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Vanguard research | Megatrends

The economics of climate change

Assessing the impact of global warming and the transition to "net zero" on the economy

About the Megatrends series

Megatrends have accompanied humankind throughout history. From the Neolithic Revolution to the Information Age, innovation has been the catalyst for profound socioeconomic, cultural, and political transformation. The term "Megatrends" was popularized by author John Naisbitt, who was interested in the transformative forces that have a major impact on both businesses and societies, and thus the potential to change all areas of our personal and professional lives.

Vanguard's "Megatrends" is a research effort that investigates fundamental shifts in the global economic landscape that are likely to affect the financial services industry and broader society. A megatrend may bring market growth or destroy it, increase competition or add barriers to entry, and create threats or uncover opportunities. Exploring the long-term nature of massive shifts in technology, demographics, and globalization can help us better understand how such forces may shape future markets, individuals, and the investing landscape in the years ahead.

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Megatrend

The economics of climate change: Assessing the impact of global warming and the transition to "net zero" on the economy

- In this paper, we assess the impact of climate change on economic activity. Our framework focuses on three dimensions: the direct physical impact of higher temperatures, the effect of stricter environmental policies, and the boost from greater "green investment" to help mitigate and adapt to climate change.
- Our work suggests that the physical impact of climate change on the economy increases significantly as temperatures rise. However, the impact will vary across regions. Economies operating in relatively cooler climates will benefit as warmer temperatures lead to new economic opportunities, while economies in already warm climates will suffer more as productivity declines.
- Economic output will also be affected by efforts to transition toward net-zero emissions. Our analysis suggests that stricter environmental policies consistent with meeting the goals of the Paris Agreement will exert a 5% to 8% drag on global GDP by 2050.
- However, the growth drag associated with higher temperatures and stricter environmental policies will, to some extent, be offset by increased investment in green infrastructure and technologies. For small temperature rises, investment will be directed toward climate mitigation. For large increases, more spending will be targeted toward adapting to the consequences of climate change.
- In all scenarios, climate change will have a negative estimated net impact on the global economy. We calculate a drag of between 2% and 4% of GDP by 2050 for small temperature rises. However, costs escalate thereafter, estimated at closer to 10% of GDP for temperature increases above 3 degrees Celsius.

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The economics of climate change: A framework

We provide a framework (**Figure 1**) to assess the impact of climate change on the economy across three dimensions:

1. The direct physical impact of higher temperatures.
2. Stricter environmental policies to achieve net-zero emissions.
3. Greater investment to mitigate and adapt to climate change.

As temperatures rise, the direct physical impact of climate change on the economy is expected to increase. This will occur through several channels, including, but not limited to, falling crop yields, reduced labor productivity, lower biodiversity, the greater spreading of disease, sea level rises, and an increased incidence of extreme weather events such as storms, forest fires, droughts, flooding, and heat waves (Carbon Brief, 2021).

FIGURE 1.

A framework to assess the economic implications of climate change

	Degrees warming: Less than 2° Celsius	Degrees warming: Between 2°–3° Celsius	Degrees warming: Greater than 3° Celsius	Impact as temperature rises
1 Physical impact	• Extreme sea level events 1–10 times more likely • Around 500 million people subject to heat/humidity stress • Yields on wheat and maize down by over 6% • Around 60 million people displaced annually from flooding by 2100 • 2% of species at risk of extinction • 3% chance of ice-free Arctic in summer	• Extreme sea level events 10–50 times more likely • Around 800 million people subject to heat/humidity stress • Yields on wheat and maize down by over 12% • Around 72 million people displaced annually from flooding by 2100 • Average length of droughts up by 4 months • 16% chance of ice-free Arctic in summer	• Extreme sea level events 50–100 times more likely • Around 1.2 billion people subject to heat/humidity stress • Yields on wheat and maize down by over 18% • Up to 200 million people displaced by 2050, with Africa being the hardest hit • 20% of land ecosystems at risk of extinction • Average length of droughts up by 10 months • 63% chance of ice-free Arctic in summer	Accelerating △
2 Stricter environ-mental policies	**Strict** • Large-scale decarbonization of the electricity grid, with up to 85% from renewables by 2050 • Phasing out petrol/gasoline and diesel cars starting in 2030 • Widespread use of carbon pricing or taxes, with the cost per ton up three times by 2030 • Protection and extension of forests	**Moderate** • Moderate decarbonization, with over 50% of electricity from zero-carbon sources by 2050 • Diesel and petrol/gasoline cars still prevalent in most emerging markets • Some usage of carbon taxes and/or permits • Some decline in rates of deforestation	**Loose** • Fossil fuels continue to make up majority of electricity mix • Diesel and petrol/gasoline cars prevalent • Limited financial penalties on emissions • Continued depletion of global carbon sinks	Diminishing ▽
3 Greater green investment	**Mitigation** • Large investment in green technologies and infrastructure to achieve net zero • Upgrade and maintain existing climate defenses • Limited investment in repair and reconstruction	**Adaptation** • Moderate investment in green technologies and infrastructure • Building, upgrading, and maintaining existing and new climate defenses	**Building back** • Building, upgrading, and main-taining existing and new climate defenses • Significant investment into repair and construction after damages to physical capital	Fairly constant ◁▷

Notes: *Degrees warming* refers to the increase in global average temperature relative to preindustrial levels. Physical capital consists of tangible goods that assist in the production of a good or service, such as buildings, infrastructure, machinery, and vehicles.

