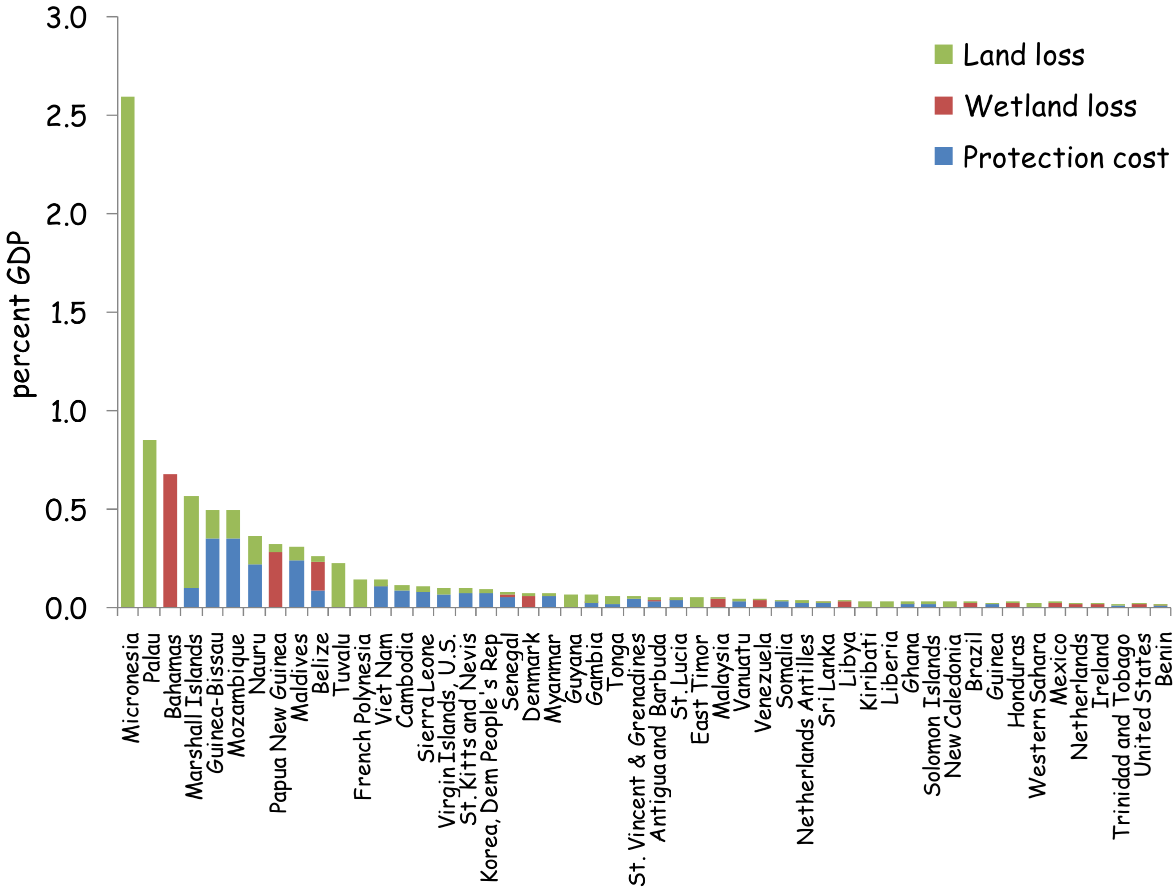

Figure 4. The fifty countries most vulnerable to sea level rise in 2100, and the composition of the annual cost.

