Can the clean energy transition boost global growth?

"Without immediate and deep emissions reductions across all sectors, limiting global warming to 1.5°C [in line with the Paris Agreement] is beyond reach." That was the unequivocal conclusion of the most recent report from the Intergovernmental Panel on Climate Change (IPCC 2020).

Reducing emissions will require a transformation, not only in the energy sector but also in transport, buildings, and agriculture. This will involve a substantial reduction in fossil fuel use, widespread electrification, improved energy efficiency, and the use of alternative fuels (such as hydrogen).

However, the macroeconomics of this clean energy transition are highly uncertain. Advocates of green development have argued the investment needed for the clean energy transition will boost jobs and growth, while other studies point to the risks of a negative supply shock if the transition results in an accelerated obsolescence of the existing capital stock and a significant reallocation of resources (Pisani-Ferry, 2021). In our analysis, the crux of this argument comes down to what is assumed in terms of terms of innovation and technical progress – since the sizeable and persistent investment needed for the clean energy transition will most likely result in higher inflation, unless matched by a corresponding shift in aggregate supply.

Here we examine the macroeconomics of the clean energy transition by simulating two stringent mitigation scenarios, using a global structural model. In both scenarios we use carbon prices to create an incentive to move away from fossil fuels and support the transition to net zero emissions by 2050 via a significant and persistent boost to global investment. However, in the first scenario we assume investment spending is largely financed by carbon tax revenues, while in the second, we relax this financing constraint and allow the increase in investment to stimulate innovation, leading to faster technological progress.

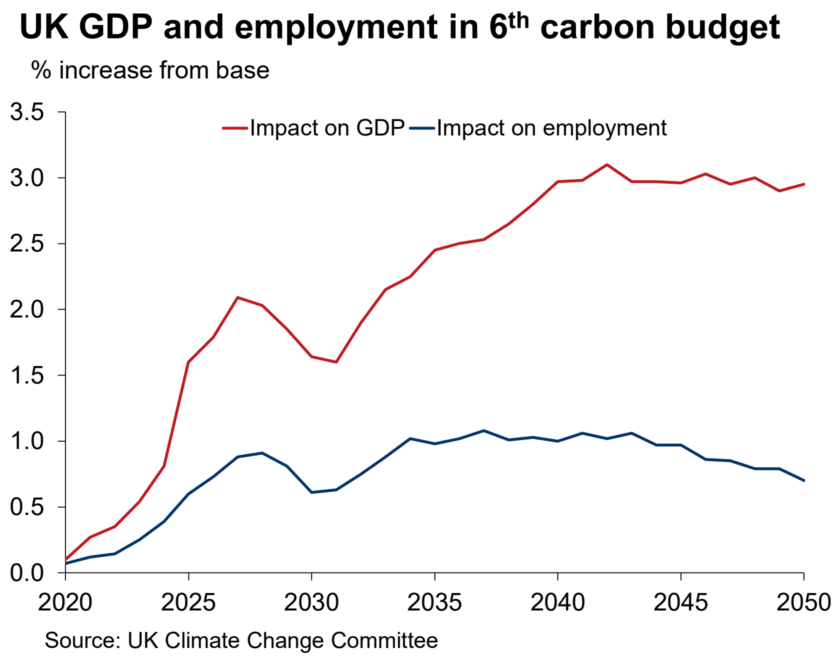
Critically, we find that without this innovation, the carbon prices needed to facilitate the transition lead to significantly higher inflation, which reduces real disposable incomes. This can leave stringent mitigation scenarios as essentially a zero-sum solution, whereby consumers finance the boost to investment. Sufficient innovation on the supply side of the economy can ameliorate this effect. Crucially, however, we find that in an accelerated mitigation pathway, the assumed effect of innovation must be significant to offset the initial negative supply shock. Hence suggestions that net zero emissions can be achieved by 2050 without negative effects on the global economy are likely to be optimistic. In this respect, economists need to be honest about the trade-offs involved and design policy accordingly.