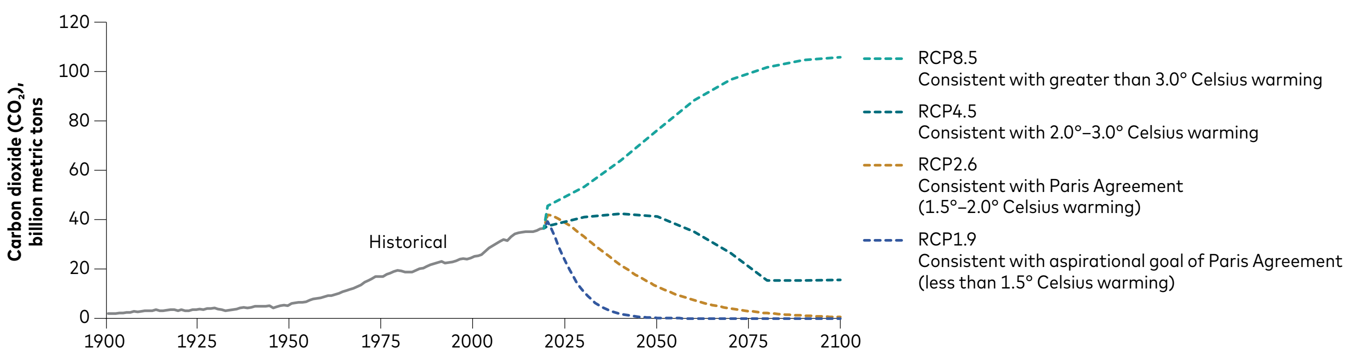
Sources: Vanguard, Carbon Brief, World Economic Forum, and Rutgers University.

Global economic activity will also be hindered by climate policies enacted to reduce emissions and transition toward net-zero emissions. **Figure 2** shows the Representation Concentration Pathways (RCPs) formulated by the United Nations' Intergovernmental Panel on Climate Change (IPCC). Each RCP represents a different trajectory for greenhouse gas (GHG) emissions over time, determined by underlying socioeconomic assumptions.

RCP1.9 is consistent with the aspirational goal of the 2016 Paris Agreement (United Nations Framework Convention on Climate Change, 2015), with average global warming of up to 1.5 degrees Celsius relative to preindustrial levels. RCP2.6 is consistent with up to 2 degrees warming, which is the limit for global warming under the Paris Agreement. To ensure that temperatures do not rise above 2 degrees, environmental policies must be relatively stringent and are likely to include a combination of restrictive carbon taxes, emission trading schemes, and tighter regulatory standards. For the RCP4.5 and RCP8.5 scenarios, future emission trajectories are higher and are therefore likely to be consistent with less stringent environmental policies.

FIGURE 2.

Projected emission pathways and implications for global warming

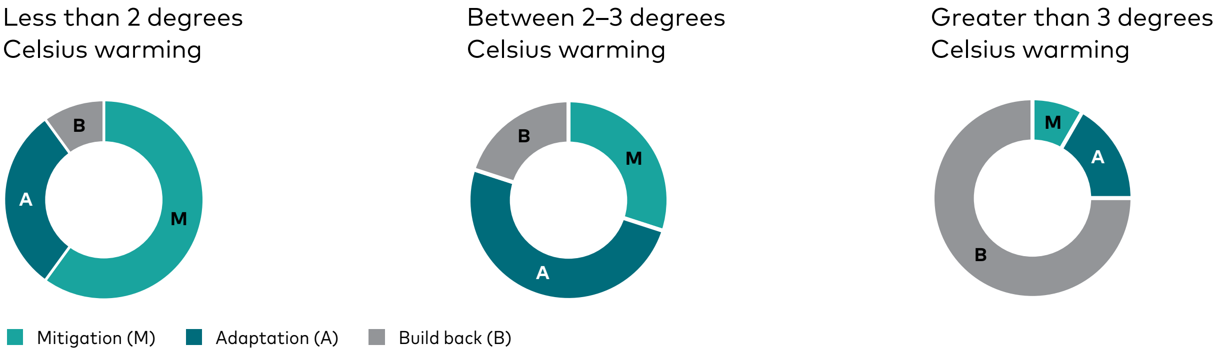


Sources: Global Carbon Project, International Institute for Applied System Analysis, and Vanguard.

Finally, the economic impact of both physical and policy-related climate change will be, to some extent, offset by increased investment in mitigation and adaption measures. In scenarios where average temperature rises are limited to 2 degrees, investment will be skewed toward mitigation measures. These include spending on green technologies and infrastructure, with the aim of reducing emissions. As temperatures rise beyond 2 degrees, it is likely that a greater share of investment will be directed toward dealing with the consequences of climate change. This includes building, upgrading, and maintaining existing climate defenses such as sea walls, which we label as adaptation investment, and spending to repair and reconstruct damages to physical capital after extreme climate events, which we label as build-back investment (**Figure 3**).

FIGURE 3.

The nature of green investment will evolve



Source: Vanguard.

Part I: Higher temperatures will reduce global economic output

In this section, we explore the direct physical impact of climate change on economic output. Our starting point is to examine the historical relationship between changes in temperature and the economy using a framework similar to that of Burke, Hsiang, and Miguel (2015).[1] Using data from these authors, as well as from the World Bank (2021b) and the United Nations (2021), we estimate the following equation from 1960 to 2019 across more than 160 countries and regions:

$$GDPC_{i,t} = \alpha + \beta_1 * Temp_{i,t} + \beta_2 * Temp^2_{i,t} + \beta_3 * Prec_{i,t} + \beta_4 * Prec^2_{i,t} + X_t + \theta_i + X_t * \theta_i + \varepsilon_{i,t}$$

Where: $GDPC_{i,t}$ is the GDP per capita of country "i" at time "t", $Temp$ is temperature of country "i" at time "t", $Prec$ is precipitation of country "i" at time "t", X_t is the time fixed effect, and θ_i is the country fixed effect.

The model is estimated using panel regression techniques that include country and time fixed effects, as well as country and time interactions, to isolate the impact of temperature on GDP per capita. The results show that historically, temperature changes have significantly influenced GDP across countries, after controlling for other country-specific and global factors that may also affect output. This finding is consistent with previous research (Newell, Prest, and Sexton, 2021; Zhao, Gerety, and Kuminoff, 2018; and Kahn et al., 2021).