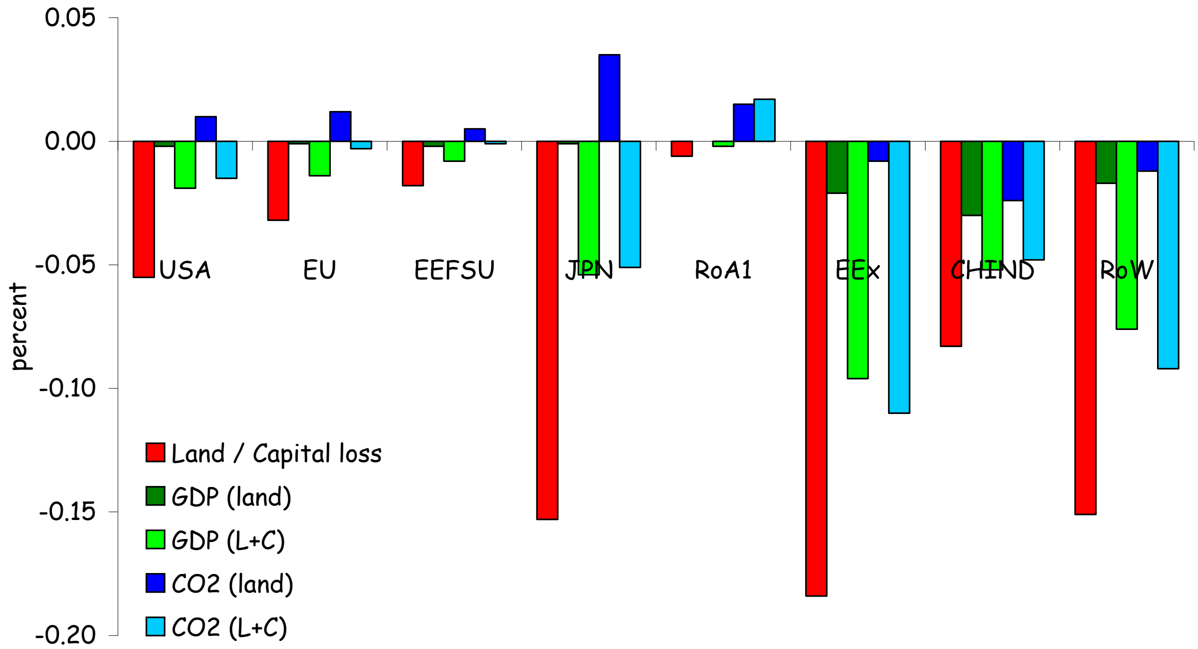

Figure 5. The impact of sea level rise (without additional coastal protection) in 2050 on GDP and CO_2 emissions.

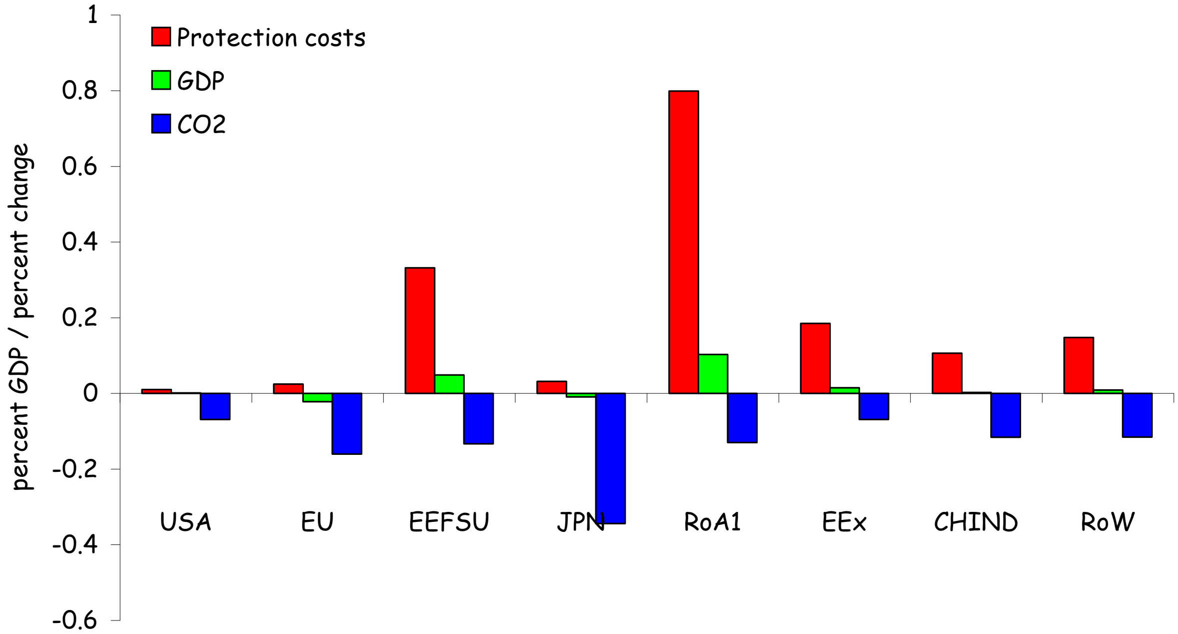

Figure 6. The impact of additional coastal protection to cope with sea level rise in 2050 on GDP and CO_2 emissions.

