Foresight

Climate change and financial markets

February 2020

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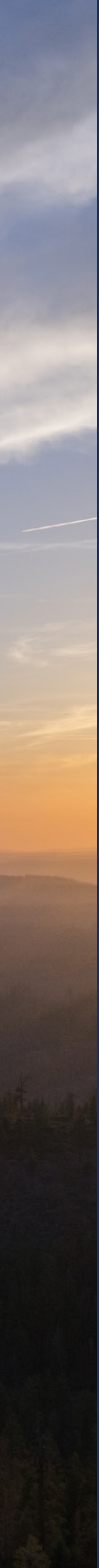
Schroders



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Executive summary

Schroders Economics Group produces 30-year return forecasts, on an annual basis, for a range of asset classes. Until now, these forecasts have been agnostic on the subject of climate change, making no explicit adjustments for the physical and transition costs associated with global warming.

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Ultimately, the potential channels through which climate change could impact growth and financial returns are too numerous, and indeed often unknown, for us to hope to model every moving part, particularly considering data constraints in poorer economies. Instead, we adopt a three step process.

The first step is a focus on what happens to output as temperatures rise, which we will refer to as the 'physical cost' of climate change. The second considers the economic impact of steps taken to mitigate those temperature increases, or the 'transition cost'. This second step is slightly more complicated, in that there are a range of possible transition scenarios. Finally, we adjust for the effects of stranded assets. This is where we take account of the losses incurred where oil and other carbon based forms of energy have to be written off, as it is no longer possible to make use of them, such that they are left in the ground.

Notable throughout is the range of uncertainty, not only around the economic relationships but also policy responses. The choice of economic model, carbon price and the use of funds raised by a carbon tax all have material consequences for the final estimate. While we do alight on a central scenario, it would be remiss of us not to acknowledge the wide range of possible outcomes around this baseline.

Physical cost assumptions

First, considering the modelling of the physical impact, a non-linear relationship between temperature and productivity seems more plausible than a linear one. With temperatures much above 35 degrees Celsius, for example, the human body simply cannot function for long. Meanwhile, Russia and Canada are already enjoying benefits of a warmer world as the Arctic becomes more navigable. For this reason, we will take the Burke and Tanutama (2019) results as our assumption for the physical cost modelling. We then need to decide which iteration of their model we want to use. The authors ran models allowing for lagged effects as well as one in which contemporaneous impacts only were considered. Again, to us, a lagged relationship makes more sense. We are used to allowing 12 to 18 months for monetary policy to feed through, and responses to warmer temperatures are also likely to take time to fully play out.

Transition cost assumptions

Secondly, we need to make an assumption about the likely policy response. Inevitably, political calculations will at least partially drive the decision made by policymakers, rather than economic concerns over efficiency or climate-driven concerns over the degree of warming. Ultimately, we arrive at the conclusion that while we may see the adoption of a carbon tax, 'optimal' pricing may prove too expensive – both financially and politically – leading to suboptimal pricing and climate outcomes. This seems particularly likely when we consider that major economies face little short term incentive to reduce emissions, as many benefit from a warmer world.

Overall productivity effects from climate change

Colder countries still benefit from a warmer world even when we account for the costs involved in any transition. Russia, Canada, Switzerland, the UK and Germany are better off even after taking aggressive mitigation methods, compared to a world in which no warming occurs. However, most of these countries (Switzerland is an exception) would clearly prefer not to undertake mitigation efforts – at least from a growth perspective.

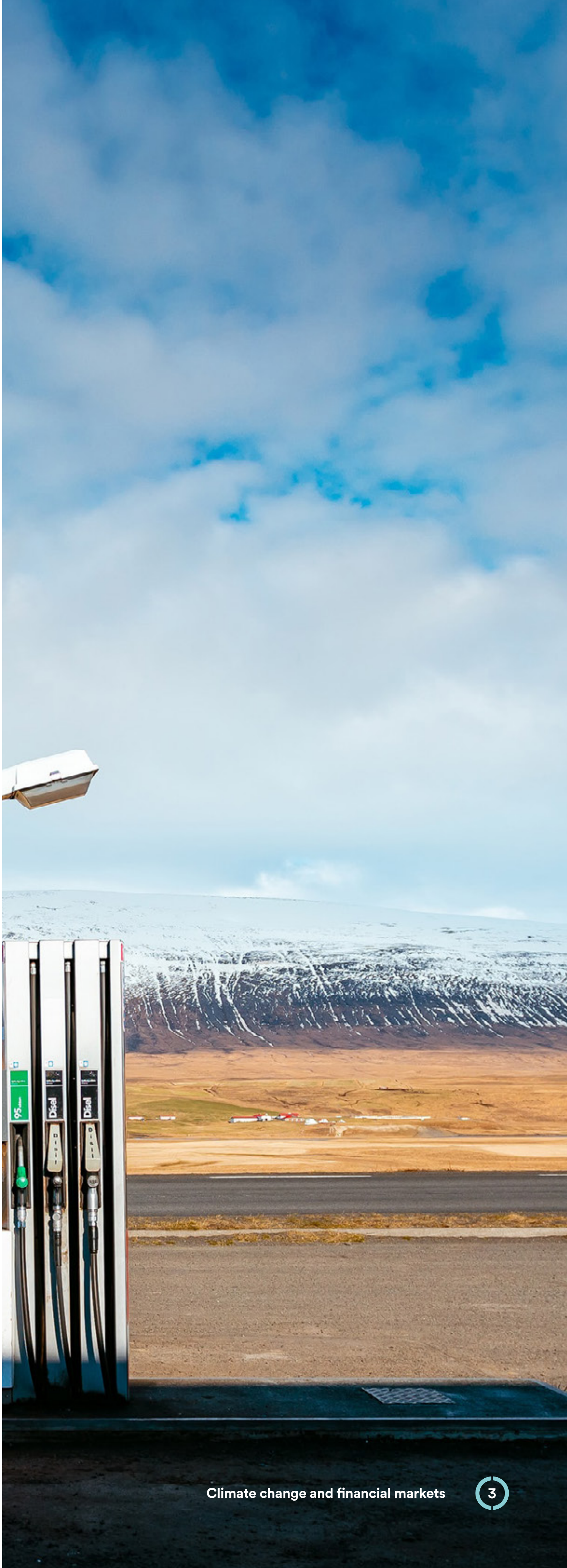
At the other end of the spectrum, things go from bad to worse for hotter countries. While Singapore is relatively indifferent between a no transition scenario and mitigation scenarios, India is a glaring example of a country where carbon pricing rubs salt in the wound opened by rising temperatures. We would note, however, that on a longer horizon mitigation would start to deliver benefits for these countries against a world in which no mitigation is attempted.

The reason for this is that we are only considering a 30-year time frame. Essentially, our projected warming by 2050 is already set. Whatever mitigation we undertake, temperature projections will only be affected in the second half of this century, but the difference is significant. A worst case scenario sees global temperatures rise 4 degrees above pre industrial norms by 2100, compared to the 2 degrees under the plausible best case outcome. Those extra 2 degrees would be very damaging for warmer countries, and so while mitigation may appear to make no economic sense based on our results here, once you extend the timeframe the argument becomes more compelling.

Asset return implications

As goes productivity, so go our return forecasts. Using the three stage climate model we have advocated in this paper, warmer countries are likely to lose out in a changing climate, with considerable reductions in expected returns for hotter countries like India and Singapore. Colder countries meanwhile may experience increased returns; considerably so for Canada and Switzerland, though the UK and US also see some benefits.

However, there are clearly many factors to take into account when deciding how to allocate assets to companies and countries. Having a clear framework for measuring the impact of climate change on a company by company basis and from a country perspective has never been more important. The message is clear: an active approach to managing the risks of climate change is no longer optional, it is essential.



Introduction

The aim

Schroders Economics Group produces 30-year return forecasts, on an annual basis, for a range of asset classes. Until now, these forecasts have been agnostic on the subject of climate change, making no explicit adjustments for the physical and transition costs associated with global warming. We have produced a separate tool – the Climate Change Dashboard – for a number of years which provided analysis of climate change but lacked the tools to form solid conclusions about investment implications.

However, driven as they are by long term assumptions around growth rates and productivity, it seems likely that climate change will have implications for our forecasts. It is not difficult to imagine ways in which this might be the case; more extreme weather events will likely inflict greater damage on infrastructure and business capital, higher temperatures could hurt labour productivity by making physical labour more arduous, and the plans to address climate change would require sacrifices of resources and abandoning existing economic growth models. Equally, warmer temperatures could make some parts of the world more attractive and productive, with melting ice easing sea navigation, facilitating agricultural cultivation in previously inhospitable climates, and so on.

Ultimately, the potential channels through which climate change could impact growth and financial returns are too numerous, and indeed often unknown, for us to hope to model every moving part, particularly considering data constraints in poorer economies. Instead, we adopt a three step process.

The first step is a focus on what happens to output as temperatures rise, which we will refer to as the 'physical cost' of climate change. The second considers the economic impact of steps taken to mitigate those temperature increases, or the 'transition cost'. This second step is slightly more complicated, in that there are a range of possible transition scenarios; we have focused on the impacts of carbon pricing, which remains the dominant policy lever for most countries. Finally, we adjust for the effects of stranded assets where we take account of the losses incurred where oil and other carbon based forms of energy have to be written off as it is no longer possible to make use of them such that they are left in the ground.

As an aside, we should be clear that in what follows we are analysing only the impact on economic growth and financial returns. We do not attempt to incorporate what economists refer to as 'externalities', or the impacts of climate change not directly captured in prices. This means our analysis does not factor in costs like reduced life expectancies or quality of life from higher pollution, for example. As a result, even where we might find a 'positive' impact from climate change, this should not be read as our advocating for global warming.

The science

While we have tried to limit the use of climate science terminology, there are cases where it becomes inevitable. There are a few basic concepts which might be helpful in understanding the work in this paper.

There is broad scientific consensus now that the world is getting warmer. What remains to be decided is just how much warmer the world will get. Chiefly, this will be determined by how much greenhouse gas (GHG) we continue to produce. The Intergovernmental Panel on Climate Change (IPCC), a UN body tasked with providing scientific information relevant to understanding the risk of climate change, issued a 2014 report[1] adopting four possible scenarios for GHG emissions. Known as Representative Concentration Pathways (RCPs), each corresponds to a different level of warming. RCP2.6 is a 'best case' scenario, in which GHG emissions are cut back sufficiently such that global warming is capped at around 1.5 to 2 degrees above the pre-industrial average. At the other end of the scale, RCP8.5 is a worst case, 'business as usual' scenario in which no effort is made to rein in emissions and as a result global temperatures increase by 4 degrees compared to the pre-industrial average by 2100.

1 IPCC AR5 Synthesis Report: Climate Change 2014. This was the last comprehensive Assessment Report detailing climate scenarios.

Modelling the impact of climate change

Step 1: The physical costs of climate change

By this point, a certain amount of global warming is baked in; regardless of mitigation efforts undertaken, we know the world will be warmer in 30 years than it is today. In our analysis, the temperature profiles of different climate change scenarios begin to diverge only after 2050, when mitigation efforts (or the lack thereof) begin making more of an impact. Consequently, the physical cost of climate change on our 30-year horizon will be the same in RCP 2.6 as in RCP 8.5.

That, however, is about as much simplification as we can expect. Even with certainty over the extent of warming, there is still much debate over the impact of that warming on economic activity. In this section we examine two possible approaches to modelling the physical costs of climate change.

Burke and Tanutama – a non-linear approach to the physical costs of a warmer world

One approach taken in assessing the physical impact of climate change is to assume a non-linear relationship between temperatures and productivity, as measured by output per person. Intuitively, this makes sense; an increase in temperatures in a cold country is less likely to adversely affect someone's ability to work than a similar increase in an already hot country. It turns out that there is plenty of evidence that labour productivity as well as health and crop yields exhibit a non-linear relationship of this kind[2]. Parlaying this into a broader macroeconomic impact is the task undertaken by Burke and Tanutama (2019)[3].

In their paper, the two authors undertake regression analysis at the 'district level' (sub-state level in the US, for example) across a historical dataset of 37 countries, to determine whether a non-linear relationship exists between aggregate output growth and increases in temperature (Figure 1, Appendix 1). The advantage of this approach, as opposed to conducting analysis at the country level, is that in larger economies like the US temperature changes in one region can be cancelled out by changes in another. This leaves average temperature at the country level little changed even as output suffers, masking the link between output and temperature.

2 Carleton, T. A. & Hsiang, S. M. Social and economic impacts of climate. Science 353, aad9837 (2016).
3 Burke, M., Tanutama, V. 'Climatic constraints on aggregate economic output' Working Paper 25779, NBER (2019).

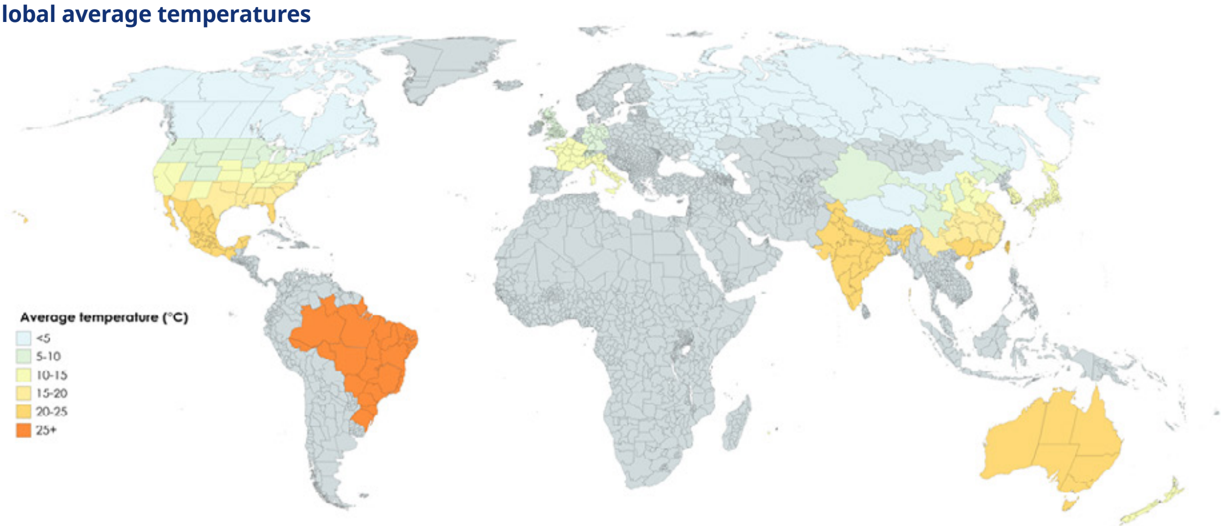
Burke and Tanutama find evidence for a non-linear relationship between changes in temperature and growth in output per capita (table 1, Appendix 1)[4]. That is, an increase in temperature is more harmful to productivity when starting from a higher base, with a greater impact when the model allows for a temperature shock to affect output in following years as well as the current one. While this effect is found to be of a similar magnitude in rich and poor countries (suggesting economic development does not yield much protection against climate change), the authors note that poorer countries are generally starting from a higher base temperature and so face greater economic losses from climate change.

An additional takeaway from these results is that there is some limited possibility of adaptation to warmer temperatures. The authors run versions of the model allowing for lagged interactions between output and temperature, on a one and five year horizon, in addition to the purely contemporaneous version of the model, allowing for delayed responses of growth or policy, for example, to changes in temperature. A degree of warming above 15 degrees Celsius is economically damaging in the 0 and 1 lag iterations of the model, but ceases to be statistically significant in the 5 lag iteration. Our interpretation of this is that, on a longer term horizon, countries in the 15-20 degree 'zone' are able to adapt to warmer temperatures. This may be through greater use of air conditioning, a switch to hardier crop varieties, or changes to working hours, for example. However, once temperatures exceed 20 degrees, it becomes much more difficult to adapt to increases without reducing output growth (constant air conditioning would increase the cost of production, for example).

We begin then to have an idea of the likely impact on some of our returns. A greater hit to productivity growth for poorer countries likely means that emerging market equity returns will suffer more as a consequence of climate change than those of their developed market counterparts.

4 Their formulation also includes precipitation but does not find it to be significant.

Figure 1: Global average temperatures



Source: Berkeley Earth, mapchart.net, Schroders Economics Group. February 2020.

Applying Burke and Tanutama to our forecasts

The most direct application for the work of Burke and Tanutama to our long run return forecasts is the case of equities. Our equity return assumptions use a Gordon's growth model approach, in which returns are generated through the initial dividend yield and the growth rate of dividends (via earnings growth). Earnings are assumed to grow in line with productivity, forecasts for which are made on a GDP per 'working capita' growth (i.e. growth in GDP/working age population, rather than GDP/total population). Consequently, we can feed the authors' work directly into our projections for productivity, and hence earnings, growth.

We can also use the productivity figures to modify our interest rate and bond returns. Following the framework developed by Laubach and Williams[5], long run equilibrium interest rates move in line with changes in trend growth in the economy. Assuming that the supply of labour is not affected by climate change then changes in productivity feed directly into changes in trend growth. In turn this directly affects the long run or equilibrium interest rate for the economy.