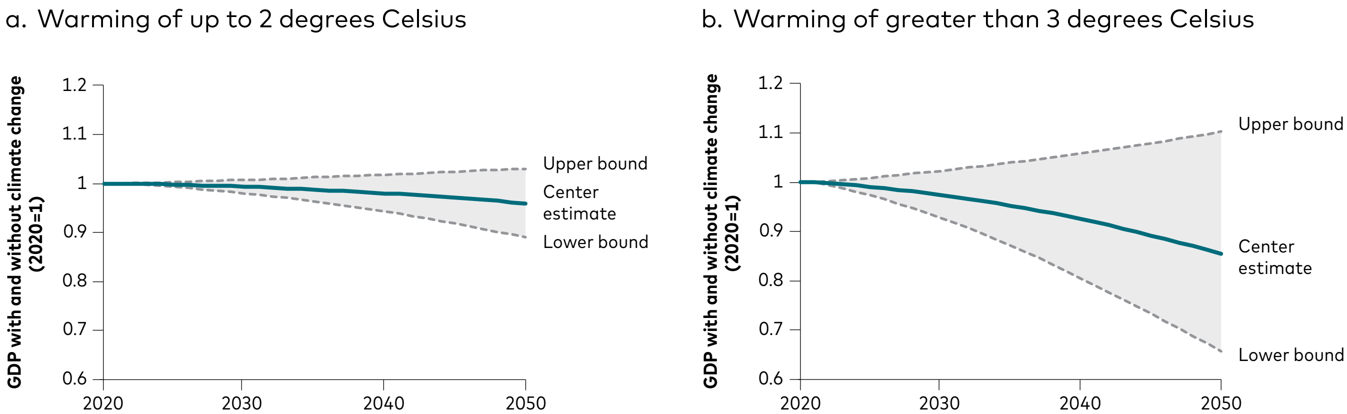
With the coefficients derived from the model, we then use future temperature and precipitation values consistent with the IPCC's RCP scenarios, together with population growth data from the United Nations, to estimate the impact on GDP relative to a world without climate change under different scenarios. We focus our analysis on the projection up to 2050, even though IPCC scenarios reach to 2100. We mainly explore scenarios to 2050 because temperature increases beyond 2 degrees, which could take place in RCP4.5 and RCP8.5 after 2050, may cause nonlinear and more catastrophic damage to the economy (Anderson and Bows, 2011).

The projected impact on global GDP under the RCP2.6 and RCP8.5 scenarios is shown in **Figure 4**. The blue line shows the central tendency, while the grey shaded areas give an indication of the degree of uncertainty around this path, which is the result of 1,000 bootstrap simulations from the model. On average, global GDP is expected to be about 2% to 4% lower by 2050 in the RCP2.6 scenario and over 10% lower under the RCP8.5 scenario. The distribution of economic outcomes is also expected to be significantly wider as GHG concentrations and temperatures increase.

1 As part of our research, we also used the methodology that was proposed by Kahn et al. (2021). The authors used abnormal temperature change to predict GDP per capita. The trend is similar to what we found using Burke, Hsiang, and Miguel. We based our analysis on Burke, Hsiang, and Miguel because their methodology offered a larger sample size.

FIGURE 4.

Projected temperature impact on global GDP under warming scenarios



Notes: The projections are based on a panel regression of GDP per capita on temperature using annual data from 1960 to 2019 across more than 190 countries and regions, consistent with the methodology of Burke, Hsiang, and Miguel (2015). The model includes country and time fixed effects, country time trends, and clustered errors at the country level. The blue line represents the central estimate from 1,000 simulations. Warming of up to 2 degrees Celsius is consistent with RCP2.6, and warming of greater than 3 degrees Celsius is consistent with RCP8.5.

Sources: Burke, Hsiang, and Miguel (2015), United Nations World Population Prospects database, World Bank, and Vanguard.

This empirical approach does not shed light on how temperature affects economic productivity. We can use evidence from other studies to help us understand the mechanism better. For example, some studies show that higher temperature leads to lower agricultural yields (Zhao et al., 2017), while others show that productivity in particularly labor-intensive manufacturing processes is sensitive to warmer climates (Energy Policy Institute at the University of Chicago, 2018). Higher temperatures can also contribute to power shortages, machine failures, and factory closures on a more regular basis, as we saw in China in 2021 (Reuters, 2021). Heat-related illness and exhaustion could play a role too.

However, we should acknowledge that technological progress may reduce the link between average temperature and economic activity over time, particularly in emerging economies where current working conditions are, in general, more vulnerable to hotter temperatures.

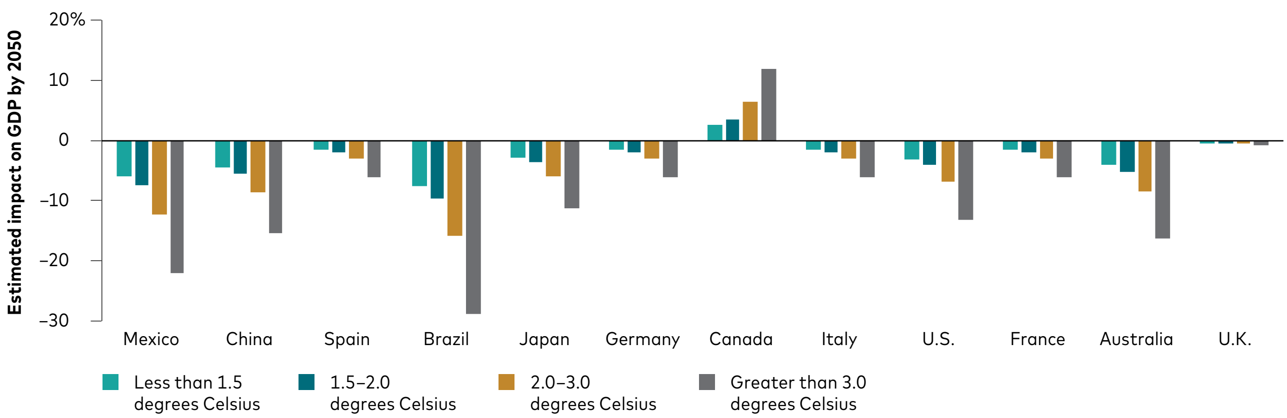
The method adapted from Burke, Hsiang, and Miguel is based solely on temperature effects, so it does not include other potential sources of physical damage associated with climate change. These include the impact of rising sea levels and the increased frequency and intensity of extreme weather events such as flooding and tropical cyclones. We use the existing research to guide us on the expected costs associated with these events under different scenarios and apply the appropriate adjustment to our estimates (for example, Jevrejeva et al., 2018). The anticipated additional cost to the economy ranges from 0.5% to 2.5% of GDP. The costs are limited because of the assumption that policymakers will implement adaptive measures as temperatures rise, such as the maintaining, building, or upgrading of sea defenses. The costs of these adaptation measures are expected to be negligible relative to the potential damages that are being saved because of them (Hinkel et al., 2014).