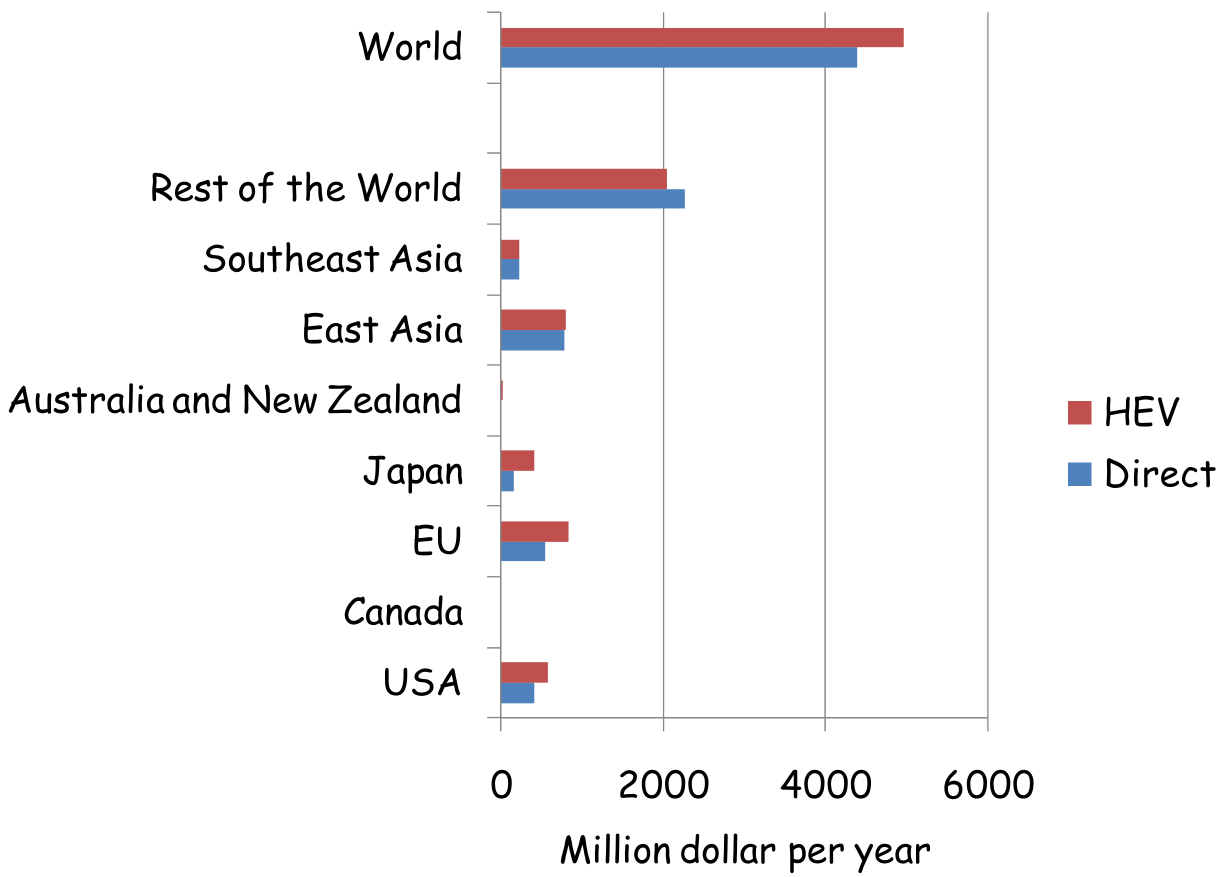

Figure 7. The direct costs and total welfare impacts of sea level rise in 2050.