First, to get some idea of how impacted each economy will be, we need to know the starting temperatures, as this affects the choice of coefficient applied to temperature increases. We follow Burke and Tanutama in utilising data from the Berkeley Earth Surface Temperature dataset[6] to obtain these starting temperatures, shown in figure 1 for the markets we forecast. Note, however, that average temperatures may not always be a suitable starting point. For China and the US in particular, the average masks a huge degree of disparity between states or provinces, with both countries seeing a range of average temperatures at the subnational level of around -5 to +20 degrees Celsius. For these two countries, we instead model the economic impact beginning at the state or provincial level to capture this disparity[7].

Combining our average temperature data (including the modifications discussed for China and US) with Burke and Tanutama's estimates for the impact of temperature increases, we can calculate the impact on output per capita growth, and in turn on productivity, for each economy over the next 30 years[8], in different versions of the authors' model (0, 1 and 5 year lags). The results are shown in chart 1.

5 Laubach and Williams, Measuring the natural rate of interest, Review of Economics and Statistics (2003).
6 Berkeley Earth Website.
7 For further detail please see the appendix.
8 This assumes two degrees of warming, in line with IPCC 2014 estimates for mid-century warming.

Countries can seemingly be divided into three clusters; those which may see benefits (though only in the five lag model), those which see no economic impact, and those which suffer economic harm. If we were to focus on the Burke and Tanutama baseline model, with zero lags, then climate change at best has no impact, and for a little under half the economies we consider has a negative impact. Note also that this is only over the next 30 years. On a longer time frame (e.g. another 30 years) we would see a further degree of warming, which would mean a number of the middle economies begin to suffer economic harm.

The implications for assets

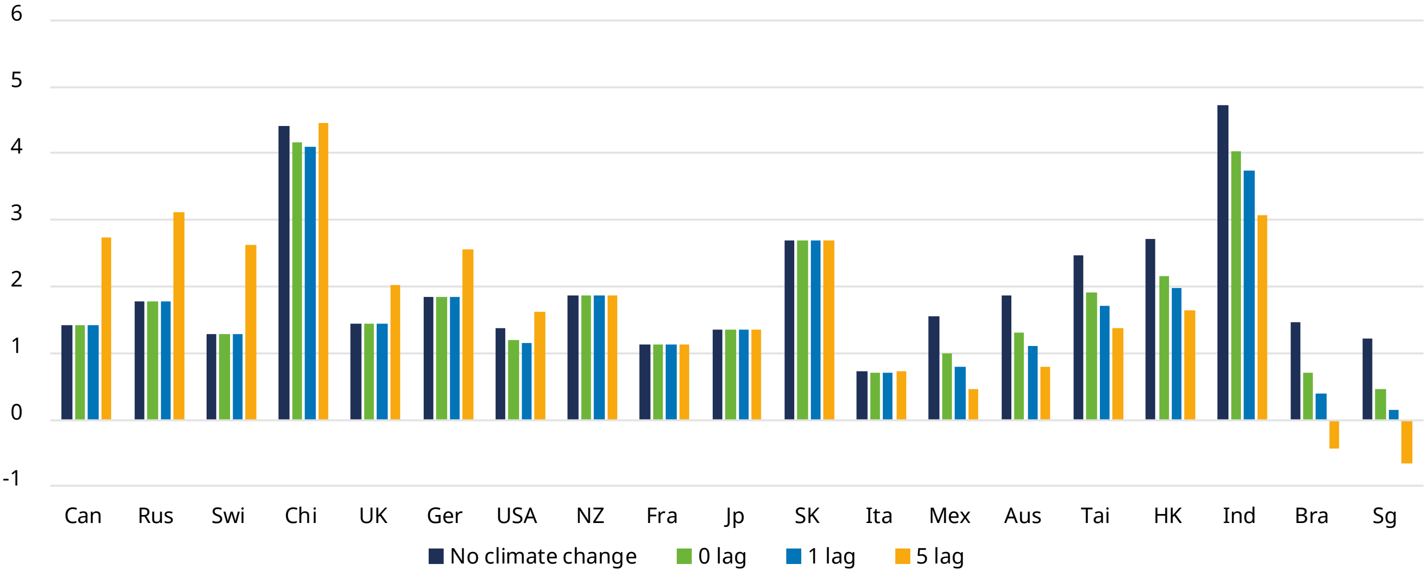
Having calculated the difference climate change makes to productivity, we are now ready to assess its impact on our asset return forecasts, starting with equities (chart 2). Climate change, viewed through this lens, is purely bad news for equity investors in the zero and one lag versions of the model, with returns adversely impacted in the US, China, Australia, Hong Kong, Taiwan, India and Singapore. We only see some benefits once we look at the five lag iteration, where benefits to cooler countries, and the now neutral impact for warm rather than hot regions (sub-20 degrees Celsius) see improved returns in Canada, Switzerland, the UK, US, Europe and China.

We can also assess the consequences for fixed income assets. Reduced productivity will feed through to a lower long run equilibrium interest rates, or r*. This will lower expected returns for cash, bonds and credit, with the latter two built on the initial cash forecast. As in equities, the warming effects of climate change will boost returns for cold countries (mostly developed markets), where the boost to activity will mean a higher equilibrium interest rate, and reduce returns in warmer countries. This results in a world where negative real yields are more common, as country after country finds it must keep rates even lower to support growth as rising temperatures take their toll on productivity[9].

9 Note that as our forecasts for bonds and credit simply add risk premia to our cash rate forecast, these impacts are the same for government bonds and credit, as we do not, for now, alter the maturity premium or credit premium as a consequence of climate change.

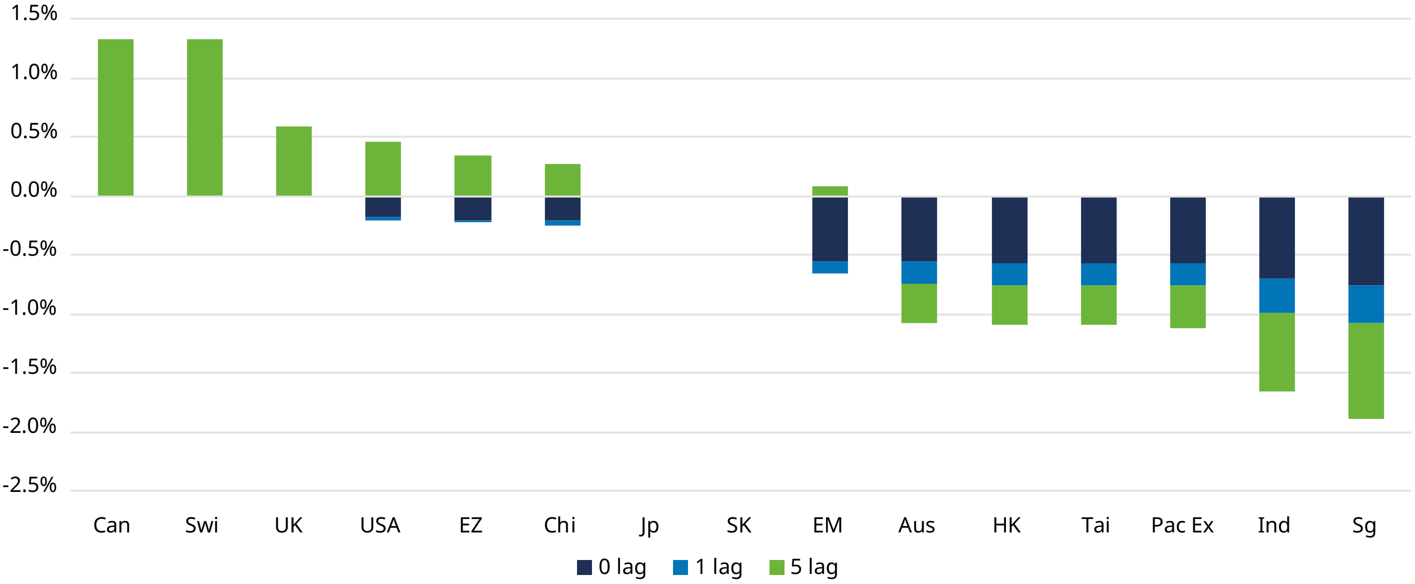
Chart 1: Productivity growth p.a. in different models

Productivity growth (% p.a.)



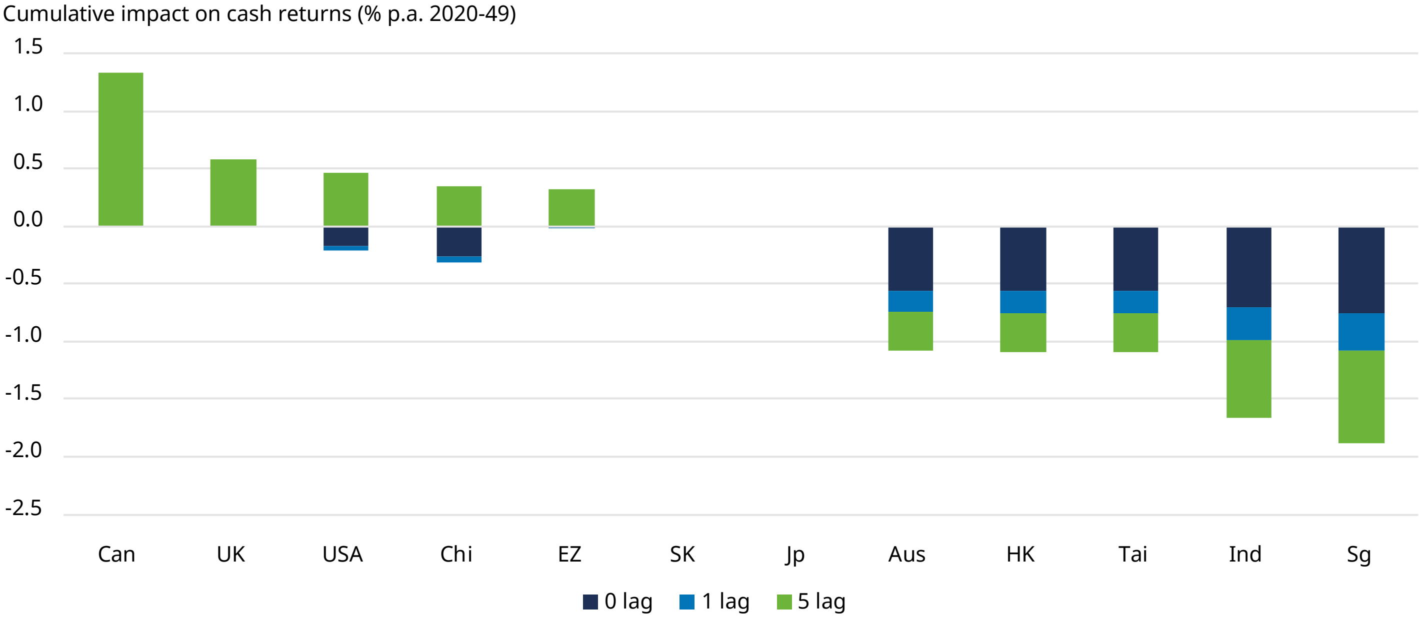
Source: Burke and Tanutama, Schroders Economics Group. January 2020.

Chart 2: The equity impact of rising temperatures



Source: Burke and Tanutama, Schroders Economics Group. February 2020.

Chart 3: The impact of rising temperatures on cash returns



Source: Burke and Tanutama, Schroders Economics Group. February 2020.

An alternative approach

The second approach we take to estimate the impact of climate change on 30-year returns is represented by the study from Kahn et al[10]. They investigate the long-term impact of climate change on economic activity across countries, building a stochastic growth model that postulates that labour productivity in each country is affected by a common technological factor and country-specific climate variables that include temperature and precipitation.

10 Kahn, M., Mohaddes, K., Ng, R., Hashem Pesaran, M., Raissi, M, and Yang, J. 'Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis' IMF Working Paper (2019).

Kahn et al. – Macroeconomic impact from rising temperatures

Similarly to Burke and Tanutama, they find that per-capita real output growth is adversely affected by persistent changes in the temperature above or below its historical norm, though with a lesser magnitude, and they also find no significant effects for changes in precipitation. Further, they find that the negative long-run growth effects are universal and affect all countries, hot or cold, and rich or poor. That starting temperatures do not matter here is a key departure from Burke and Tanutama.

GDP per capita under the RCP 8.5 Scenario

In the counterfactual analysis they estimate the output effects of country-specific average annual increases in temperatures over the period 2015-2050 as predicted under RCP 2.6 and RCP 8.5 scenarios. They compare them with a baseline scenario under which temperature in each country rises following its historical trend of 1960-2014. In particular, in the RCP 8.5 scenario, which assumes higher greenhouse gas emissions in the absence of mitigation policies, they find that an increase in average global temperature of 0.04 degrees Celsius per annum would reduce global real GDP per capita by 2.51% in 2050 and by 7.22% in 2100. Under their RCP 2.6 scenario, which corresponds to the December 2015 Paris Agreement and where temperature increases 0.01 degrees Celsius per annum, the output loss would be substantially reduced to 0.11% in 2050 and 1.07% in 2100.

Table 1, appendix 2 shows the per annum growth in GDP per capita under the RCP 8.5 Scenario and the scenario in which temperature rises according to its historical norm. The impact of climate change on productivity would be larger for countries such as Japan, Canada and Italy, and smaller for Germany, Australia and Russia.

We borrow their estimates of GDP per capita loss under the RCP 8.5 scenario and, by adjusting for work population, we are able to calculate the impact on productivity that we use to calculate 30-year equity returns. The results are summarised in table 2, appendix 2. Over the next 30 years, Indian equities will be hit the most in a scenario in which greenhouse emissions continue to trend higher and mitigation policies are not put into place. Canadian equities will also suffer, registering a 5.9% cumulative loss by 2050. German and UK equities will be less exposed to climate change as their return will decrease by only 1.4% and 2.5%, respectively.

Comparing the two approaches

When we compare the results from our two approaches (table 3, appendix 2), we note that the climate change impact on equity returns estimated following the analysis of Burke and Tanutama is higher than the estimates produced using the second study. Additionally, the returns estimated using the Kahn et al approach are lower than the returns under a no climate change scenario for all countries, and this is in line with the authors' findings that the negative growth impact of rising temperature is universal. On the contrary, if we follow the analysis run by Burke and Tanutama, equity returns of countries like UK, Canada, Switzerland, the US and the eurozone will see a positive boost from climate change.

For fixed income, the same pattern holds. With much smaller revisions to productivity, the changes to cash, and hence bond and credit, returns are correspondingly much more marginal, and no country benefits from warmer temperatures; climate change means globally lower interest rates.

Deciding on an approach

In our analysis, we have opted to follow the Burke and Tanutama methodology. Partly this is because their work utilises a much larger, and more granular, dataset. Partly it is because there is an intuitive appeal in a non-linear relationship between temperatures and output, and in the idea that colder regions should benefit as temperatures rise. It is also because their results give us something we can work with – if Kahn et al are right then the impact on equities is close to negligible and we need not worry about climate change[11].

We assume also that warming from now until 2050 is unavoidable and essentially unalterable and that the world is now destined to be at least 1.5 degrees warmer, if not 2 degrees. Some of this, relative to pre-industrial averages, has already happened. We will assume therefore that temperatures rise at 0.04 degrees Celsius per year until 2050, as in Kahn et al, regardless of efforts to limit warming, which only yield benefits after 2050. To the extent that we are wrong on this and mitigation efforts do limit warming before 2050, it would represent an upside risk to our return forecasts.

11 Readers who prefer the Kahn et al approach could simply discount the physical cost from all future estimates in this paper.

Step 2: The transition costs of climate change

Business as usual, when it comes to climate change, is projected to give us a much warmer world in the years to come. If the promises of world leaders are to be believed, business as usual will very much be disrupted. The aim of the 2015 Paris Agreement, for example, is to limit warming to no more than two degrees above the pre-industrial average.

At present, the world is not on track to meet the Paris Agreement objectives. Nations are already falling short on self imposed targets which in themselves are anyway insufficient to limit warming to 2 degrees, and the gap is widening[12]. We take a look at some estimates of what is needed to bring emissions in line, and the economic cost of those measures. In what follows, we will draw heavily on recent work from the International Monetary Fund (IMF)[13] and the International Energy Agency (IEA)[14].

The choice of mitigation tool is important

In order to reduce carbon emissions, we have a few options. Governments could act to forbid pollution via regulation, shutting down carbon heavy industries and keeping cars off the road, as happens in China during periods of particularly heavy air pollution. Alternatively, we could allow pollution if the polluter is willing to pay, and calculate a price likely to result in the desired level of carbon emissions, which under so called 'cap and trade' schemes allow economies to adjust by curtailing the least economically valuable activities first.

Economists tend to prefer the second option, seeing it as more efficient, which in this context means minimising the cost to the broader economy of a given reduction in pollution. We would like the impact on growth to be as small as possible. Introducing a carbon price also provides an incentive to households and corporates to find ways of reducing emissions, as every additional unit of carbon produced incurs additional costs. Regulations, meanwhile, do not have these incentives, as they instead prohibit certain polluting activities without pushing for a reduction in emissions elsewhere.

12 IPCC 2018
13 See, for example, IMF Fiscal Monitor 'How to Mitigate Climate Change' October 2019
14 World Energy Report 2019.

We will be optimistic, and hope that policymakers plump for the more efficient policy choice. But even within pricing, there are a number of different options. Again, we will assume that the most efficient path is taken, which according to the IMF would be a carbon tax[15]. This would apply a tax on the supply of fossil fuels in proportion to their carbon content. This has the added benefit (for governments, anyway) of generating additional revenues.