Figure 5 shows the estimated combined physical impact of climate change across select countries under various RCP scenarios. Economies such as the U.K., Germany, and Italy are predicted to experience only a modest negative GDP impact, while Brazil, Mexico, and Australia are expected to suffer more as higher temperatures make certain economic activities less productive and materially increase the risk of extreme weather events occurring. By contrast, Canada is likely to gain in economic terms as rising temperatures open up new economic opportunities.

We can also compare our empirically driven results to the climate-damage functions that are popular in other research and widely used in climate-change integrated assessment models. **Figure 6** illustrates how our estimated damage function is higher than those implied by the Nordhaus (2008), Weitzman (2012), and Dietz and Stern (2015) models for temperatures up to 2 degrees Celsius above preindustrial levels but is lower than the Dietz-Stern model beyond 2.5 degrees.

FIGURE 5.

Estimated direct physical impact of climate change on GDP across countries

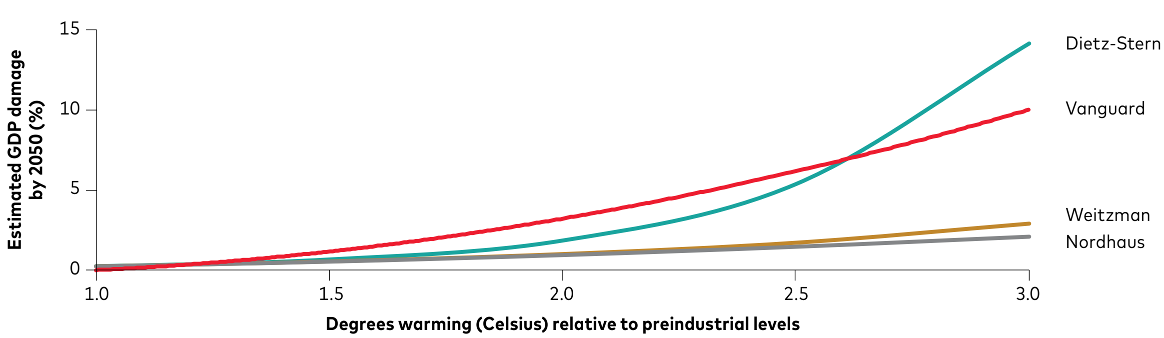


Note: Warming of less than 1.5 degrees Celsius is consistent with RCP1.9, warming of 1.5–2.0 degrees Celsius is consistent with RCP2.6, warming of 2.0–3.0 degrees Celsius is consistent with RCP4.5, and warming greater than 3.0 degrees Celsius is consistent with RCP8.5.

Source: Vanguard.

FIGURE 6.

A comparison of our empirically estimated climate-damage function to some popular functions



Notes: The red line is the Vanguard empirically estimated climate-damage function, proxied as the GDP-weighted average of Mexico, China, Spain, Brazil, Japan, Germany, Canada, Italy, the U.S., France, Australia, and the U.K. The Nordhaus function is based on Nordhaus (2008) and is calibrated as $1 - (1 + \left(\frac{T}{\alpha}\right)^2)^{-1}$ where $\alpha = 20.46$. The Weitzman and Dietz-Stern functions are calibrated using $1 - (1 + \left(\frac{T}{18.8}\right)^2 + \left(\frac{T}{\beta}\right)^{\Upsilon})^{-1}$ where $\beta = 6.081$ and $\Upsilon = 6.754$ under Weitzman (2012) and $\beta = 4$ and $\Upsilon = 6.754$ under Dietz-Stern.

Sources: Vanguard, Nordhaus (2008), Weitzman (2012), and Dietz and Stern (2015).

Part II: Transitioning toward net zero will necessitate a policy drag

Global policymakers are becoming increasingly engaged in addressing climate change.[2] The transition toward a greener way of life represents both challenges and opportunities for economic output.

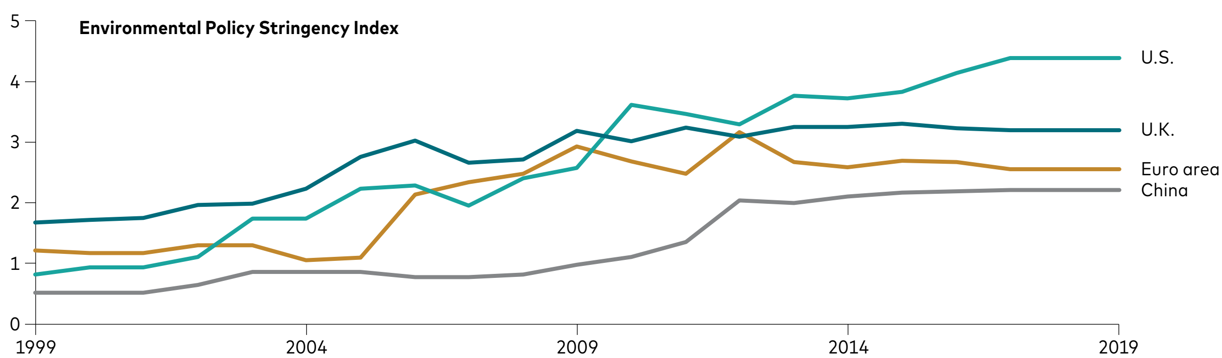
In this section, we focus on the potential economic cost associated with implementing policies that are designed to reduce GHG emissions. This impact is to be balanced with the potential benefit of investment in greener technologies and infrastructure, which is covered in Part III.