The challenge

The macroeconomics of climate change mitigation are complex, with many different mechanisms, made more challenging by the need to make assessments over long time frames.

Furthermore, from a Keynesian perspective, it is tempting to see the global savings glut as, at least in part, a cause of the slow productivity growth that has followed the global financial crisis. This suggests there is a large pool of excess savings that could be used to finance investment and the resulting increase in aggregate demand, if sustained over many decades, could boost potential output. However, the key challenge is likely to be raising the necessary finance since the excess demand for safe assets is not necessarily in the countries where the investment to decarbonise needs to take place.

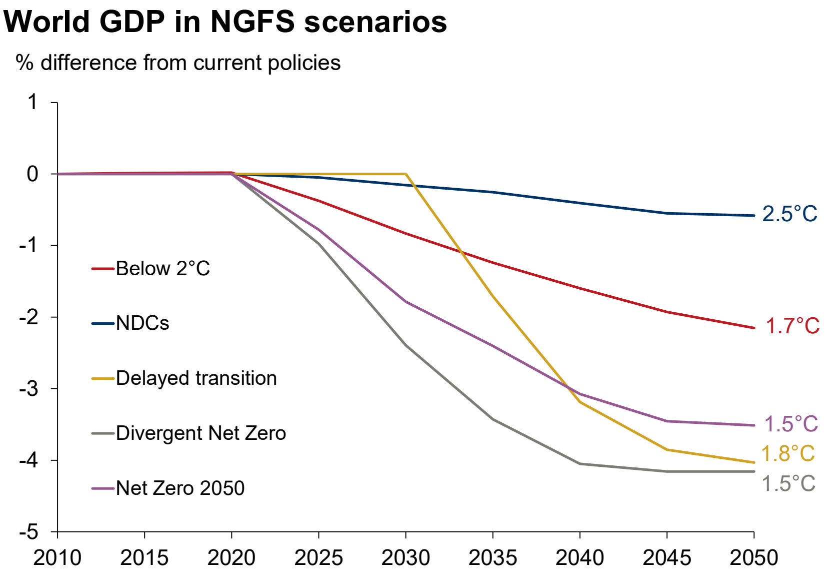
Often investments in low carbon technology are perceived as positive for growth, through increased domestic demand or reduced imports of fossil fuels. For example, the UK's Climate Change Committee (CCC), in its analysis for the 6th Carbon Budget, argues additional spending on the net-zero pathway could drive up UK GDP 2% by 2030, with an accompanying boost to employment of around 1%. This analysis assumes the added spending will be funded by increased borrowing, and investment makes use of spare capacity in the economy. The CCC also assumes regulation will be preferred over carbon taxes and will not increase energy prices, and the reduction in fossil fuel imports will be a persistent boost to growth.



In reality, greater investment will only generate increased domestic inflationary pressure if aggregate supply remains unresponsive. Paroussos et al. (2019) argue the economic impact of higher investment depends on whether there are unused or underutilised resources in capital or labour – with 'crowding out' a significant risk if this is not that case – or (as is more likely) on whether this low rate of resource utilisation can be maintained over several decades.

This is nicely illustrated by studies that take a general equilibrium perspective, which tends to view mitigation as a zero-sum outcome. Examples include the work that informs the IPCC's latest assessment (AR6) and scenarios run for the Network for Greening the Financial System (NGFS). This research shows a carbon tax increases the price of energy in the short term and the revenues raised (if used to fund increased investment) amount to a net transfer away from consumption towards investment. Without changes to potential growth or significant excess capacity that persists for many decades, mitigation is modelled as a negative supply shock as carbon-intensive capital is scrapped.

Mitigation in these scenarios inevitably leads to losses in global GDP, until the carbon intensive capital stock has been replaced and there is a shift towards cleaner energy. These losses arise because we are moving to a new environmentally constrained optimum, where the costs associated with a previously under-priced externality are now internalised.



Source: IIASA NGFS Scenario Explorer, REMIND model
End century warming projections shown (RHS)

Although often neglected by economists, the accelerated depreciation of the existing carbon-based capital stock will be a critical determinant of potential output and will therefore have important implications for economic growth.