What is the best price for carbon?

Having decided that we want to look at the costs of a carbon tax, we now need to know how high that tax would need to be in order to achieve the Paris Agreement aim of limiting warming to 2 degrees. Estimates vary, with the IMF arguing for a $75 per tonne tax globally, and the IEA proving more aggressive, with a tax starting at $100 per ton for developed market economies and $75 per tonne for emerging, increasing after a decade.

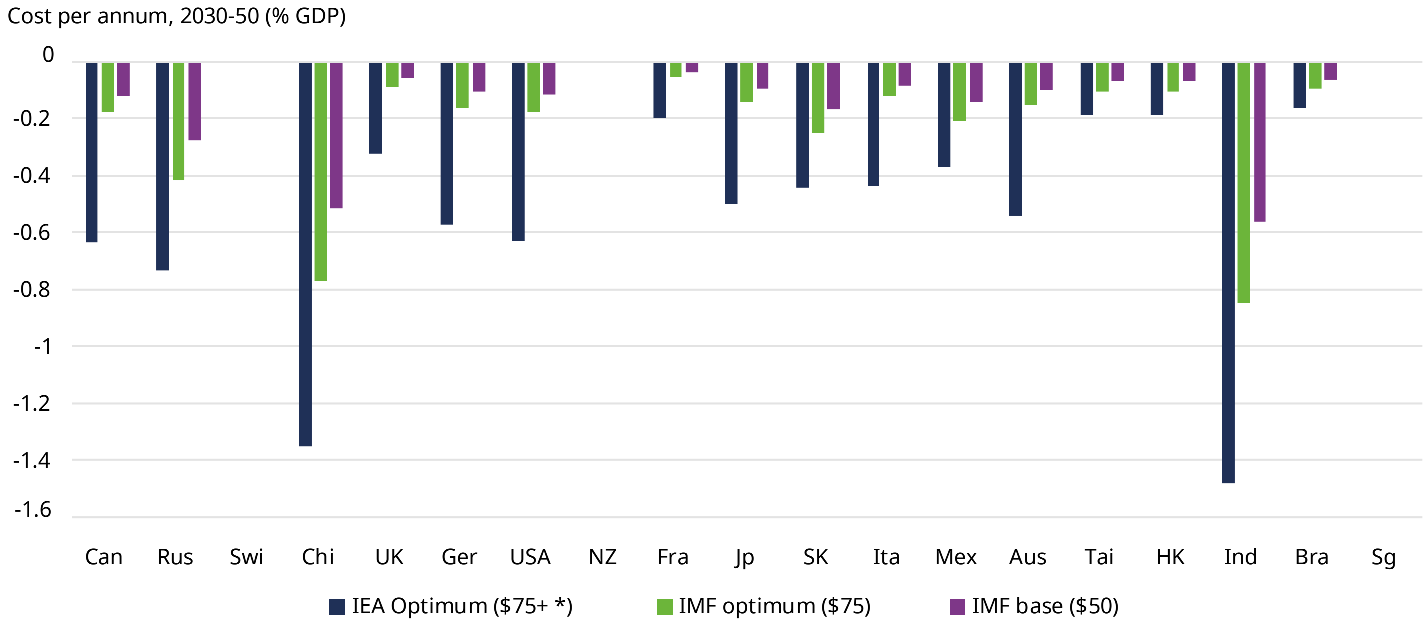
This split between developed and emerging hints at another consideration in any modelling exercise for climate change. What solution is politically palatable? It might seem fairer to charge emerging market economies less for carbon because they are earlier in their development stages and so naturally at a more carbon intensive phase, which advanced economies have all been allowed to exploit. Against that, developed market economies may complain of the competitive advantage this hands to industries, particularly given the tensions between China and the US at present.

These considerations hold at the more local level as well; how willing will electorates prove to accept a large increase in the price of carbon? The IMF estimates for example that the average global carbon price is currently around $2 per tonne, implying a huge increase. Only Finland, Sweden and Switzerland are near, or above, the IMF's optimal $75 price. Political considerations also affect the use of any revenues from a carbon tax, an issue we will revisit.

For these reasons, the IMF explicitly models the costs of a $50 per tonne carbon tax, with the view that this may be the best we can hope for within the realms of political feasibility. In our analysis, we will consider the costs of each proposed tax level.

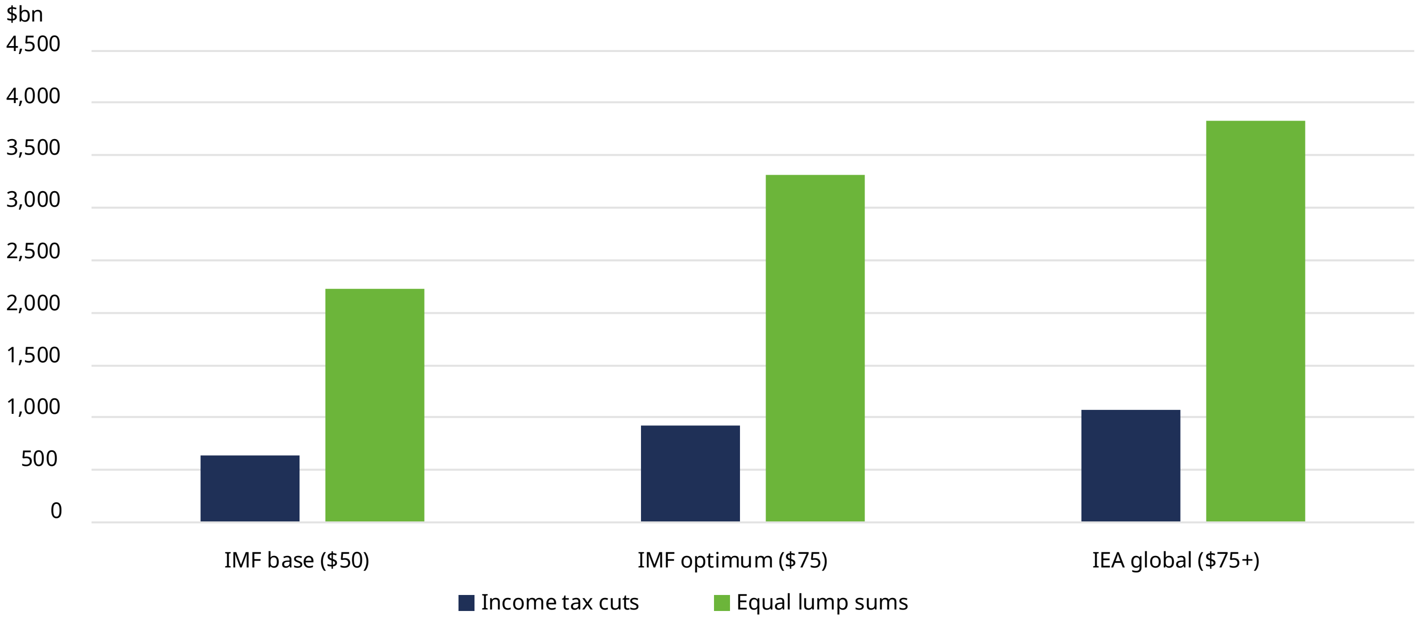
15 We would note that this is not universally accepted, and a case could also be made for emissions trading, though this would potentially limit government revenues.

Chart 4: Efficiency costs of a carbon tax



Source: IMF, IEA, Schroders, February 2020.
* IEA pricing starts at $75 per ton for EM, $100 per ton for DM, and climbs to $100 and $140 respectively after 10 years.

Chart 5: The global output cost of carbon pricing (2030-50)



Source: IMF, IEA, Schroders, February 2020. IEA pricing starts at $75 per ton for EM, $100 per ton for DM in 2030, and climbs to $100 and $140 respectively after 10 years.

The cost of cleanliness

The analysis produced by the IMF considered two main channels for mitigation costs. Perhaps the more obvious is the cost to the economy of higher energy prices, bringing with it reduced consumption and production. In addition to this though we also need to include the cost of a shift to cleaner, but more expensive, technologies and equipment as firms and others try to cut their carbon bill.

The IMF looked at the cost to a small subset of economies in its Fiscal Monitor, but based this on a much larger dataset constructed for an earlier paper[16] which looked at over 100 economies. In general, the per annum cost of a $50 carbon tax seems to be between 0.1 to 0.5% of GDP, rising to 1% in higher emitting economies like China and India. We have scaled these costs in line with our different carbon tax estimates in chart 4. Note that the IMF and IEA assume that any tax does not begin until 2030, presumably because of the political realities involved.

Efficiency costs are higher for higher emission countries, as we might expect. Within DM, Canada, Australia and the US, all with substantial energy and commodity extracting industries, face larger burdens. Germany is also more exposed than other European economies, possibly a result of a large manufacturing base and relatively unclean sources of energy. In EM, oil producers join major oil consumers, with three of the four BRIC[17] economies facing substantial costs from the shift to cleaner technologies. The costs though are particularly high for India and China, highlighting the challenge in getting agreement on any plan to tackle climate change. As a final note, we should add that these are likely overestimates of cost. We might expect that the per annum cost will diminish over time as newer technologies are adopted – the IMF only gives the annualised cost in 2030.

16 IMF 'Fiscal policies for Paris climate strategies – from principle to practice' May 2019 Policy Paper
17 Brazil, Russia, India, China

Output losses

The IMF also estimates the cost of a carbon tax in terms of the lost economic output. In the Fiscal Monitor, this work focuses on the US, and so a note of caution is warranted in extrapolating to other economies. With that caveat in mind, what is notable about this element of the tax's cost is that it varies hugely depending on the assumption made about how the resulting revenues get used.

Again, if we slip into economics jargon for a moment, the IMF's focus is on how 'distortionary' the overall tax burden is. That is, how big an impact taxes are having on the decisions of households and corporates as to whether or not to spend, invest, and so on. Clearly a carbon tax has some distortionary effect – that's the whole point – in reducing consumption of energy and supply of carbon intensive goods. To reduce the efficiency loss, the IMF proposes using revenues from the carbon tax to offset other distortionary taxes in the economy: namely income tax.

This, they argue, would reduce the cost of a $50 per tonne tax to $20 per tonne of carbon reduced. This view is not without its sceptics; it would seem to rely on the idea that income taxes in the US are too high and that cutting them would increase work effort. Suffice to say this is not a unanimous view.

Such a policy, of course, would also be highly regressive. As a share of income the carbon tax would take most heavily from the poorer in society, and the income tax cuts would disproportionately benefit the wealthiest. It is not difficult to see that this might be politically unpopular. The IMF suggest an alternative, less efficient but more politically acceptable policy, in which the revenues from the carbon tax are redistributed as a lump sum to all households. This, they estimate, would incur a cost of $70 per tonne of carbon reduced for a $50 per ton tax. A third option is also discussed, of partial redistribution and partial tax reduction, which seems to fall somewhere in the middle. However, hard figures are not provided. For our purposes, we will use the two numbers we have; costs of $20 per tonne and $70 per tonne, as an indicative range.

Now that we have a cost per ton reduced, the next thing we need to know is how many tons of carbon we need to get rid of. This time, the IEA have done the hard work for us, with three scenarios for carbon emissions assuming varying efforts to meet global targets. Compared to a business as usual scenario, the global reduction needed to hit the Paris targets is as much as 31.6 gigatonnes (Gt)[18]. The global cost of this reduction depends on the carbon price assumption we make, and as discussed the use made of any revenues. On our calculations using the IMF analysis alongside the IEA data, we come up with a total cost of $636 billion to $3.8 trillion (chart 5).

Spread over twenty years this seems fairly manageable, when considered against global GDP of $90 trillion. However, the burden is unlikely to be shared evenly; some economies produce much less carbon than others for every dollar of GDP. The more carbon intensive economies will face a much higher absolute burden from any move toward carbon pricing.

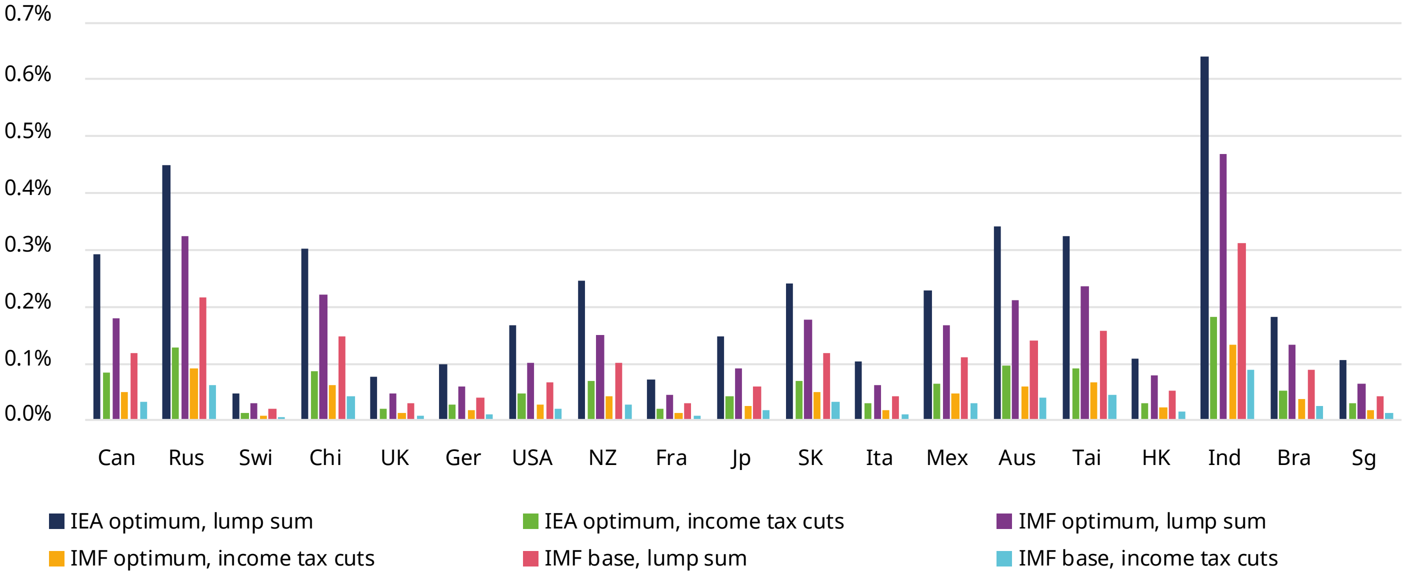
Calculating the output cost to individual economies

A partial disaggregation of carbon emissions, current and projected, is available from the IEA. We combine the IEA data with data from the World Bank on current greenhouse gas emissions to estimate the likely carbon reduction required for each of our economies, and the associated cost (chart 6). As expected, economies we might think of as being more carbon intensive tend to see a larger cost associated with a carbon tax. India in particular stands out here. Europe looks less exposed than other developed market economies, and service heavy economies in particular have little to worry about.

18 One gigatonne is one billion tonnes

Chart 6: Individual country output costs of carbon pricing

Cost p.a. (2030-50), % 2030 GDP



Source: IMF, IEA, World Bank, Schroders. February 2020.

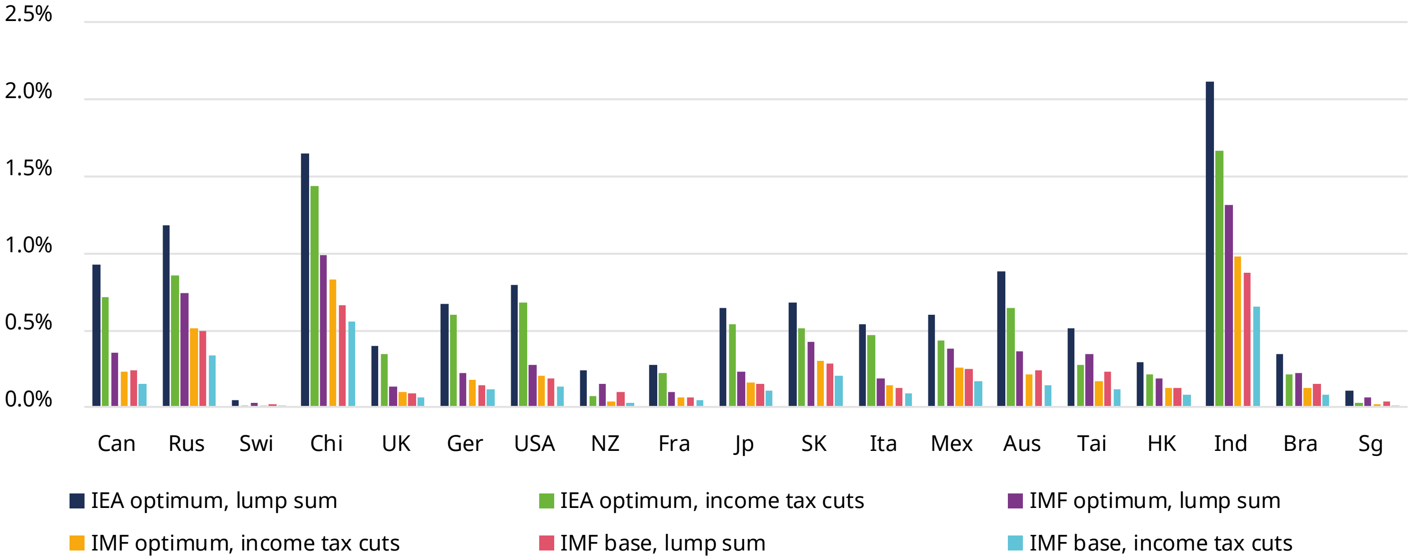
Total losses from mitigation

Combining our two sets of estimates for costs, from efficiency losses and foregone output, we arrive at our estimates for the total transition costs for the economies we cover in the 30-year returns analysis. Very obviously the choice of carbon price and the use of the tax revenues makes a huge difference to the economic cost. For more service oriented economies the difference is only 20 or 30 basis points of GDP a year, but for commodity focused economies the range is close to, or in excess of, 100 basis points (chart 7).