Governments can discourage the production of GHG emissions in various ways. These include, but are not limited to, tighter regulatory standards, emission trading permits, emission taxes, and shifting subsidies away from fossil fuel energy sources to renewable ones.

To capture the relative severity of emissions-targeted policies in an internationally comparable way, we construct an index of environmental policy stringency using data and guidance from the Organisation for Economic Co-operation and Development (OECD, 2021a) and Yale University (2020). **Figure 7** shows this measure for the U.S., the U.K., the euro area, and China from 1999 to 2019, where stringency is defined as the degree to which policies put an explicit or implicit price on environmentally harmful behavior. In all cases, emissions-based policies have become tighter over the last 20 years, though the level of stringency is currently higher in the euro area than in the U.S. or China.

FIGURE 7.

Environmental policy has become stricter over the last 20 years



Notes: We use the OECD's Environmental Policy Stringency Index (EPS) from 1999 to the latest year available, typically 2012 or 2015, depending on the country. Thereafter, we model the EPS using Yale University's Environmental Performance Index and use the fitted values to extrapolate the index to 2019. The euro-area index is constructed using the GDP-weighted average of the indexes for Germany, France, and Italy, based on 2019 values.

Sources: OECD, Yale University, and Vanguard.

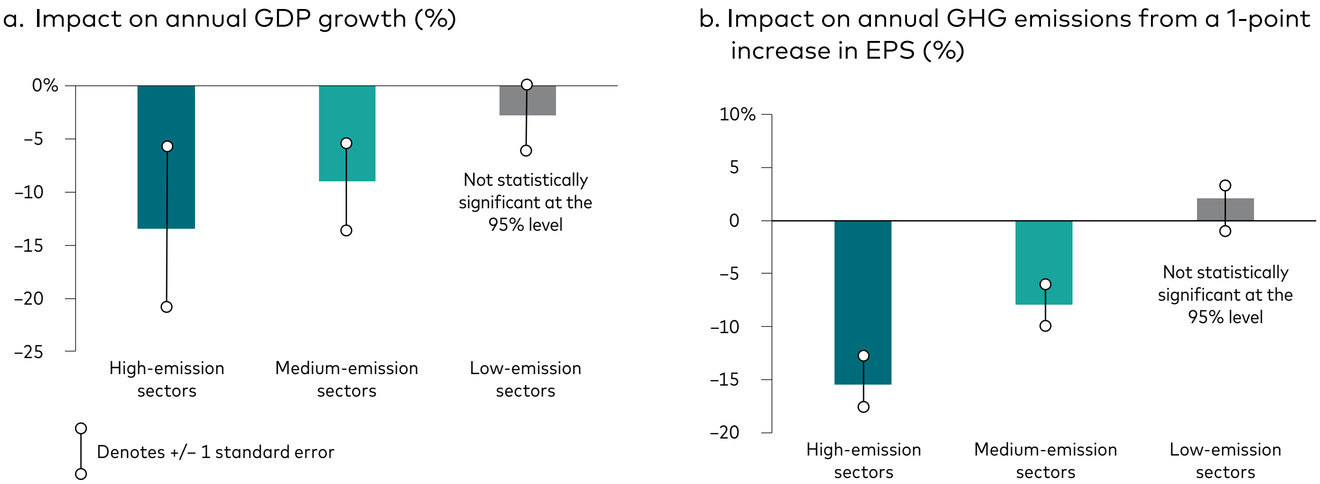
2 See, for example, *COP 26 Outcomes*, UN Climate Change Conference, at https://ukcop26.org/the-conference/cop26-outcomes/.

Using this index, GHG emissions data from the OECD (OECD, 2021b), and gross value-added data from various national sources, we examine the empirical relationship between environmental policy stringency, the production of GHG emissions, and GDP growth at the sector level.

We find, using panel regression techniques, that more stringent environmental policies are consistent with both lower emissions and GDP growth for high-emitting sectors (such as mining and utilities, agriculture, and manufacturing) and medium-emitting sectors (such as construction and transportation services). However, the observed impact of policy stringency on emissions and GDP is negligible for low-emitting sectors, such as professional services, education, and health care (**Figure 8**).

FIGURE 8.

More stringent environmental policies are consistent with lower emissions and GDP growth in high- and medium-emitting sectors



Notes: Estimates are derived from a panel regression of emissions growth on the OECD's Environmental Policy Stringency Index (EPS) for 12 developed-market economies using annual data between 2000 and 2019. The specification accounts for country-specific fixed effects and includes lags of both the dependent and independent variable. For each country, emissions data have been smoothed using the Hodrick-Prescott filter (lambda: 6.25) to control for business-cycle fluctuations.

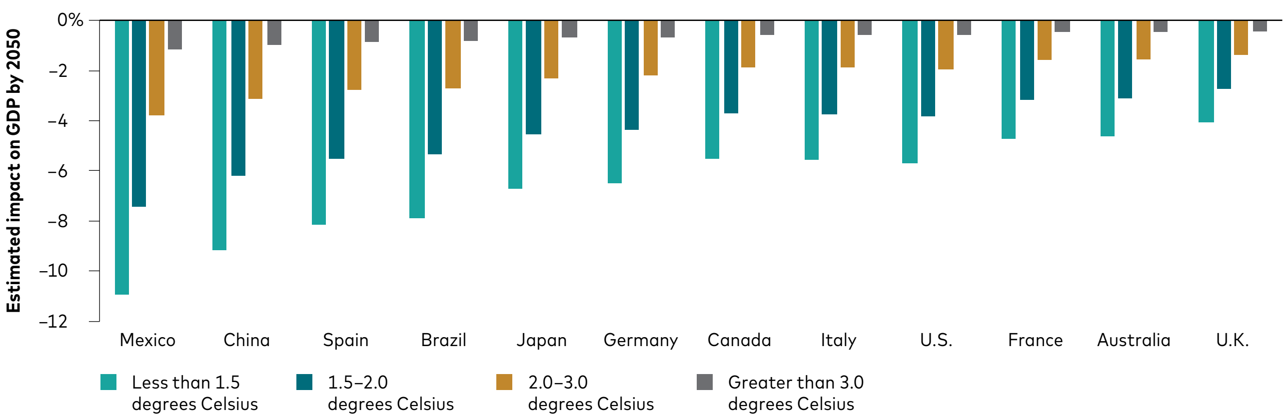
Sources: Vanguard calculations, based on data from the OECD, Eurostat, and Yale University.