The earlier we begin the transition to a low carbon economy the weaker this capital depreciation channel because we could take advantage of the natural investment cycle. As such, the longer the lifespan of capital in an industry, the greater its exposure to the risks of a delayed transition. This is especially true in the power sector, where power plants typically have lifespans of 30 to 45 years. Rogelj et al. (2015) note there is a definite price to be paid if stringent mitigation action is delayed, both in terms of a reduced probability of hitting the Paris Agreement climate targets and in terms of a heavier reliance on net negative emissions after the middle of the century.

Indeed, the IPCC's Special Report on 1.5°C of Global Warming notes that "delaying GHG emissions reductions over the coming years also leads to economic and institutional lock-in into carbon-intensive infrastructure, that is, the continued investment in and use of carbon-intensive technologies that are difficult or costly to phase-out once deployed."

Mitigation pathways projected over several decades also call for a more sophisticated treatment of technological progress to help ease the supply-side constraint. As Ekins et al (2022) note: "The requirements for the rate and nature of technological developments are challenging." In the spirit of Ayres and Warr (2009), this requires seeing technical progress as something that increases the efficiency with which individual factors of production can be utilised and not something that just progresses exogenously. Perhaps most critically, this poses the question about whether a demand stimulus, again sustained over many decades, can facilitate the necessary innovation, essentially making aggregate supply endogenous to aggregate demand. These questions have not been systematically addressed by the economics profession in the context of the clean energy transition.

Ultimately, the final impact on growth is likely to depend on how exactly the clean energy transition is financed and whether investment and innovation can boost long-run potential growth.

There are also economic benefits associated with the clean energy transition from slower global warming and the associated lower frequency of natural disasters. Our research extends and updates an approach by Burke, Hsiang, and Miguel (2015) which identifies a non-linear relationship between productivity and temperature, where per capita income growth rises to an average (population weighted) temperature of just under 15°C – the temperature-growth 'sweet spot'. The global benefits are therefore largely concentrated in the second half of the century as more counties pass the 'sweet spot'. For simplicity we have therefore excluded this channel out of our analysis as we focus on the impacts over the next three decades. Furthermore, there remains a great deal of uncertainty around the quantified economic impact of global warming with future trends unlikely to match existing patterns, particularly if we reach an environmental tipping point.

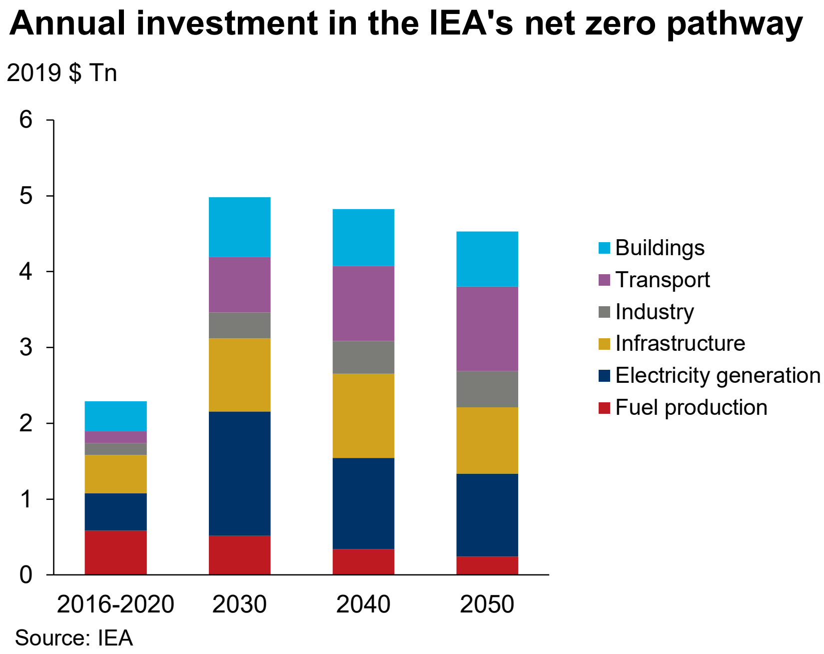
How can we reach net zero emissions?