Translating mitigation losses into their impact on asset returns

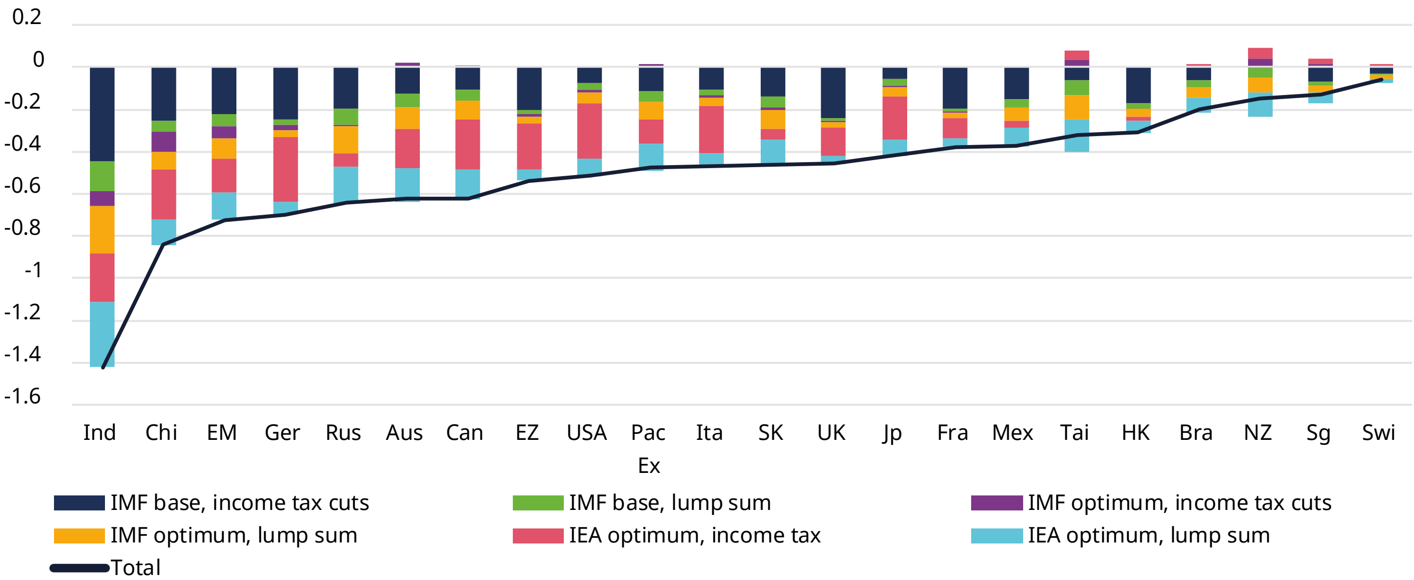
As with our work looking at the physical costs of climate change for investors, mitigation costs are expected to exert a drag on returns by reducing productivity growth, which in turn feeds through to lower earnings growth and cash rates. One slight difference though is that as the tax is assumed to kick in only in 2030, returns are unaffected by mitigation costs until then, slightly diluting the impact of the costs shown above when we consider them over the full 30-year period. Chart 8 shows the range of expected returns under different scenarios.

Chart 7: Aggregate costs of transition



Source: IMF, IEA, World Bank, Schroders, February 2020. Note that these are potentially overestimates for per annum impact on growth as they are based on 2030 GDP, and as discussed earlier some costs should decrease over time as the economy becomes more carbon efficient.

Chart 8: The impact of transition costs on equity returns



Source: IMF, IEA, World Bank, Schroders. February 2020. The chart shows how increasing carbon prices weighs on equity returns, subject to the use of the resultant revenues.

Consistent with the theme observed throughout, equities in service focused economies suffer far less than those in commodity intensive areas. Singapore and Switzerland face very limited mitigation costs, for example, as they have a negligible carbon reduction need. Canada, Australia and the US take more of a hit, though in more modest mitigation scenarios and with a more efficient use of resulting revenues, it looks quite manageable. For example, US equity returns are expected to be 0.5% p.a. lower with the highest carbon price and lump sum dividends, but if we assume the IMF optimum price of $75 and income tax cuts, then per annum returns are reduced by just 0.1%.

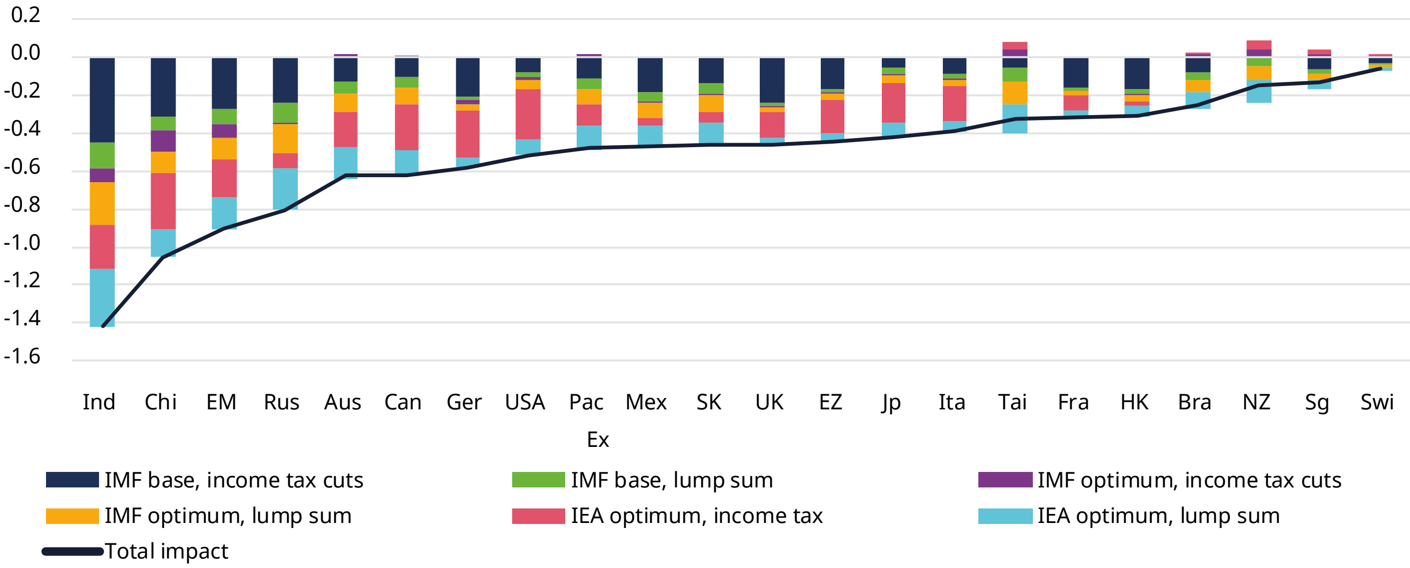
For emerging markets, the pain seems more palpable. China and India in particular look badly hit, and this feeds through to the EM aggregate. Per annum returns for EM fall 0.7% with full mitigation efforts, and even if we pare the carbon price down to $50 per tonne and implement tax cuts, returns fall by 0.2% p.a. But this level of pricing does not reach the Paris Agreement goals.

Fixed income returns (chart 9) tell a similar story. Focusing on real cash rates (with a reminder that the changes here will be matched one for one in revisions to bond and credit returns) we see some quite dramatic reductions in expected returns. Under more extreme scenarios, Indian real cash returns see a decline of 1.4% per annum, the largest downward revision of the markets we forecast. China too sees a sizeable fall of almost 1.1%, while in developed markets the worst affected are Canada and Australia, where annualised returns fall by 0.6 percentage points each. In a slight difference from the physical costs, no country benefits from the effects of transition in this timeframe; returns are lower everywhere as a result of the costs associated with mitigation efforts.

One final part of the transition process we have yet to consider is the question of stranded assets. In particular, any attempt to limit global carbon emissions is going to mean we have to reduce the quantity of fossil fuels we burn. Yet present valuations of energy companies, for example, implicitly assume that their energy reserves have future market value. If this changes, there will be consequences for equity markets.

Chart 9: The impact of transition costs alone on cash returns

Cumulative impact on real cash returns (% p.a. 2020-49)



Source: IMF, IEA, World Bank, Schroders. February 2020.

Step 3: Stranded assets and equity returns

In order to limit the increase in global temperature to 2 degrees Celsius as established in the Paris Agreement, a fraction of the existing reserves of fossil fuels must remain in the ground, thereby becoming stranded assets.

Current reported fossil fuel reserves worldwide consist of around 1 trillion tonnes of coal, 1,700 billion barrels of oil and 200 trillion cubic meters of gas. Recent analysis from the International Energy Agency IEA finds that the CO2 emissions that would result from combusting these reserves account for around 2800 Gt of CO2, more than three times the carbon budget allowed in the 2°C Scenario (880 Gt)[19]. In particular, the IEA highlight that, globally, almost 60% of oil and gas reserves, and over 80% of current coal reserves should remain unused in order to meet the target of 2°C.

Chart 10 shows the cross-country distribution of reserves of fossil fuels, highlighting that Russia has by far the largest amount of reserves, followed by the US and China. This suggests that these countries are therefore at risk of witnessing severe wealth losses if climate policies were to be implemented in a low carbon transition. In this scenario fossil fuel markets would dramatically shrink and the prices would decline substantially, with large losses to asset owners. Proven reserves, which are estimated to be extracted profitably at current prices, may also remain undeveloped if governments impose policies to limit the market supply of fossil fuel resources. Recent research shows that approximately $4 trillion of financial value could vanish off their balance sheets globally in the form of stranded assets[20].

This would clearly pose risks to financial markets, particularly on stock markets, as companies' equity value is likely to shrink in a low carbon transition scenario. For this though, we need to know the listed ownership of these reserves, rather than their geographical distribution. As an example, the UK has negligible reserves but the UK equity index contains a number of large energy companies which will hold reserves in multiple jurisdictions. Chart 11 shows reserves held by listed entities instead[21].

19 IEA 'Perspectives for the energy transition' (2017).
20 Mercure et al 'Macroeconomic impact of stranded fossil-fuel assets' (2018)
21 Note that this will exclude some large energy companies which are state owned and therefore not listed

Our approach

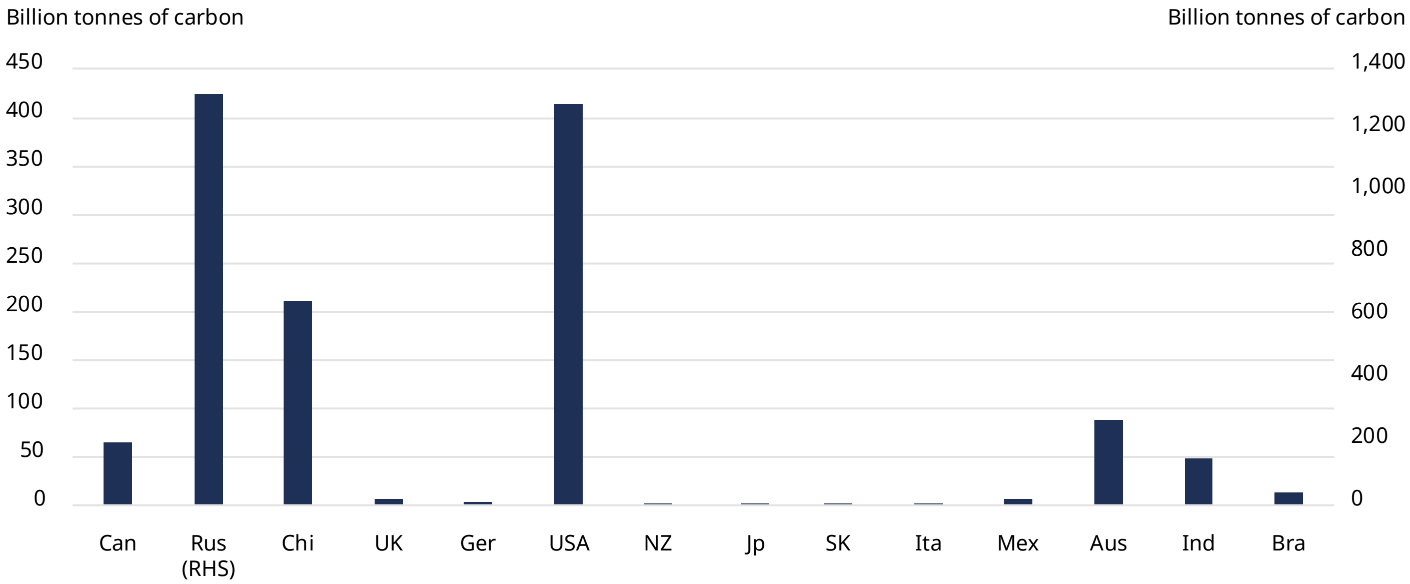
Using the estimate of global wealth loss and data from Fossil Free Indexes LLC that reports potential CO2 emissions from coal, oil and natural gas reserves owned by public companies we calculated the loss that companies' balance sheets would register given the fraction of un-burnable reserves of oil, coal and gas for each equity index. We use estimates from the IEA[22] for the share of un-burnable reserves in two scenarios; one consistent with no more than 2 degrees of warming, and one in line with stated policies which leads to 3 degrees of warming or more. We then estimated by how much equity returns would be reduced in a stranded asset scenario by calculating the ratio of wealth loss over market capitalization for each equity index.

The results are shown in chart 12, highlighting the sizeable impact to EM returns, particularly in India, China and Russia. Even if a more lax approach is taken and warming is allowed to exceed Paris Agreement targets, overall EM equity returns are still some 1% lower per annum. Developed markets look better off than their emerging counterparts, though returns in Australia are expected to be some 0.4-0.5% lower per annum. In the US, returns see only a small downward adjustment; a reflection of the sheer size of the equity market, even relative to its oil giants.

In the next section, we combine this analysis with our prior work on transition and physical costs to produce an aggregated impact from climate change.

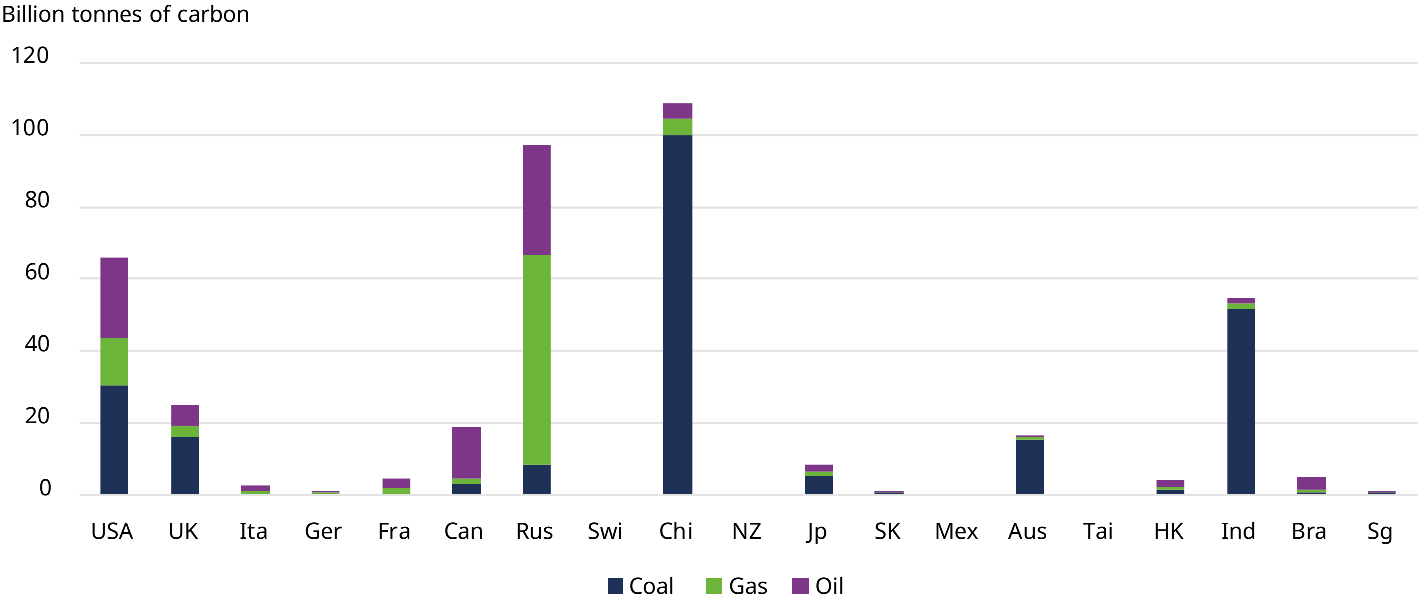
22 IEA 'The Oil and Gas Industry in Energy Transitions', (2019)