These results can be used to model the impact of future climate policy scenarios on the economy. For example, for the United States to meet its nationally determined contribution by 2030, as per the IPCC, it will need to reduce its net GHG emissions by about 50% relative to its 2005 level (U.S. Government, 2021). Our analysis shows that to achieve such a large-scale reduction in emissions, policy would need to be more than four times more stringent than it is today, and implementing these policies would exert approximately a 0.2% drag on annual U.S. GDP growth over the next decade.

Figure 9 shows the modeled impact of tighter emissions policy on the level of GDP by 2050 across a selection of developed and emerging economies under different climate-emission scenarios. If all countries are assumed to reduce emissions to a level consistent with temperatures rising by a maximum of 2 degrees Celsius above preindustrial levels (RCP2.6), the estimated cost to GDP from stricter policy ranges from 2.5% to 7.5%. Scenarios consistent with higher temperatures are associated with a lower reduction in GHG emissions and therefore are a lower policy-related drag on the economy.

FIGURE 9.

Estimated GDP drag across countries from tighter environmental policy



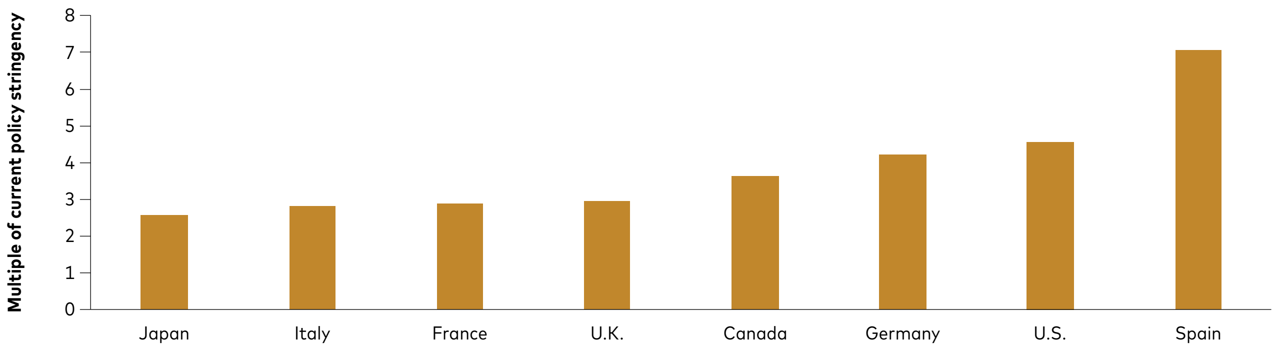
Note: Warming of less than 1.5 degrees Celsius is consistent with RCP1.9, warming of 1.5–2.0 degrees Celsius is consistent with RCP2.6, warming of 2.0–3.0 degrees Celsius is consistent with RCP4.5, and warming greater than 3.0 degrees Celsius is consistent with RCP8.5.

Source: Vanguard.

The country variation in impacts can be explained by two primary drivers. First, the economies that require greater emissions-policy tightening to reach their goals, such as Spain and the United States, will experience larger drags to economic growth (**Figure 10**). Second, countries that have a larger proportion of their economy skewed toward high- and medium-emitting sectors will also experience relatively large economic costs as they transition toward "cleaner" activities (**Figure 11**).

FIGURE 10.

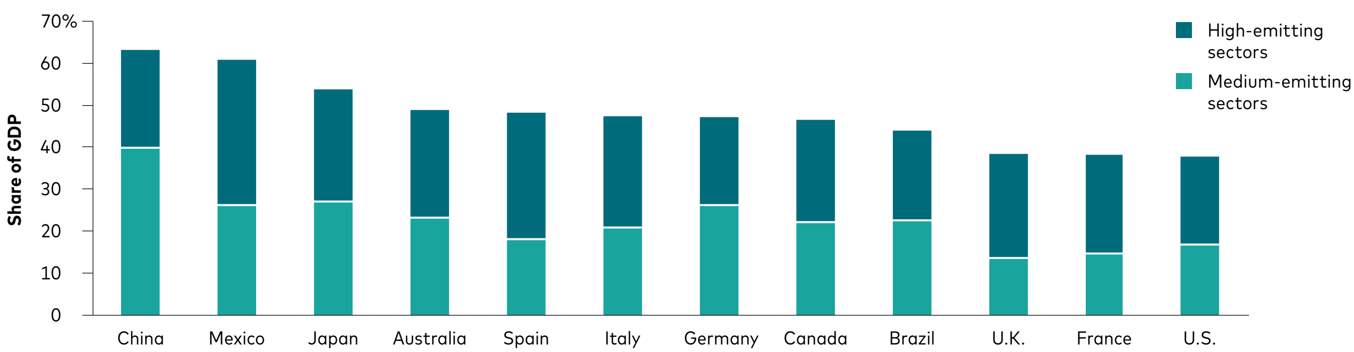
Countries such as Spain and the U.S. require more severe policy tightening to meet Paris Agreement goals



Sources: OECD, Yale University, and Vanguard.

FIGURE 11.

In China and Mexico, economies are more vulnerable to decarbonization



Sources: Bloomberg, OECD, and Vanguard.

Part III: Quantifying the green investment effect

Direct physical and policy-related costs to the economy will be, to some extent, offset by greater investment to mitigate and adapt to climate change.

In the more optimistic climate scenarios, investment will be skewed toward **mitigation** measures that aim to reduce emissions and transition toward net zero, perhaps through spending on greener technologies and infrastructure. But as temperatures rise beyond 2 degrees, a greater share of investment will likely be needed to defend against the impacts of climate change (**adaptation** investment) and to repair and reconstruct physical capital (**build-back** investment).