We have identified three key policies required to facilitate the clean energy transition: adequate carbon pricing to create the incentive to transition away from fossil fuels; the necessary investment in renewable energy sources and infrastructure; and the role of innovation and technical progress.

1. Carbon pricing. Effective carbon pricing – either through a tax, regulation, or an emissions trading scheme – will play an integral role in efforts to reduce carbon emissions. By capturing the cost of greenhouse gas emissions, a carbon price incentivises consumers to move to low-carbon products and firms to innovate away from them. Given the difficulty in estimating either the rate of transition into low-carbon technologies or the social cost of carbon, the trajectory of carbon prices is likely to remain uncertain. Most stringent mitigation scenarios aimed at limiting global warming to 1.5°C suggest carbon prices well above current levels and imply sustained future increases. The NGFS net zero scenario, for example, implies a 6%-8% increase annually until 2050, which carries significant macroeconomic implications for growth and inflation.

2. Investment. Transitioning away from fossil fuels and carbon-intensive modes of production will require significant investment in low-carbon alternatives and the provision of public goods. Underscoring the scale of the transformation required to achieve net zero emissions, the IEA argues in its Net Zero Roadmap that it will take nothing less than a "complete transformation of how we produce, transport, and consume energy." Much of the existing carbon-based capital stock will have to be scrapped and replaced by a new low or carbon-free capital stock. A decarbonised economy will need decarbonised infrastructure to support it, including a new larger energy grid and potentially upgrades to the existing road and rail networks. Increases in efficiency and cost optimisation will increasingly be based around smart networks, which will require an overhaul of the mobile and fibre broadband networks. Critically, this requires very significant investment – not just within the energy supply industry but also in new infrastructure and retrofitting existing buildings.

The IEA estimates global energy investments currently stand at around $2.2tn per year, or 2.5% of world GDP. In its illustrative Net Zero Roadmap, the IEA predicts this will have to rise to almost $5tn, or 4.5%, of World GDP by 2030 and stay there until at least 2050 to reach net zero by 2050. Much of this will be spent on electricity generation and infrastructure to electrify new economic sectors and to make the electricity system more suitable for much higher volumes and variability of renewable energy. Other net-zero pathways point to similar orders of magnitude. Nevertheless, the precise investment needs of getting to net zero by 2050 are unknowable, because they will depend on the cost dynamics of the different technologies and effectiveness of policies implemented.



3. Innovation and technical progress. Technology plays a key role in reducing the carbon intensity of energy provision and can, through investments in more efficient technologies, also be used to reduce the volume of energy needed for a specific level of energy inputs. The widespread diffusion of novel, low-carbon technologies, however, requires cost reductions that are achieved through the uncertain processes of innovation, achievement of economies of scale, and learning by research and by doing (Zhou and Gu, 2019; Verdolini et al. 2018).

Ekins et al (2020) argue that "with renewable electricity now competitive with that produced from fossil fuels in many countries (IRENA, 2021), the cost impact on economic growth from the switch to zero-carbon energy sources seems likely to be limited and may even be positive." This is far too optimistic a statement that fails to account for the impact intermittent renewable energy sources may have on the energy system as a whole or the cost implication that upscaling renewable energy generation may have on the price of raw material inputs. Models showing enhanced levelized cost of electricity, such as that produced by BEIS (2020) for the UK, suggest no such competitive advantage for renewables, at least until energy storage or more active demand management systems are developed at scale. In this sense, the economic case for renewable energy to be competitive continues to rest on the need to price carbon emissions correctly to reflect the negative externality associated with continued emissions.

Scenario analysis is a vital tool

The outlook for climate change is very uncertain, academic research surrounding climate change is constantly evolving, as are the policy commitments. In the face of such uncertainty and complexity – particularly when we consider long forecast horizons – climate scenario analysis is a vital tool that helps us to prepare for a range of future pathways.