Chart 10: Reserves of oil, gas and coal



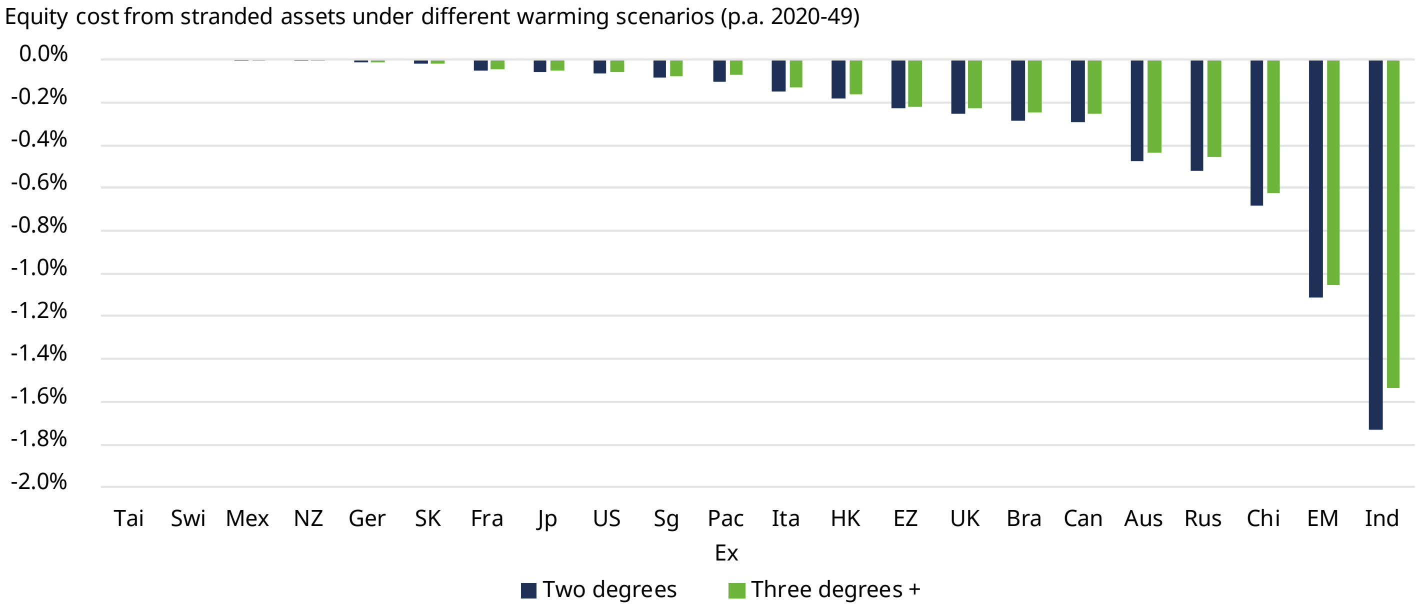
Source: BP Statistical Review of World Energy 2019. 8 January 2020. We have focused on countries for which we provide market forecasts.

Chart 11: Carbon emissions in reserves of listed companies



Source: MSCI, Refinitiv Datastream, Schroders. February 2020.

Chart 12: Reduction in equity returns



Source: Refinitiv Datastream, Fossil Free Indexes, Schroders Economics Group. February 2020. For Russia, we use the MICEX Index instead of the MSCI Russia, given the low number of listings on the latter. We also use the Nifty Index for India and the Shanghai Stock Exchange Composite Index for China since we have data for companies listed on their domestic stock exchange.

Step 4: The aggregate impact of climate change

In earlier sections we analysed separately the effect of the physical aspects (a warmer world) and transition costs (carbon pricing and stranded assets) of climate change on productivity growth and hence on equities. Now we look to combine those estimates to provide a single figure for the impact of climate change on economic growth and asset class returns.

Notable throughout has been the range of uncertainty, not only around the economic relationships but also policy responses. The choice of economic model, carbon price and the use of funds raised by a carbon tax all have material consequences for the final estimate. To narrow down our results, we will have to make some decisions about what seems a more likely scenario.

Physical cost assumptions

First, considering the modelling of the physical impact, a non-linear relationship between temperature and productivity seems more plausible than a linear one. With temperatures much above 35 degrees, for example, the human body simply can not function for long. Meanwhile, Russia and Canada are already enjoying benefits of a warmer world as the Arctic becomes more navigable. For this reason, we will take the Burke and Tanutama (2019) results as our assumption for the physical cost modelling. We then need to decide which iteration of their model we want to use. The authors ran models allowing for lagged effects as well as one in which contemporaneous impacts only were considered. Again, to us, a lagged relationship makes more sense; we are used to allowing twelve to eighteen months for monetary policy to feed through, and responses to warmer temperatures are also likely to take time to fully play out. We will use the five year lag version of their model in what follows.

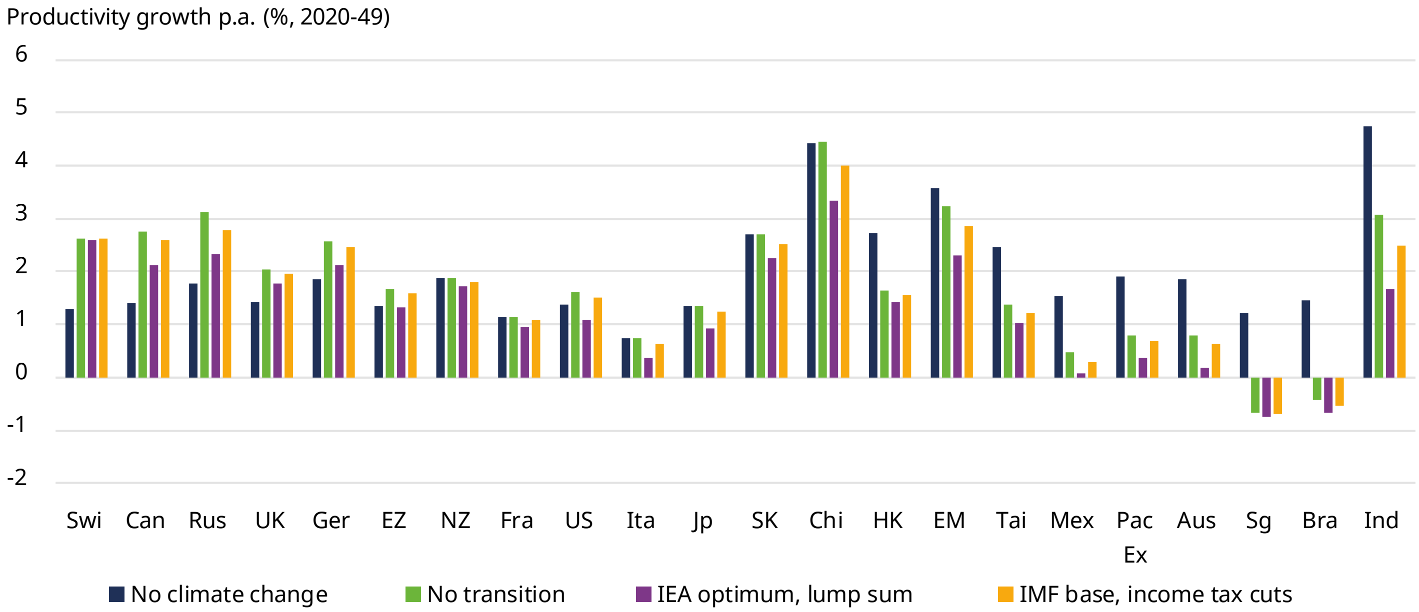
Transition cost assumptions

Secondly, we need to make an assumption about the likely policy response. In the previous section we ran through a number of possibilities, both in terms of the price set on carbon by any carbon tax (which we have already assumed is the chosen policy, rather than quotas, or a carbon trading scheme for example) and in how the revenues of such a tax might be used. Inevitably, political calculations will at least partially drive the decision made by policymakers. We might (optimistically) hope that politicians committed to the Paris Agreement goals opt for the IEA recommended pricing of carbon – higher than the IMF's – but choose to make it politically palatable by using the revenues to pay lump sums to all citizens. On the IMF's analysis, such a policy would increase the economic distortions and hence the cost, but we think it will likely be more acceptable to electorates than a regressive policy of essentially taking money from the poor with a carbon tax and giving it to the wealthy (the IMF's more efficient solution). Of course, we may still be too naïve on the politics. The IMF suggest a carbon price of $50 per ton given political difficulties.

Stranded assets

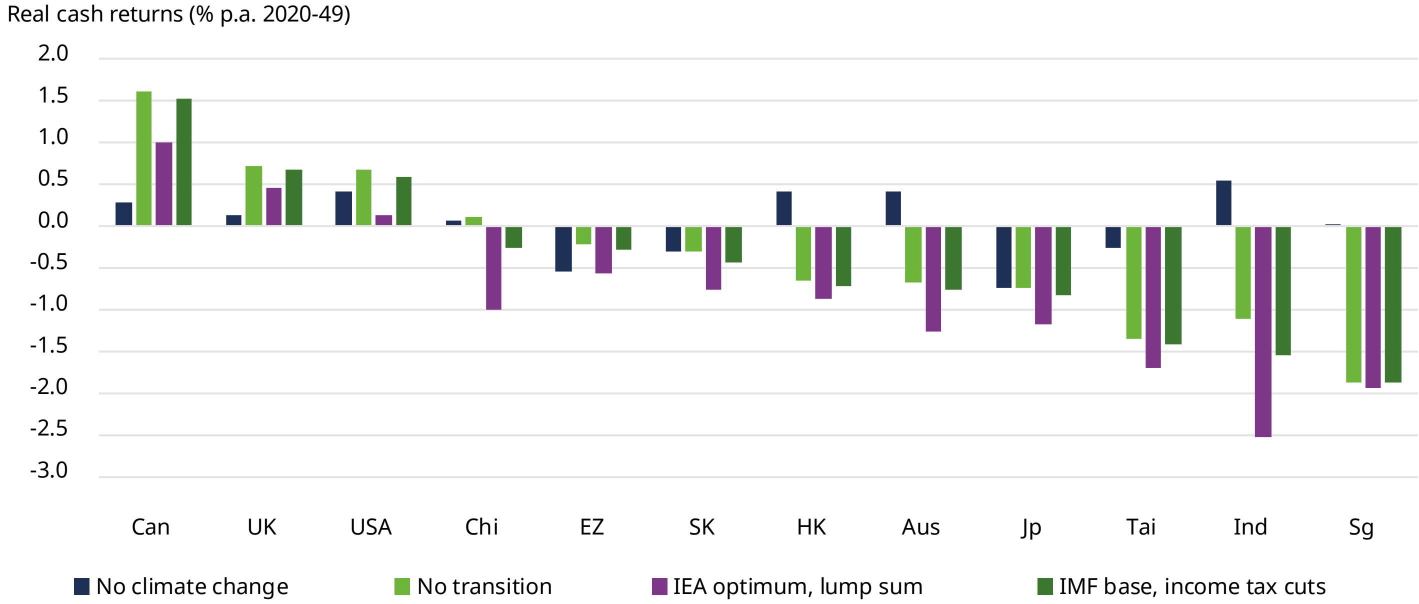
Finally, to complete our transition analysis, we need to make an assumption about the lost or stranded assets occasioned by climate change policy. We assume that nearly 60% of oil and gas reserves, and 80% of coal reserves are left in the ground resulting in a $4 trillion reduction in global market cap for a scenario consistent with meeting the Paris Agreement. If governments opt to fall short, the value of stranded assets will be less but still enough to weigh materially on equity returns.

Chart 13: Productivity growth and climate change



Source: IMF, IEA, World Bank, US Census Bureau, Schroders. February 2020. 'No transition' assumes no efforts are made at mitigation, and so captures physical costs (or benefits) only.

Chart 14: Real cash returns in different climate change scenarios



Source: BEST, IMF, IEA, World Bank, US Census Bureau, Schroders. February 2020.

Overall productivity effects from climate change

Chart 13 shows productivity growth per annum in these two scenarios, and for comparison also shows a world without climate change, and one in which no transition efforts are made. We might think of these different scenarios as mapping onto the different RCPs; no transition efforts would be consistent with RCP 8.5, a carbon price of $50 per tonne, insufficient to cap temperature increases at 2 degrees Celsius, would be more consistent with RCP 4.5, and the IEA optimum pricing is what is needed to achieve RCP 2.6.

First, we would note that colder countries still benefit from a warmer world even when we account for the costs involved in any transition. Russia, Canada, Switzerland, the UK and Germany are better off even after taking aggressive mitigation methods, compared to a world in which no warming occurs. However, most of these countries (Switzerland is an exception) would clearly prefer not to undertake mitigation efforts – at least from a growth perspective.

At the other end of the spectrum, things go from bad to worse for hotter countries. While Singapore is relatively indifferent between a no transition scenario and mitigation scenarios, India is a glaring example of a country where carbon pricing rubs salt in the wound opened by rising temperatures. We would note, however, that on a longer horizon mitigation would start to deliver benefits for these countries against a world in which no mitigation is attempted.

The reason for this is that we are only considering a 30 year time frame. Essentially, our projected warming by 2050 is already set. Whatever mitigation we undertake, temperature projections will only be affected in the second half of this century, but the difference is significant. RCP 8.5 sees global temperatures rise 4 degrees above pre industrial norms by 2100, compared to the 2 degrees under RCP 2.6. Those extra 2 degrees would be very damaging for warmer countries, and so while mitigation may appear to make no economic sense based on our results here, once you extend the timeframe the argument becomes more compelling.

In between these two extremes sit the majority of developed market economies, for whom a warmer world is, initially at least, neutral or slightly positive. As a consequence, transition leaves them worse off than a no climate change world or a no transition world. For the more service focused economies though the cost of transition is at least relatively modest. As for investors, the final step is to translate these productivity forecasts into asset class returns.

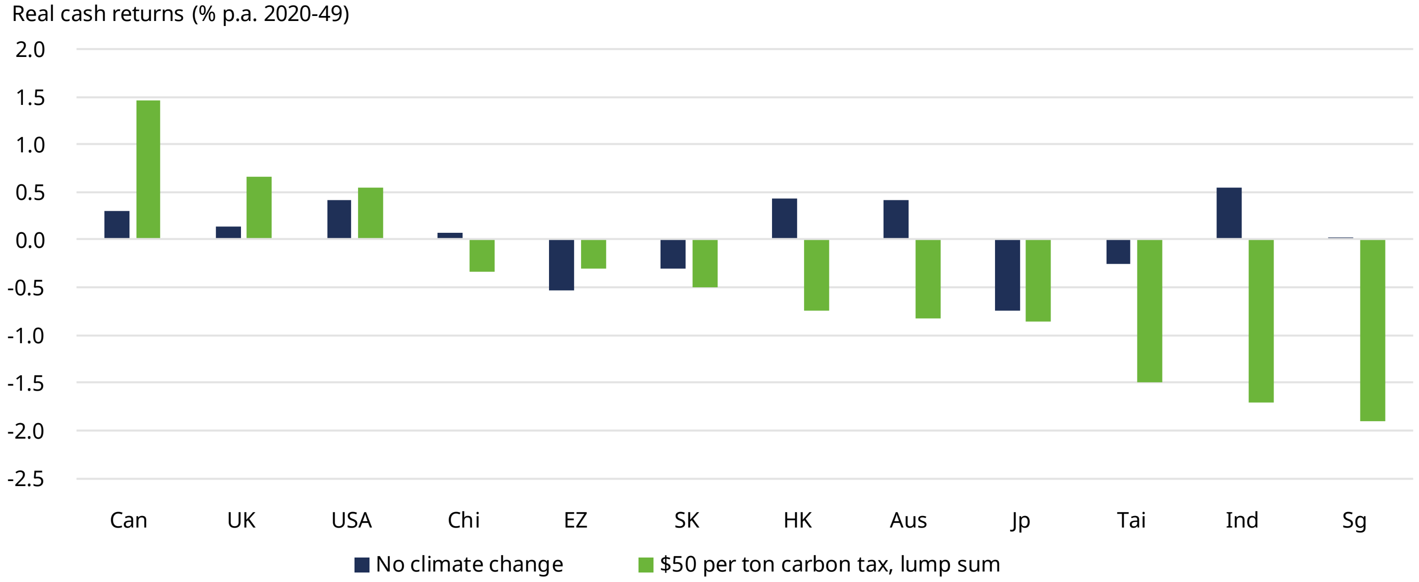
Climate change and asset returns

Now that we have aggregate estimates for the impact on productivity from climate change, we can produce a forecast for cash and other fixed income returns incorporating both the physical and transition costs of climate change. Focusing on cash rates first, given their role in driving the rest of our fixed income returns, chart 14 shows real cash returns under a range of climate change scenarios, from lowest impact to highest, though using in all cases the five lag iteration of the Burke and Tanutama model.

Compared to a world without climate change, real interest rates look a lot lower in hotter countries; as much as a two percentage point difference in some cases. Cooler countries, typically developed markets, could actually end up with higher real rates thanks to the productivity boost of rising temperatures in colder climes. Particularly Canada, but also the US and Europe end up with higher rates under any climate change scenario, benefiting the most if no attempt is made to mitigate climate change. This DM-EM split likely spells trouble for attempts to co-ordinate a global response.