Mitigation investment

To quantify the effect of mitigation-related investment on the economy, we need to understand the amount of additional investment in green technologies and infrastructure required to meet climate policy goals, and the expected elasticity of green investment to long-run economic growth.

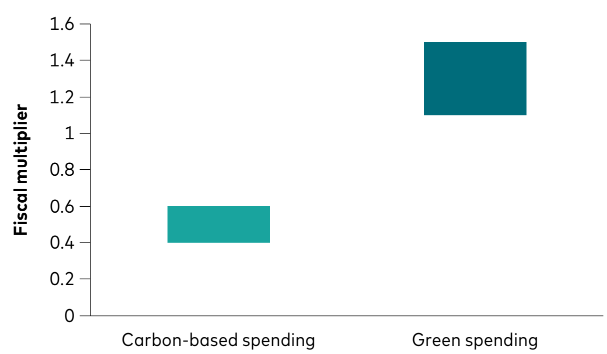
There is a large degree of uncertainty associated with both of these drivers. However, we can use existing research to give us a sense of the expected magnitude. For example, the OECD estimates that infrastructure spending will need to be around 10% higher over the coming decade to meet Paris Agreement goals (OECD, 2017). This translates to an annual increase in spending of about $600 billion a year, or 0.7% of global GDP. Similarly, the International Renewable Energy Agency estimates that annual investment in the energy sector will need to double over the coming decades to be consistent with each country's nationally determined contribution, earmarking additional spending of around 1% of GDP (Gielen et al., 2019).

Overall, we expect the additional investment required for countries to meet the aspirational goal of the Paris Agreement to range from 0.5% to 1.5% of GDP per annum to 2050, consistent with the RCP1.9 scenario. We apply reductions of 33%, 66%, and 90% to these numbers for the RCP2.6, RCP4.5, and RCP8.5 scenarios, respectively, implying that falling short of Paris Agreement goals corresponds with lower investment in green technologies.

The extent to which additional investment boosts long-run economic growth will depend on the type of investment implemented and the degree to which the private sector is crowded out, among other factors. The consensus from our reading of the existing research is that fiscal multipliers on public spending tend to be larger than those of tax cuts and transfers, particularly for spending on infrastructure projects (Gechert, 2015).[3] In addition, as shown in **Figure 12**, spending on green initiatives typically exhibits higher multipliers than traditional carbon-based spending (Batini et al., 2021).

FIGURE 12.

Green-spending multipliers are estimated to be twice as large as traditional carbon-based spending



Sources: Batini et al. (2021) and Vanguard.

3 The fiscal multiplier is the degree to which a given change in taxes and/or government spending will ultimately affect economic output.

For public investment to have a sustainable positive impact on long-run economic growth, there must be a degree of complementarity between public and private investment; otherwise, the private sector will be crowded out. We have conviction that this will be the case during the green transition, as environmentally friendly investment in infrastructure and technology will almost certainly have a social rate of return that is above the private rate of return, generating positive externalities that cannot be captured by the private sector alone (Fournier, 2016).[4]

Adaptation and build-back investment

As global temperatures rise, an increasing share of investment is likely to be dedicated to dealing with the consequences of climate change. This includes preemptive adaptation measures, such as sea walls or enhanced irrigation, as well as repairing and reconstructing physical capital that may be damaged by climate-related events.

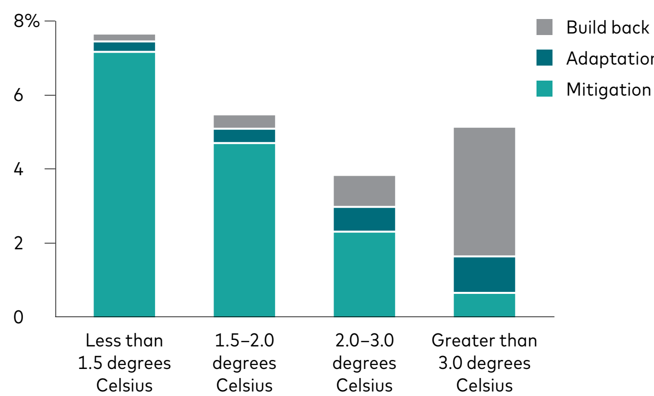
To quantify the impact of such measures on the economy, we first use projections of adaptation spending by region from both the World Bank (Margulis et al., 2010) and the United Nations (Neufeldt, Christiansen, and Dale, 2021) to calibrate our estimates across scenarios. This results in an increase in global GDP of less than 0.5% by 2050 under the optimistic climate scenarios (RCP1.9 and RCP2.6), where temperature increases are limited to below 2 degrees. The impact rises to above 1% under the more dire RCP8.5 scenario.

We then add the build-back effect to these estimates, using the work of Skidmore and Toya (2002) on the impact of natural disasters. This study suggests that building back from climatic disasters may actually raise GDP above its no-disaster counterfactual over the medium term as economies upgrade their physical capital and integrate new technologies in a way they would not have done otherwise.

Assuming that the frequency of climate-related disasters increases significantly as global average temperatures rise, we estimate that the boost to GDP from build-back investment will be between 0% and 0.5% under the RCP1.9 scenario by 2050. This increases to as much as 3%–5% of GDP under the RCP8.5 scenario. **Figure 13** summarizes our baseline estimates of investment across the mitigation, adaptation, and build-back channels.

FIGURE 13.

The green investment effect will add between 4% and 8% to global GDP by 2050



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Source: Vanguard.

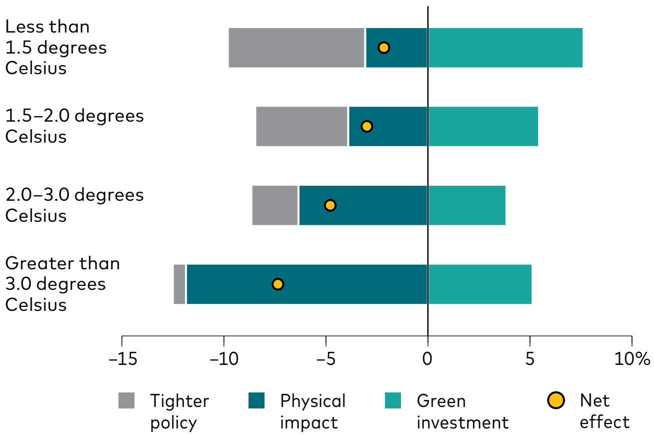
4 An externality is a spillover effect from an activity that is not fully captured by market prices.