To explore the potential upsides of a transition to net zero carbon emissions we have run two net zero scenarios off our baseline forecast. They help us to demonstrate the reduction of emissions and economic growth need not be zero sum.

As will be evident from the discussion above, long-term mitigation scenarios therefore depend on many moving parts that can affect the results. It is therefore useful to be very explicit about the assumptions being made.

Baseline

Countries' current commitments under the Paris Agreement will help limit future growth in emissions but they are not ambitious enough to meet the legally binding threshold of 1.5°C in the accord. For example, the EU, China, and the UK have stated their intention to achieve carbon neutrality by mid-century, but those ambitions are not currently backed by measures and require radical changes.

Our baseline aligns with the IEA's stated policy scenario. It reflects policy commitments that are backed up by measures and believed to be sufficiently detailed. As such, there is slow and limited progress in carbon pricing and green investment from where we are today. This places emissions on a pathway that would be consistent with 2°C of warming by 2050 relative to pre-industrial levels.

Scenario 1: Net Zero

In this first scenario, governments implement stringent policies and innovations to target global warming of 1.5°C, reaching net zero CO_2 emissions worldwide in 2050. Aggressive, globally coordinated carbon pricing and investment support a move towards cleaner and more efficient energy consumption.

The key macroeconomic assumptions are:

1. Carbon price. Policymakers induce a transition to low-carbon energy by increasing the price of carbon. The carbon price can be thought of as a summary of mitigation policies or a shadow price, and so is closely linked to the extent of transition risk. Carbon prices, in real terms, increase to around $600-$800 per tonne of CO_2 by 2050. This is in line with the Network for Greening the Financial System (NGFS) scenarios.

A terminal shadow price of around $700/t$CO_2$ may seem large but what we have used sits well within the projected range. When we look at the range of future carbon prices used in the Intergovernmental Panel on Climate Change (IPCC) scenarios the price varies from $250 to $35,000/t$CO_2$ in real terms.

Shadow prices also account for trading schemes and regulatory measures, from which revenues are not necessarily levied. Therefore, we assume that only 50% of the shadow price is levied as government revenues. Nevertheless, carbon tax revenues are sufficient to meet the government's investment injection, meaning the transition is not debt financed.

2. Investment. We take the IEA's assumption that $2.7tn of global annual investment is needed in the energy sector by 2030, which is roughly 1.5% of GDP. This estimate is broadly seen to be the consensus. In this scenario, 50% of energy investment initially comes from the private sector. Over time this share increases to more than 70% as the private sector's role increases.

In both net zero scenarios we assume climate action starts today, which means we can take advantage of the natural investment cycle. As such, we assume that from 2030 onwards the additional investment needed for the transition to net zero starts to contribute to the capital stock, after accounting for historical capital depreciation rates. Prior to 2030 we assume this investment just replaces capital that is being scrapped.

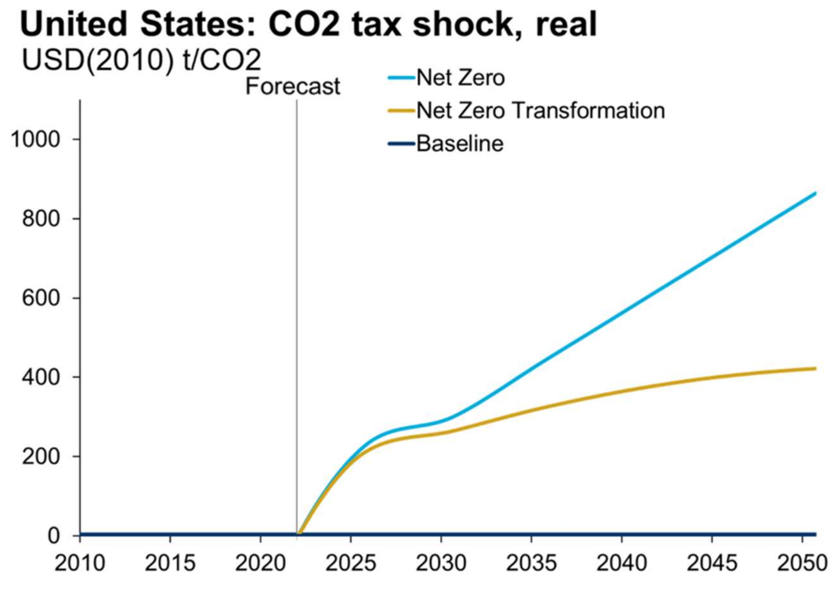
3. **Innovation.** In this scenario we do not assume investment brings spare capacity into the economy, nor do we quantify any benefits associated with innovation. Higher taxes and initially inelastic commodity demand cause significant inflationary pressures that eat into profits and household wealth. But the investment drive and productivity benefits help reduce the economic impact.