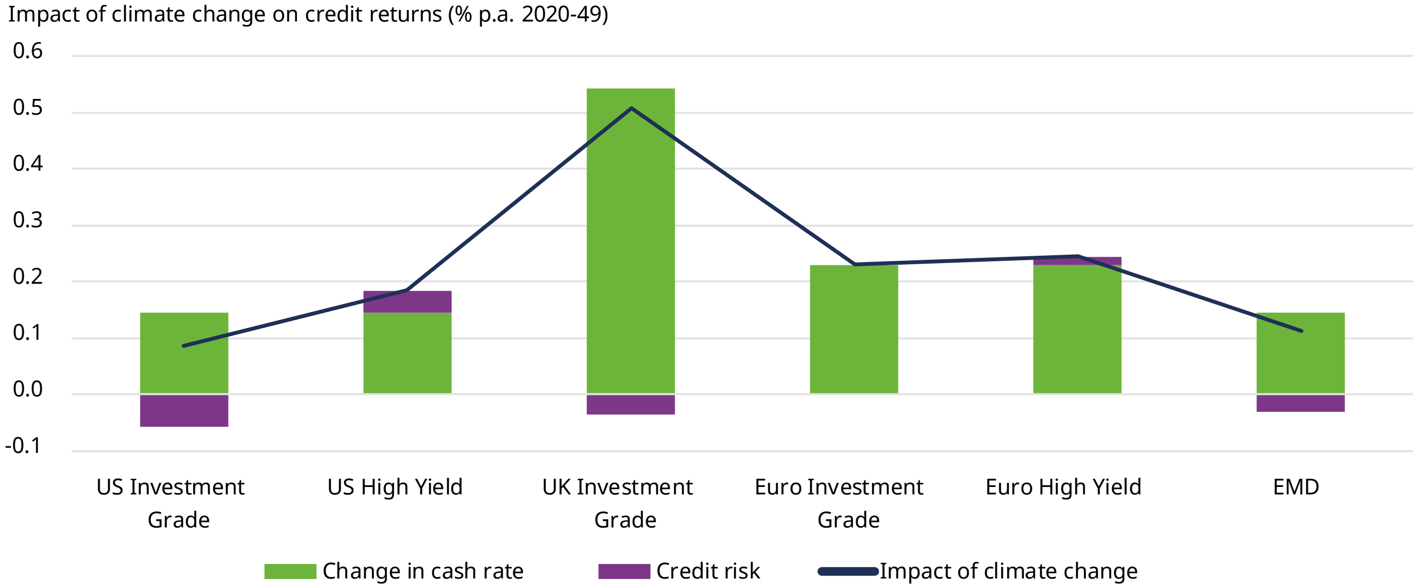
Ultimately of course we need to make an assumption about which of these scenarios will occur. Without wanting to seem overly cynical, it would appear that the shorter term calculus for political leaders will be to defer the pain. We have seen that the losses to growth, and to markets, are smaller the less effort is expended on mitigation efforts, even if it spells higher costs further down the line. Not only that, but the economies in a position to make the greatest difference typically have the smallest incentives to do so. The US and China, for example, would prefer (from a short-term financial perspective) to do nothing and so reap the immediate benefits of higher temperatures, or at least avoid the costs of acting. Consequently, we think that even when pressured to act, it is likely politicians will opt for the least expensive and politically costly choice. This implies a $50 per tonne carbon tax, with the revenues used to make lump sum payments to the electorate.

Chart 15: Cash returns in our base case scenario



Source: BEST, IMF, IEA, World Bank, US Census Bureau, Schroders. February 2020.

Chart 16: Credit return changes largely driven by new cash rate forecasts



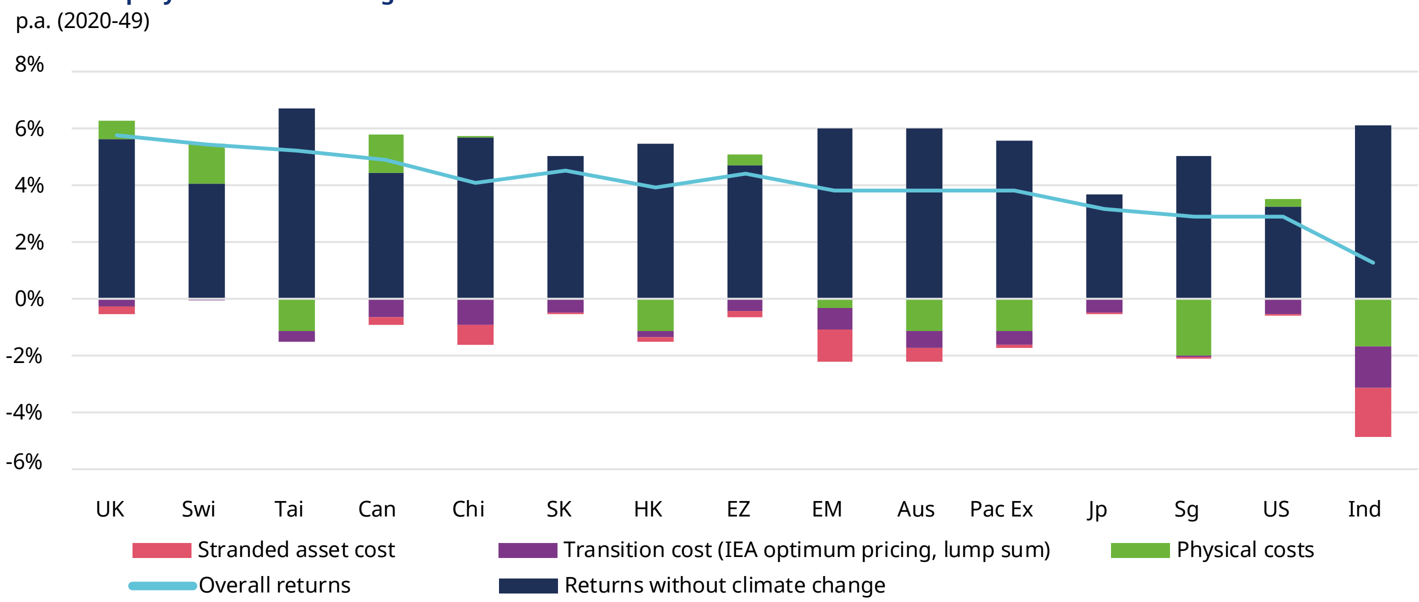
Source: BEST, IMF, IEA, World Bank, US Census Bureau, Schroders. February 2020.

On balance, this leaves cash returns in Canada, the UK and US above where they would be in a world without climate change (chart 15); the benefits from warmer temperatures outweigh the limited costs of mitigation efforts. Cash returns elsewhere are lower than pre-climate change, but this is largely the result of the physical costs of warming. With reductions of 2.2% p.a. and 1.9% p.a., India and Singapore are easily the worst affected markets.

While there are no additional consequences for sovereign bond returns beyond those we have already explored for cash rates, our forecast approach for credit returns does require us to make some adjustments for climate change. Essentially, our forecast for credit includes forecasts for default rates and spreads, which are linked to our expectations for GDP growth. As climate change impacts those expectations, it necessitates an additional revision of our credit return forecasts. The gains to US GDP slightly reduce default risk and hence spreads for credit assets. Overall changes to returns are relatively marginal, with the UK the greatest beneficiary; UK investment grade credit returns are 50 basis points (bps) higher per annum thanks to climate change, against gains of around 10 to 20 bps elsewhere (chart 16).

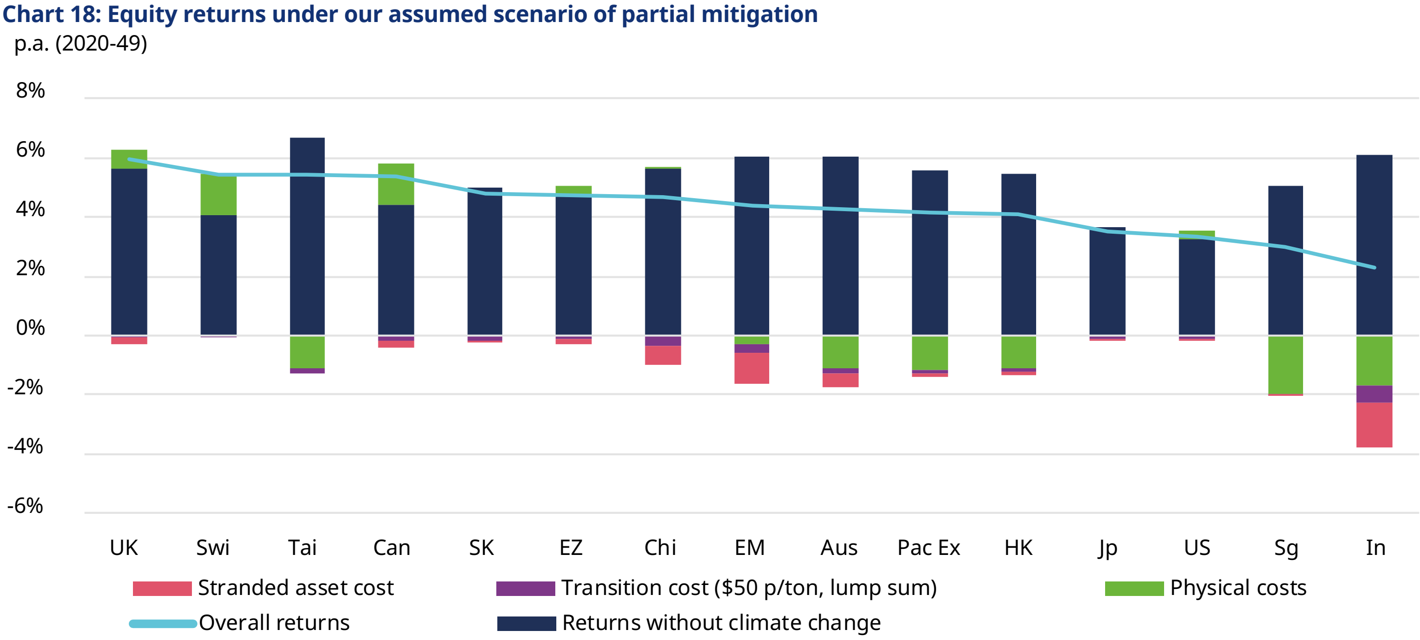
For equities, given the Gordon growth model approach we adopt (where returns equate to dividend yield and the growth in dividends), the next step is to turn our productivity forecasts from chart 13 into earnings growth projections. We can also now incorporate stranded assets into our per annum equity returns. We assume that equity markets gradually discount these stranded assets over a ten year horizon, from 2020-30, but the losses would look similar if we assumed instead a sudden, one off write down, or if we defer the writedown period to the final ten years.

Chart 17: Equity returns accounting for losses from stranded assets



Source: BEST, IMF, IEA, World Bank, US Census Bureau, Refinitiv Datastream, BP Statistical Review of World Energy, Schroders Economics Group. February 2020.

Chart 18: Equity returns under our assumed scenario of partial mitigation



Source: BEST, IMF, IEA, World Bank, US Census Bureau, Refinitiv Datastream, BP Statistical Review of World Energy, Schroders Economics Group. February 2020.

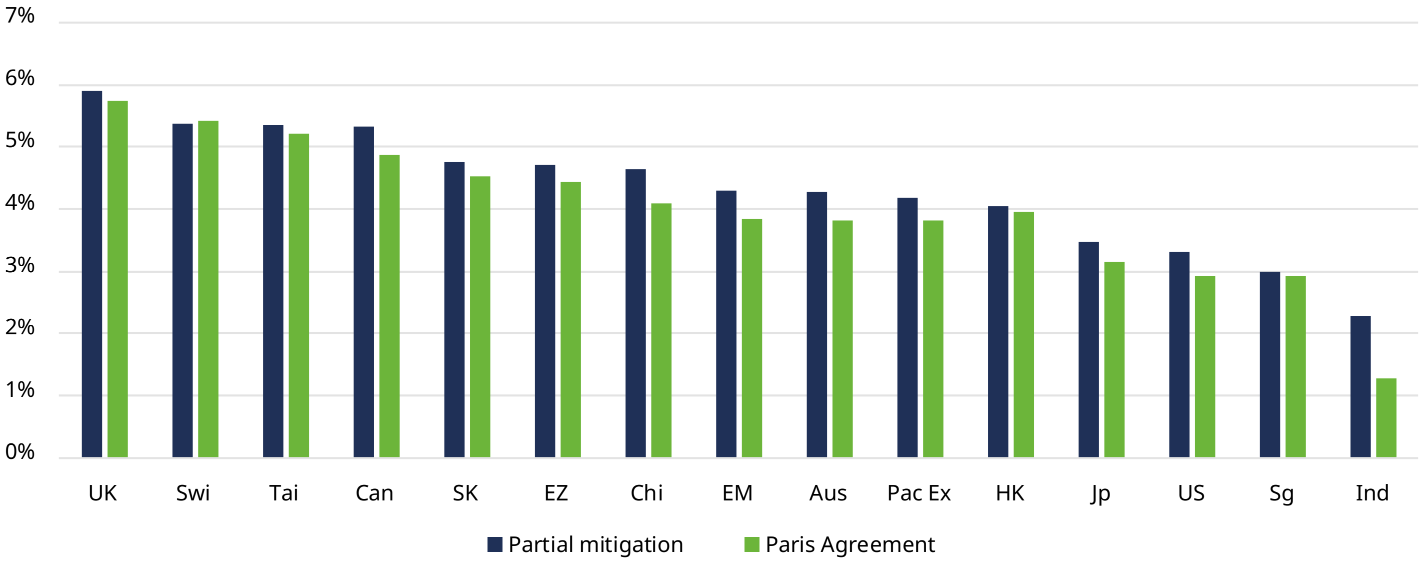
In chart 17 we show the impact for equities if policymakers target the Paris Agreement goals, limiting global warming to 2 degrees. This implies the highest carbon price we have considered (previously referenced as the IEA optimum) and a larger value of stranded assets. We also assume that to make such a scenario more politically palatable, the revenues from the carbon tax are used to finance lump sum payments.

Given that returns consistent with the Paris Agreement are nearly uniformly below returns in a world without climate change, it should be obvious that this is bad news for equity investors, particularly those in emerging markets. The biggest blow comes via India, Russia and China, reducing overall EM returns by around 2.2% p.a. This is enough to materially alter the relative attractiveness of EM equities, previously the fourth highest return forecast, it now slips to ninth. More generally, climate change plays havoc with our equity rankings. A large number of EM markets drop down the ladder and the UK is nudged into first place, just ahead of Switzerland. Only three countries are better off, once all climate change costs are accounted for; the UK, Switzerland, and Canada. Losses are material for most other equity markets, though the Eurozone, Japan and the US see only marginal reductions in expected returns.

Note however that this assumes the most costly form of transition; a very high carbon price and an economically inefficient use of the funds from the proposed carbon tax. It is perfectly plausible, if not more likely, that governments opt for a less costly transition. This would come at the cost of greater warming further down the line and hence greater economic losses by 2100, but long term thinking has been in notoriously short supply. As discussed previously, we think it is highly plausible that global politicians will try to minimise the short term pain of efforts to mitigate climate change, and opt for a $50 per tonne carbon tax, coupled again with lump sum payments to minimise political pain. The greater tolerance of warming is also assumed to reduce losses from stranded assets. We show the overall equity impact in chart 18.

Chart 19: Comparing equity returns under the best and 'worst' carbon prices

Forecast returns (p.a. 2020-49)



Source: BEST, IMF, IEA, World Bank, US Census Bureau, Refinitiv Datastream, BP Statistical Review of World Energy, Schroders Economics Group. February 2020.

This change in costs is beneficial to India and EM more broadly, where returns are some 0.5-1% p.a. higher than in our previous scenario. EM undoubtedly is still worse off than in a world without climate change, however. Canada and Australia also move up in the rankings, with Canada now better off than in a world without climate change. Perhaps a clearer illustration of the difference the change in carbon pricing has is in chart 19. Given the additional costs associated with Paris Agreement carbon prices, and that those costs are concentrated in China (0.6% p.a.), the US (0.4% p.a.) as well as populous India (1.0% p.a.), it is not difficult to see why we are leaning towards scepticism on the likely outcome.

Climate change and inflation

So far we have focused on the impact of climate change on output, without considering the consequences for prices and inflation. Given that we are discussing applying a tax to carbon in a deliberate attempt to make carbon intensive products more expensive and so reduce their consumption, some inflationary impact seems obvious. We do have some numbers to work with. The IMF[23] provided some estimates of the impact of a carbon tax on energy prices in their 2019 Fiscal Monitor, reproduced opposite.

A separate study[24] looks at the impact on product prices of a push for net zero emissions. In general, end product prices are estimated to increase only marginally, but intermediate goods prices increase more substantially. For example, cement could double in price, ethylene could see a 50% increase, and steel costs could increase by 20%, but end user products: construction, plastics, and autos, would increase in price by only 1-3%. Perhaps the biggest consequence for consumers would be in aviation, where a doubling of fuel costs would result in a 20% increase in long distance economy flight prices.

As McKibbin et al (2017)[25] note, what these increases mean for the inflation profile depends on how the carbon reduction methods are implemented; all at once, or gradually over time. A sudden imposition of carbon taxation in 2030, for example, would see a sudden spike in inflation for that year before price growth returned more or less to trend, with price levels permanently elevated. A more gradual increase would see less of an immediate spike but would mean higher inflation over an extended period. For the 30 year period we are considering, the price increases discussed above should not be that noticeable when averaged out. Bear in mind also that increases in energy prices, though large, are only a relatively small part of most inflation baskets.