Part IV: Putting it all together

Figure 14 summarizes the net impact of green investment, tighter policy, and physical impact on the level of global GDP by 2050.

FIGURE 14.

The net impact of climate change on global GDP by 2050



Note: Warming of less than 1.5 degrees Celsius is consistent with RCP1.9, warming of 1.5–2.0 degrees Celsius is consistent with RCP2.6, warming of 2.0–3.0 degrees Celsius is consistent with RCP4.5, and warming greater than 3.0 degrees Celsius is consistent with RCP8.5.

Source: Vanguard.

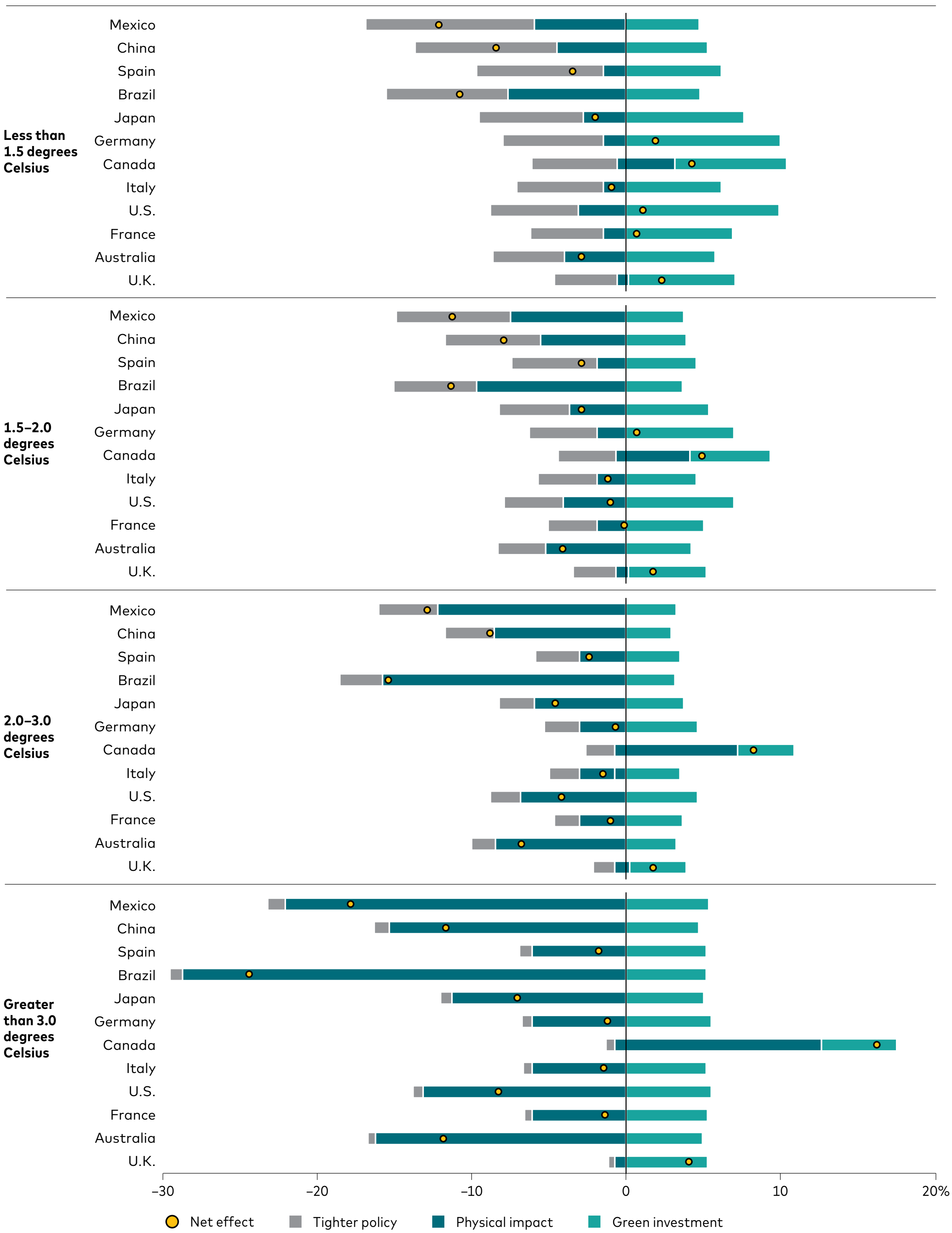
The aggregate effect is relatively small for temperature increases up to 2 degrees above preindustrial levels—between 2% and 4% of global GDP by 2050. But the net cost to the economy increases meaningfully thereafter, with an estimated drag of close to 10% of GDP as temperatures rise above 3 degrees.

However, there is a large variation in net impact across countries, as **Figure 15** illustrates. For scenarios consistent with temperatures rising up to 2 degrees (RCP1.9 and RCP2.6), the direct physical impact is modest. But countries such as China, Brazil, and Mexico are expected to experience costs between 10% and 20% of GDP, driven primarily by a large policy-related drag.

For scenarios consistent with temperatures above 3 degrees (RCP8.5), the direct physical impact dominates. Even significant investment may not be enough to prevent damages of around 20% to 30% of GDP in selected markets by 2050.

FIGURE 15.

Net climate change impact on GDP across major economies



Notes: Warming of less than 1.5 degrees Celsius is consistent with RCP1.9. Warming of 1.5–2.0 degrees Celsius is consistent with RCP2.6. Warming of 2.0–3.0 degrees Celsius is consistent with RCP4.5. Warming greater than 3.0 degrees Celsius is consistent with RCP8.5.

Source: Vanguard.

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