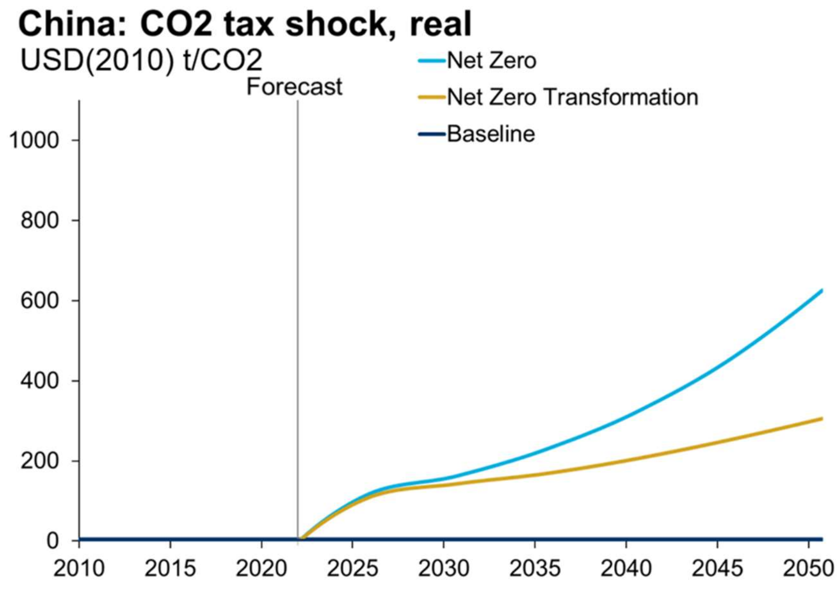
Scenario 2: Net Zero Transformation

In this scenario, carbon pricing and well-targeted structural economic policies incentivise green investment. As a result, the global economy moves up to a new equilibrium growth rate in a Keynesian shock that reverses much of the stagnation we have seen over recent years.

The Net Zero Transformation is like the Net Zero scenario, but with variations in some key macroeconomic assumptions that influence long-run GDP:

1. Carbon price. We assume technological advancements reduce the costs of carbon abatement through to 2050. This softens the optimal carbon pricing trajectory compared with that in our original Net Zero scenario. This reflects the observation that the carbon abatement curve is likely to shift over time, as innovations bring an increasing number of technologies into cost competitiveness with any given carbon prices. However, for some emissions no successful mitigation technology is likely to be available at scale – which suggests there will continue to be a trade-off between carbon pricing and residual emissions, which will have to be dealt with using some form of carbon capture and storage solution. In the new scenario, the necessary real carbon price is 50% of that in the Net Zero scenario, adding 1.1% to world GDP levels. Benefits to growth accrue over the century. As per the Net Zero scenario, we assume only 50% of the shadow price is levied as government revenues.