However, the overall consequences for inflation, as for growth, are ambiguous. Climate change seems likely to manifest as both a demand and supply shock. The demand shock has been a recurring theme through this paper; GDP is set to be lower in many economies, which means lower income growth. But that lower growth is coming about, at least partly, because climate change is also acting as a shock to the supply side. Lower productivity growth means the productive capacity of the economy is reduced relative to what it might have been in the absence of climate change. Of course, for some economies there is an overall boost to output and productivity, and the effects run in the opposite direction.

The question for us, and for policymakers, is where the balance between the two effects lies. Is the weaker demand sufficiently disinflationary to offset the higher costs of production associated with lower productivity and a carbon tax? This is a question that central bankers have begun to ponder but, as the BIS[26] note, "there are still relatively few studies analysing the impact of climate related shocks on inflation" and for now "the impacts of climate change on inflation are unclear".

Given the degree of uncertainty around the overall direction and size of any inflationary impact, we will opt for an agnostic view at this point. Our inflation numbers will therefore not explicitly reflect any climate change impact, but we must be aware of the risks around that base case.

Table 1: Impact of Carbon Taxes on Energy Prices, 2030

	Price increase (%)	
$75/ton carbon tax	**Electricity**	**Gasoline**
Argentina	48	13
Australia	75	15
Brazil	7	13
Canada	11	17
China	64	13
France	2	9
Germany	18	8
India	83	13
Indonesia	63	32
Italy	18	9
Japan	42	11
Korea	42	6
Mexico	74	18
Russia	25	12
Saudi Arabia	40	28
South Africa	89	16
Turkey	40	9
United Kingdom	16	8
United States	53	20
Simple average	43	14
$50/ton carbon tax		
Simple average	32	9

Source: IMF Fiscal Monitor 2019.

23 2019 Fiscal Monitor.
24 Mission Possible: Reaching net-zero carbon emissions from harder to abate sectors by mid-century, Energy Transitions Commission (2018).
25 McKibbin, W., Morris, A., Panton, A., Wilcoxen, P., 'Climate Change and Monetary Policy: Dealing with Disruption' 2017 CAMA Working Paper, no 77/201.
26 Bolton, P., Despres, M., Pereira da Silva, LA., Samama, F., Svartzman, R., "The Green Swan: Central banking and financial stability in the age of climate change" BIS (2020).

Summing up: warmer world, lower returns?

Nothing is certain

Overall, the impact of climate change on asset returns is very uncertain. Throughout our analysis, we have had to make a number of simplifying assumptions, many, if not all, of which are open to challenge. There is no agreement as yet in the literature about the impact of climate change on economic activity even for a given quantity of warming, and even less so for the costs of transition where there is also no agreement on what form mitigation efforts will take.

Consequently, we would be remiss not to flag, one last time, the immense variability in asset return forecasts depending on the models used and assumptions made. There are some countries for which all our forecasts are for lower returns as temperatures rise even if the extent of that reduction remains uncertain, but for others – particularly countries which are neither hot nor cold – whether climate change helps or hurts returns hinges on the assumptions we make. In this section, we provide only our forecast returns without climate change and under our 'base case' climate change scenario, as outlined below.

Key assumptions

- **Physical costs;** we use the Burke and Tanutama model incorporating a five year lag for the impact of temperature changes on productivity, and assume that temperatures rise by 0.04 degrees Celsius per year throughout the 30 year forecast period. Note that a different lag structure would radically alter our returns, with negative consequences for all countries below 20 degrees Celsius
- **Transition costs and mitigation efforts;** we assume the world adopts carbon pricing in the form of a carbon tax in the year 2030, imposing a price of $50 per ton of carbon emitted. We assume that the revenues from this tax are used to make lump sum payments to the electorate and maintain political support, weighing on efficiency further. Again, our results are sensitive to this assumption; if we instead assumed a carbon price consistent with the Paris Agreement, returns would be reduced considerably for a number of developed market economies
- **Stranded assets;** we assume that 60% of oil and gas reserves, and 80% of coal reserves are left in the ground resulting in a $4 trillion reduction in global market cap. In keeping with a less ambitious mitigation effort, we assume a larger quantity, consistent with at least three degrees of warming by 2100, are consumed

The tables on the following pages summarise our results for asset class returns, before and after our chosen base case for climate change. What we see is that as goes productivity, so go our return forecasts. Warmer countries lose out in a changing climate, with considerable reductions in expected returns for hotter countries like India and Singapore. Colder countries meanwhile see increased returns; considerably so for Canada and Switzerland, though the UK and US also see some benefits. For the most part, the split between hot and cold is also the split between EM and DM, and so climate change ultimately seems to favour an increased allocation to developed market assets, even if EM equities remain somewhat competitive.

The risk of complacency

On the fact of it, climate change does not appear to pose a problem to developed markets. One takeaway might be that the US and others should make no attempt to prevent rising temperatures and instead enjoy the boost to productivity and returns. However, this is because we focus here on a 30 year horizon, within which we assume temperature increases are fixed. The path of temperatures after 2050, however, will depend on the actions taken before then. Absent mitigation efforts, temperatures will rise by 4 degrees by 2100, bringing negative consequences not only for EM, but also to the handful of beneficiaries identified in this paper. Our finding of higher returns for the next 30 years for some countries should not be read as an endorsement of standing still on climate policy.

Table 2: Global returns with and without climate change

% p.a. 2020-49	Nominal			Real	
	No climate change	Climate change	Inflation	No climate change	Climate change
Cash					
$ cash	**2.4**	**2.6**	2.0	**0.4**	**0.5**
£ cash	**2.1**	**2.7**	2.0	**0.1**	**0.7**
€ cash	**1.4**	**1.6**	1.9	**-0.5**	**-0.3**
¥ cash	**0.3**	**0.2**	1.1	**-0.7**	**-0.9**
Canada	**2.3**	**3.5**	2.0	**0.3**	**1.5**
Australia	**2.9**	**1.6**	2.5	**0.4**	**-0.8**
Hong Kong	**2.4**	**1.3**	2.0	**0.4**	**-0.7**
Singapore	**1.7**	**-0.2**	1.7	**0.0**	**-1.9**
G4 cash	**1.9**	**2.0**	1.9	**0.0**	**0.1**
Government bonds (10y)					
US Treasury bond	**3.5**	**3.7**	2.0	**1.5**	**1.6**
UK Gilt	**2.9**	**3.5**	2.0	**0.9**	**1.4**
Eurozone (Germany)	**2.2**	**2.4**	1.9	**0.2**	**0.5**
JGB	**0.9**	**0.7**	1.1	**-0.2**	**-0.3**
Canada	**3.1**	**4.3**	2.0	**1.1**	**2.3**
Australia	**3.2**	**2.0**	2.5	**0.7**	**-0.5**
Hong Kong	**3.5**	**2.3**	2.0	**1.5**	**0.3**
Singapore	**2.4**	**0.5**	1.7	**0.7**	**-1.2**
G4 bond	**2.8**	**2.9**	1.9	**0.9**	**1.0**
Inflation-linked					
Barclays 7-10 year IL Gilts	**1.9**	**2.5**	2.0	**-0.1**	**0.5**
Barclays 7-10 year TIPS	**3.0**	**3.2**	2.0	**1.0**	**1.1**
Credit					
US Investment Grade	**4.7**	**4.7**	2.0	**2.6**	**2.7**
US High yield	**5.7**	**5.9**	2.0	**3.6**	**3.8**
UK Investment Grade	**3.7**	**4.2**	2.0	**1.7**	**2.2**
Euro Investment Grade	**2.6**	**2.9**	1.9	**0.7**	**0.9**
Euro High Yield	**4.6**	**4.9**	1.9	**2.7**	**2.9**
$EMD	**5.6**	**5.7**	3.0	**2.4**	**2.6**
Real estate					
UK Commercial	**5.0**	**5.0**	2.0	**2.9**	**2.9**
EUR Commercial	**5.2**	**5.2**	1.9	**3.2**	**3.2**
Equity markets					
US	**5.4**	**5.4**	2.0	**3.3**	**3.4**
US small cap	**6.7**	**6.8**	2.0	**4.6**	**4.7**
UK	**7.8**	**8.1**	2.0	**5.7**	**6.0**
UK small cap	**9.2**	**9.4**	2.0	**7.0**	**7.3**
Europe ex.UK	**6.3**	**6.8**	1.8	**4.5**	**5.0**
Eurozone	**6.7**	**6.8**	1.9	**4.7**	**4.8**
Japan	**4.8**	**4.6**	1.1	**3.7**	**3.5**
Canada	**6.5**	**7.5**	2.0	**4.4**	**5.4**
Switzerland	**5.2**	**6.6**	1.1	**4.1**	**5.4**
Singapore	**6.9**	**4.7**	1.7	**5.1**	**3.0**
Pacific ex.Japan	**7.9**	**6.5**	2.2	**5.6**	**4.2**
Emerging markets	**9.6**	**7.5**	3.0	**6.3**	**4.4**
MSCI World	**5.7**	**5.8**	1.9	**3.7**	**3.8**
Global (AC) Equity	**6.1**	**5.8**	2.0	**4.0**	**3.8**

Source: Schroders Economics Group. January 2020.

Table 3: Asia returns with and without climate change

2020-49 (% p.a.)	Nominal			Real	
	No climate impact	Climate change	Inflation	No climate impact	Climate change
Equity markets					
Asia ex.Japan	**8.2**	**6.8**	2.4	**5.7**	**4.3**
Taiwan	**8.1**	**6.7**	1.2	**6.7**	**5.4**
Korea	**7.2**	**6.9**	2.0	**5.1**	**4.8**
China	**8.7**	**7.7**	2.8	**5.7**	**4.7**
India	**10.4**	**6.4**	4.0	**6.2**	**2.3**
Hong Kong	**7.6**	**6.2**	2.0	**5.5**	**4.1**
Singapore	**6.9**	**4.7**	1.7	**5.1**	**3.0**
Australia	**8.7**	**6.9**	2.5	**6.0**	**4.3**
Cash					
TWD	**1.0**	**-0.3**	1.2	**-0.3**	**-1.5**
KRW	**1.7**	**1.5**	2.0	**-0.3**	**-0.5**
CNY	**2.9**	**2.5**	2.8	**0.1**	**-0.3**
INR	**4.5**	**2.2**	4.0	**0.5**	**-1.7**
HKD	**2.4**	**1.3**	2.0	**0.4**	**-0.7**
SGD	**1.7**	**-0.2**	1.7	**0.0**	**-1.9**
AUD	**2.9**	**1.6**	2.5	**0.4**	**-0.8**
Government bonds (10y)					
Hong Kong	**3.5**	**2.3**	2.0	**1.5**	**0.3**
Singapore	**2.4**	**0.5**	1.7	**0.7**	**-1.2**
Australia	**3.2**	**2.0**	2.5	**0.7**	**-0.5**
Asian Government Bonds	**3.7**	**2.4**	2.9	**0.8**	**-0.4**
Credit					
Asian Credit (JACI Index)	**5.2**	**5.4**	2.4	**2.7**	**2.9**
Asian Local Currency Bonds	**4.0**	**2.7**	2.9	**1.1**	**-0.2**

Source: Schroders Economics Group. February 2020.

Future directions for this research: what have we missed?

As we said at the outset, ultimately, the potential channels through which climate change could impact growth and financial returns are too numerous, and indeed often unknown, for us to hope to model every moving part. While the unknown unknowns, to echo Donald Rumsfeld, will become apparent only in time, if ever, there are some known unknowns which we have not addressed in this paper. There is potential for us to address these in future versions of this research, but for now we will have to content ourselves with highlighting areas of additional risk to our forecast.

Climate Minksy moment

One transition cost we glossed over is the risk associated with a sudden imposition of carbon pricing; recall that we assume in our modelling that carbon prices jump in 2030, and again in 2040 in some scenarios. We implicitly limited ourselves to looking at the impact on growth assuming a smooth adjustment to those price increases. However, such a rapid transition carries additional risks, to quote Mark Carney[27]: "A wholesale reassessment of prospects, as climate related risks are re-evaluated, could destabilise markets, spark a pro-cyclical crystallisation of losses, and lead to a persistent tightening of financial conditions: a climate Minsky moment."

This represents a downside risk to current forecasts.

Extreme events

Our analysis of physical costs – the impact on GDP of rising temperatures – made no explicit allowance for the effects of severe weather events or natural disasters. Yet these are expected to increase as global temperatures rise. These may be partially captured in the Burke and Tanutama coefficients, as the historical experience of higher temperatures will also have included increased severity of weather events, but we can not be confident that such a risk is fully captured, particularly given the likely "fat tailed" nature of the distribution of such events.

This represents a downside risk to current forecasts.

Stranded assets

Our initial analysis of stranded assets has focused on energy reserves rendered unusable by climate targets. For now we have imposed the cost of those reserves on the markets in which they are geographically located, rather than the markets in which the owning firms are based. This is a gap we hope to address in future research once we have additional data; mapping country reserves to individual energy companies will take time.

We have also excluded, for the time being, stranded assets resulting from rising sea levels and other physical effects of climate change. Coastal regions at risk of being submerged are often areas of dense economic activity.

This represents a downside risk to current forecasts.

27 Carney, M., 'Resolving the Climate Paradox' Text of the Arthur Burns Memorial Lecture, Berlin, 22 September 2016.

Insurance costs

We have not looked at the cost of insuring against climate-related losses. The rise of insured values in desirable areas combined with the severity of events and more stringent building codes will likely cause insurance prices to rise faster than incomes. Aside from the cost to household and corporate income, these premiums will likely generate price increases and deter certain activities and investments.

This represents a downside risk to current forecasts.

Credit risk

As noted by the BIS Green Swan report, "climate related risks can induce, through direct or indirect exposure, a deterioration in borrowers' ability to repay their debts". Though we have linked default risk to growth, which is impacted in our analysis, we are likely underestimating both default risk and loss-given-default in a world subject to more severe weather events and a world in which stranded assets represent a considerable cost for energy companies.

This represents a downside risk to current forecasts.

Inflation

Although we discussed inflation and the uncertainty around the outlook, we have not explicitly modelled the future relationship between price behaviour and climate change.

The Porter Hypothesis

After a rather gloomy list of downside risks, there is at least one potential upside excluded from our analysis. It has been argued[28] that environmental regulation can have a positive impact on innovation, boosting productivity. Significant investment will be needed in infrastructure to meet the Paris Agreement goals; the IPCC estimated this would amount to an additional $830 billion annually. This could boost growth particularly if, without climate change, investment remained as subdued as it has been in the post crisis period. It has however been noted[29] that empirical evidence for this effect is mixed at best.

This represents an upside risk to our forecasts.

28 Porter and van de Linde "Toward a new conception of the environment competitiveness relationship" Journal of Economic Perspectives, Vol 9 (4), pp 97-118, 1995
29 NGFS Call for Action Report

Appendix

Appendix 1: Burke and Tanutama model

Figure 1: Estimation used by Burke and Tanutama (2019)

$$y_{istd} = f(T_{ist}) + \lambda_1 P_{ist} + \lambda_2 P_{ist}^2 + \rho_d + \alpha_i + \eta_{st} + \varepsilon_{istd}$$

Source: Burke and Tanutama (2019). y is the per capita growth rate, f(T) is a quadratic function of temperature, T. P is precipitation, and other variables represent assorted fixed effects, and a residual or error term.

Table 1: The non-linear impact of temperature increases on growth in output per capita

Temperature (◦C)	0 lag	1 lag	5 lag
5	0.00033	0.00369	0.02074***
10	-0.00269	-0.00142	0.00822
15	-0.0057***	-0.00652**	-0.0043
20	-0.00871***	-0.01163***	-0.01682**
25	-0.01172***	-0.01674***	-0.02934***
30	-0.01474***	-0.02184***	-0.04186***
35	-0.01775***	-0.02695***	-0.05438***

Source: Burke and Tanutama (2019). The table shows the change to annual p.c. growth in output resulting from a one degree increase in temperature under different versions of the model. So for example, in the five lag iteration, a one degree increase reduces p.c. growth by 5.4 percentage points. Asterisks denote varying levels of statistical significance, with zero asterisks indicating that a result is statistically insignificant

Appendix 2: Kahn et al approach

Table 1: Annual impact of climate change on real GDP

	GDP per capita growth per annum (average over 30 years)		
	Temperature not deviating from its historical norm	RCP 8.5 Scenario (temperature rising by 0.04 degrees per year)	Impact of climate change in 2050
Japan	0.90%	0.73%	-0.17%
New Zealand	1.40%	1.25%	-0.15%
Italy	0.50%	0.37%	-0.13%
Canada	0.60%	0.47%	-0.13%
Switzerland	0.80%	0.67%	-0.13%
Korea	1.80%	1.68%	-0.12%
Mexico	1.40%	1.29%	-0.11%
Brazil	0.90%	0.80%	-0.10%
US	1.20%	1.11%	-0.09%
India	4.80%	4.71%	-0.09%
France	0.80%	0.71%	-0.09%
China	3.80%	3.71%	-0.09%
UK	1.10%	1.05%	-0.05%
Russia	1.30%	1.26%	-0.04%
Australia	1.20%	1.16%	-0.04%
Germany	0.80%	0.79%	-0.01%

Table 2: Impact of climate change on equity returns

	Cumulative impact on equity returns over 30 years
India	-9.3%
Canada	-5.9%
Switzerland	-5.7%
China	-5.6%
US	-5.6%
Korea	-5.5%
New Zealand	-5.3%
Brazil	-4.9%
Australia	-4.7%
Mexico	-4.0%
Japan	-3.9%
Russia	-3.6%
France	-2.9%
Italy	-2.9%
UK	-2.5%
Germany	-1.4%

Table 3: Equity returns comparison (% p.a.)