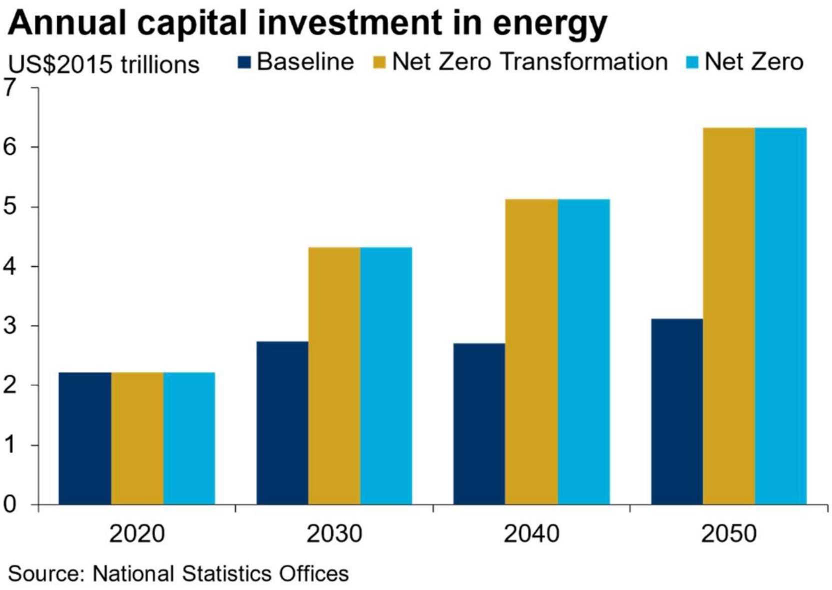


2. Investment. We model the same investment shock for the two Net Zero scenarios. The government, however, only funds 30% of the required investment at the start of the scenario and this is financed by increased government borrowing.

In our Net Zero Transformation scenario, carbon pricing and structural government policies provide the necessary sticks and carrots to incentivise large-scale green investment in the private sector. Carbon pricing acts as a 'stick' to drive green investment, pricing in negative externalities and changing the relative return on green capex. While well-targeted regulation and structural policies such as risk guarantees, R&D tax credits, or co-financing are the 'carrots' that incentivise investment, increasing the absolute return.

We also assume green investment is not a substitute for traditional investment. Indeed, the stock of savings is so big that interest rates are unlikely to rise much, so 'crowding out' is improbable.

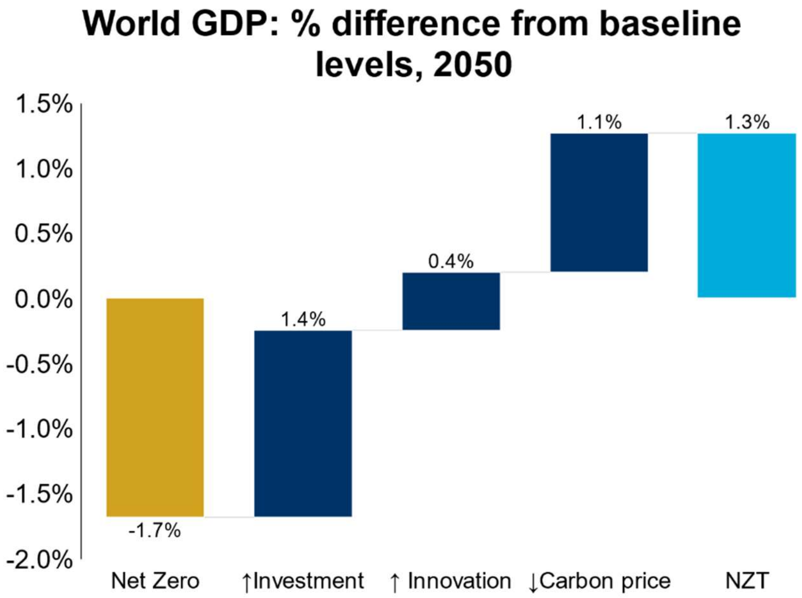
As a result, higher green spending will raise aggregate demand in a Keynesian shock, spurring firms to invest more in total and elevating total equilibrium investment. We estimate this would add 1.4% to world GDP levels by 2050.



3. Innovation. Critically, in this scenario we allow the boost in aggregate demand from green investment to provide incentives for innovation and technical progress that therefore also enables a boost to aggregate supply.