	Burke & Tanutama	Kahn et al.	No climate change
UK	6.2	5.5	5.6
Canada	5.7	4.2	4.4
EM	5.7	5.4	6.2
China	5.6	5.4	5.6
Taiwan	5.5		6.6
Switzerland	5.4	3.9	4.1
Korea	5.0	4.8	5.0
Australia	4.9	5.8	5.9
Eurozone	4.8	4.6	4.7
India	4.4	5.8	6.1
Pac Ex	4.4		5.5
Hong Kong	4.3		5.4
Japan	3.6	3.5	3.6
US	3.5	3.1	3.2
Singapore	3.1		5.0

Appendix 3: US and Chinese temperatures

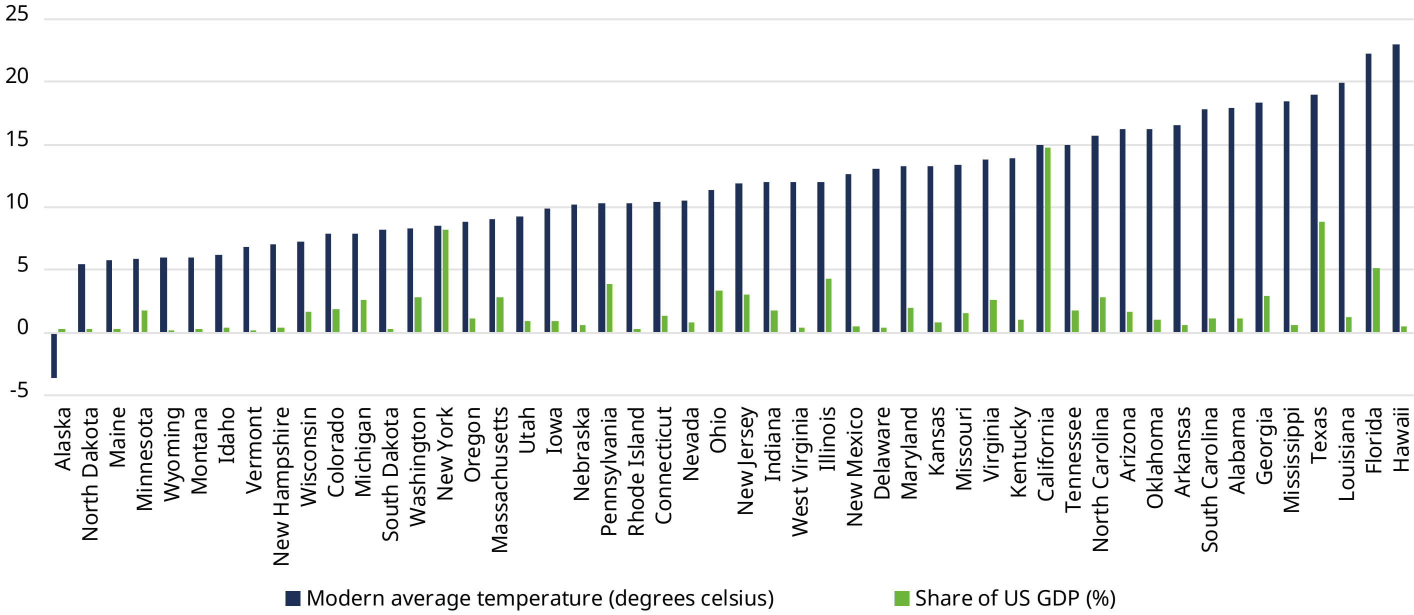
The US and China pose an additional challenge to our modelling work. It is not only that the two are geographically large, but that unlike other large countries like Canada, Australia and Russia they are subject to a wide range of average temperatures at the subnational level. In the US, for example, the average temperature in Alaska is around -3.5 degrees Celsius, while in Florida it is over 22 degrees. In China, the average temperature in Qinghai province is -1 degree Celsius compared to 21.7 degrees in Guangdong. A national average temperature of around ten degrees for both countries would hide the losses likely in the hotter states and provinces, and the gains in the colder regions.

Fortunately, temperature data is available at the subnational level, as is GDP, and we can use this information to build a bottom up model for China and the US. We will look at the US first.

Clearly some substantial shares of US GDP are found in the warmer states, particularly California, Texas and Florida. Among the colder states, New York is the only one with a share greater than 5% (chart 1).

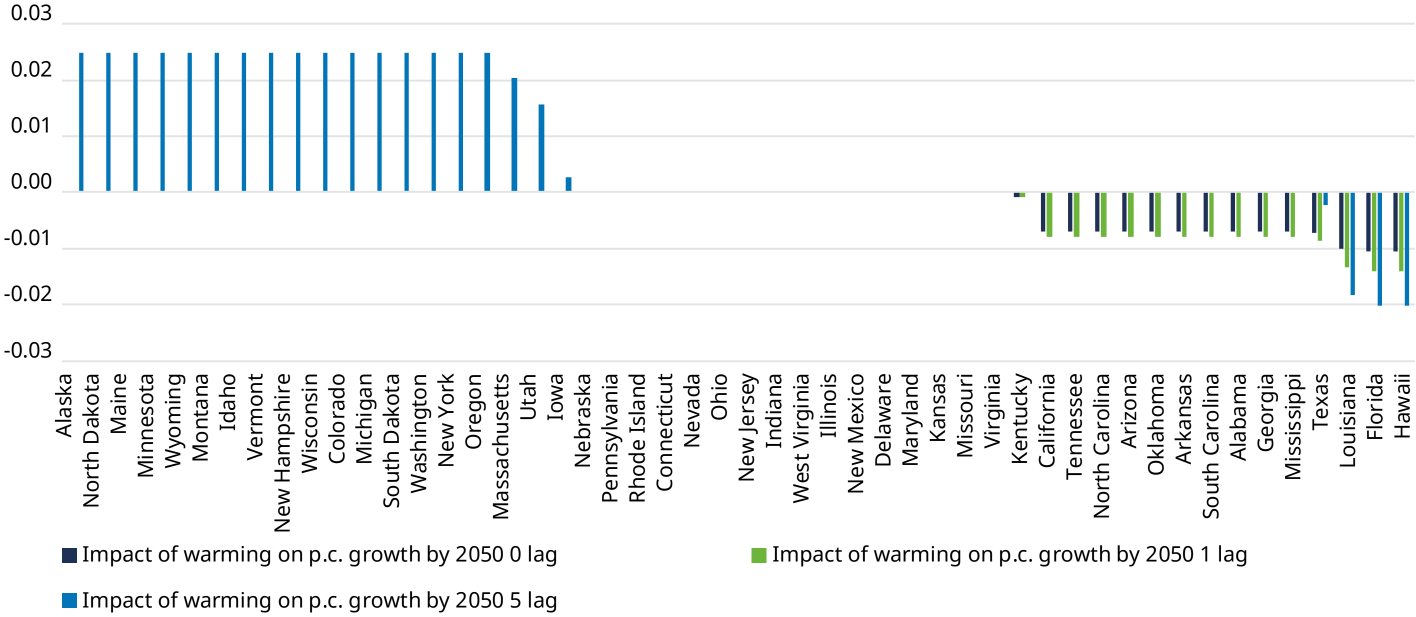
Mapping these temperatures onto the growth coefficients implied by the Burke and Tanutama model gives us an idea of the growth impact by state by 2050. As in our country level analysis, the choice of model makes a big difference. In the zero and one lag iterations, there are no benefits from warmer temperatures and consequently we see only losses, concentrated in warmer states. In the five lag iteration, however, the colder states see benefits to output growth, and many warmer states no longer see an impact. Only Louisiana, Florida and Hawaii are still negatively impacted (chart 2).

Chart 1: US states' average temperatures and shares of total GDP



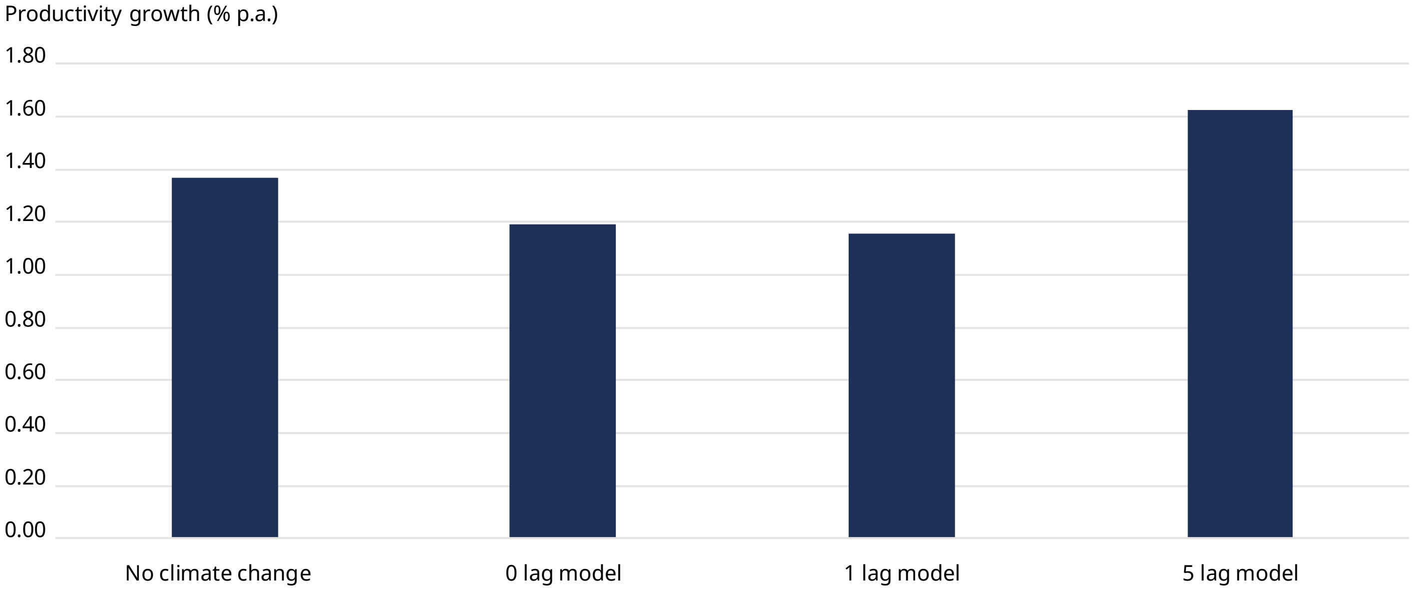
Source: BEST, Refinitiv Datastream, Schroders Economics Group. 8 January 2020.

Chart 2: The choice of model makes a big difference to US growth



Source: Burke and Tanutama, BEST, Refinitiv Datastream, Schroders Economics Group. 8 January 2020.

Chart 3: Physical impact of warmer temperatures on US productivity growth

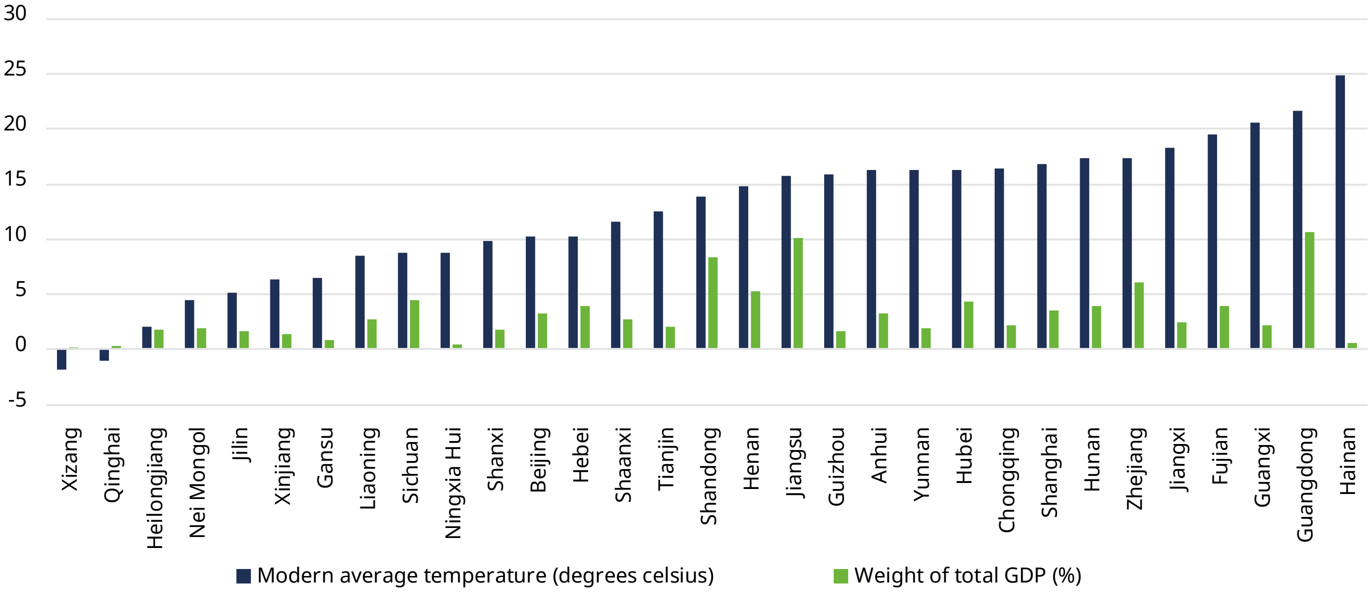


Source: Burke and Tanutama, BEST, Refinitiv Datastream, Schroders Economics Group. 8 January 2020.

We can then combine these numbers into a US aggregate for each version of the model, weighting the per capita growth impacts by each state's share in total GDP. This then translates into the productivity numbers shown in chart 3. As should now be clear, the choice of model makes a big difference, essentially determining whether the US is a winner or loser from climate change.

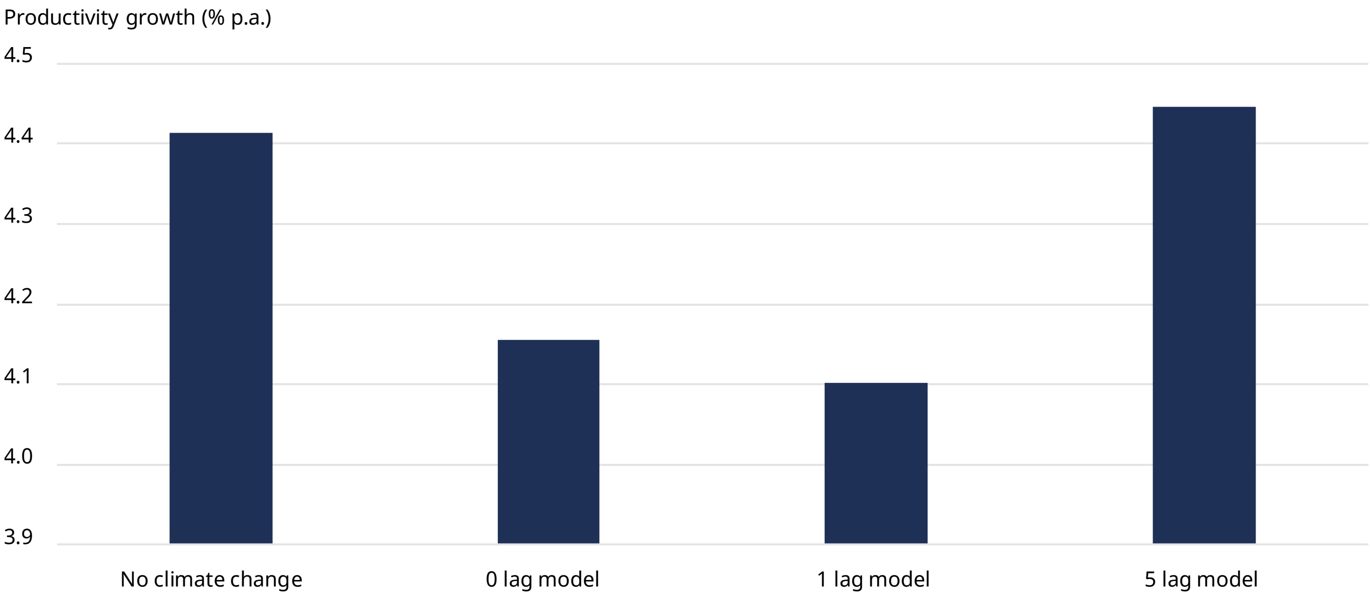
For China, things are very similar. Again, there is a wide range of temperatures, and a large share of GDP residing in warmer provinces (chart 4). But again, as with the US, the choice of model is important. In the five lag iteration, most provinces (in the 10-20 degree temperature range) drop out of consideration.

Chart 4: The choice of model also makes a big difference to Chinese growth



Source: BEST, Refinitiv Datastream, Schroders Economics Group. 8 January 2020. NB Xizang province is also known as Tibet and Nei Mongol as Inner Mongolia.

Chart 5: Physical impact of warmer temperatures on Chinese productivity growth



Source: Burke and Tanutama, BEST, Refinitiv Datastream, Schroders Economics Group. 8 January 2020.

Notably though Guangdong, a large and rich province, has an average temperature of over 20 degrees Celsius and remains affected by warmer temperatures in all iterations of the model. The end result is that China benefits only very marginally from climate change in the five lag iteration, and sees more considerable costs in the other iterations (chart 5).

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