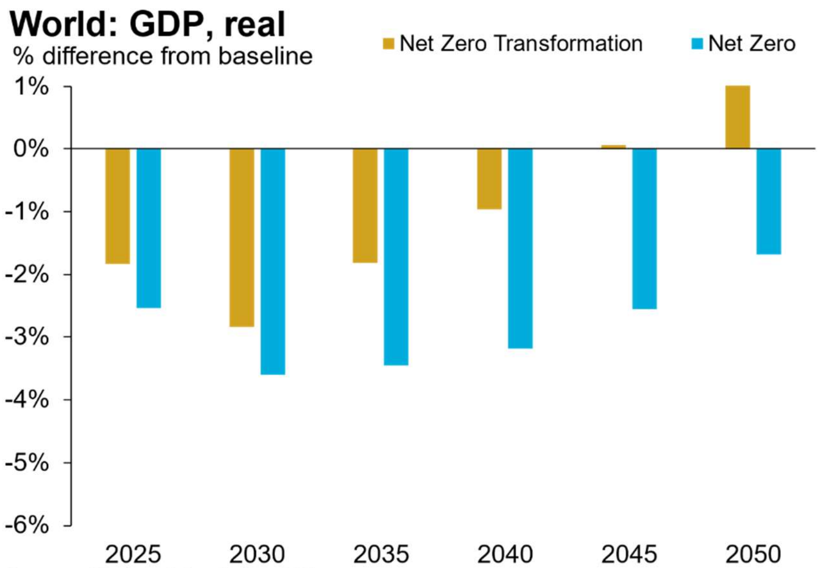
Innovation would ease the decarbonisation process, yet there are few estimates in the public domain of what it would comprise. This is because innovation is by nature new and unpredictable.

Our research shows the external benefits to R&D investment can be significant and wide-ranging, concluding that on average – across all sectors – for every $100 invested in R&D there is a long-term indirect benefit of $45 to the wider economy. Learning by doing generates new techniques and ideas that boost productivity through knowledge sharing and imitation. In our Net Zero Transformation scenario, we assume green investment shares the same characteristics as R&D. Using this approach, the boost to world GDP levels by 2050 is almost 0.4%, modelled as an ex-ante shock to total factor productivity.



Scenario Results

In the Net Zero Transition scenario there is a Keynesian shock that boosts short-term demand but also boosts long-run productivity. Due to the co-benefits of greater equilibrium investment, innovation, and weaker carbon pricing, the Net Zero Transformation sees global steady state growth rise above 2% year-on-year by 2050, some 0.2ppt-0.3ppt higher than in our stated policies baseline forecast. Layering on each of the above assumptions brings world GDP levels up to 1.3% above the baseline. While the initial shock produces a sharp short-term uptick in inflation, it decays rapidly in the Net Zero Transformation scenario due to a lower carbon price trajectory and the supply-side benefits of higher equilibrium investment and innovation. In our original Net Zero scenario, higher inflation erodes real incomes, lowering world GDP 3.2% below baseline levels in 2040 and ends at 1.7% below baseline levels in 2050.



Source: National Statistics Offices

Conclusions

It is something of an axiom among advocates of green investment that the clean energy transition will be good for jobs and growth. And while this is undoubtedly true for certain sectors, from a general equilibrium perspective it hard to see how this can be true for the economy across a horizon spanning several decades, unless the transition also brings about a burst of technical progress that increases aggregate supply. Clearly there is scope for technology to bring down the costs of the transition, but it is perhaps still unrealistic to expect technology to do all the heavy lifting and bring about the transition autonomously.

Our scenario analysis suggests the effect of innovation on growth must be fairly punchy to offset the negative supply shock that results from higher carbon prices in a stringent mitigation scenario. This optimistic scenario is by no means impossible but does suggest there needs to a concerted policy effort to foster the necessary supply-side response. This will not necessarily be easy, but it is time economists were honest about the challenges we will have to face economically if we are to halt global warming on the sort of timescales scientists are telling us is necessary.

(3,681 words excluding references and charts)

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