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PERSPECTIVE

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Why sustainable, inclusive, and resilient investment makes for efficacious post-COVID medicine

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Abstract

The global economy is facing an unprecedented challenge, with the risk of a protracted depression following the response to COVID-19. In 2014, I argued here that macroeconomic conditions made it a relatively favorable time to kick-start investments in a resource-efficient, low carbon economy. Yet the opportunity was, for the most part, squandered. Failure to utilize active fiscal policy contributed to growing private indebtedness, limited productivity and wage growth and widened inequality helping erode trust in institutions. All the while, greenhouse gas emissions continued to rise. This time, there are grounds for optimism that a more coordinated response toward generating an ambitious transition to net zero emissions might contribute to a strong, sustainable, and resilient recovery.

This article is categorized under:

Climate Economics > Economics of Mitigation

KEYWORDS

COVID, economy, invest, policy, recovery, sustainable

1 | INTRODUCTION

In 2014, I argued that macroeconomic conditions made it a relatively favorable time to kick-start investments in a resource-efficient, low carbon economy. At the time, I reasoned that there was no shortage of private money, just a perceived lack of opportunity. I concluded that governments across the world had an opportunity to unlock private investment in low carbon infrastructure. This was necessary as waning private confidence generated record net desired saving and drove real risk-free interests rates to below zero (Zenghelis, 2011). Failure to utilize these savings to invest in key assets, in part reflecting inadequate fiscal stimulus, pushed global real risk-free interest rates below zero, seriously testing the efficacy of monetary policy.

Six years on and the world faces even more challenges, though many of the responses remain painfully familiar. Once again there is a clear risk that the combination of uncertainty and reluctance to spend, particularly on investment, proves self-fulfilling, delivering a weaker economy through classic "multiplier" and "accelerator" effects. Before assessing the scope for economic stimulus, it is important to distinguish between governments' immediate rescue and job preservation plans, in the face of an ongoing pandemic (plans which will, understandably, preserve the status quo) and economic strategies for recovery and investment in a resilient economy once the pandemic is behind us. The

distinction matters because the deliberate suppression of social and economic activity, necessary to curtail the spread of the virus, will be followed by the need to get people back to work and restore economies to health once the disease is under control. Even with a sharp post-COVID recovery, the IMF in its September *Economic Outlook* (IMF, 2020) predicts in that, in 2021, advanced economies' GDP will be around 6% lower than it would have been in the absence of the pandemic. And such a recovery is far from guaranteed in the near term.

At the same time, the global climate crisis has not gone away and requires urgent action. Since 2014, atmospheric CO_2e concentrations, the key factor driving climate change, have continued to rise from 441 to 459 ppm currently (European Environment Agency, 2019). After stabilizing briefly (from 2014 to 2016), global CO_2e emissions have risen from 52 to 55 Gt (UN Environment Programme, 2019). Yet all the while, the economy has continued to underperform. After a temporary reduction following the response to the spread of COVID-19 in the first half of 2020, global emissions are already rebounding and the pandemic is unlikely to have much impact on concentrations of greenhouse gasses in the atmosphere (Hepburn et al., 2020).

Yet the current macroeconomic environment offers governments across the world an ideal opportunity to unlock private investment and access available finance, because resource costs are low and the potential to crowd out alternative investment or employment is minimal. Public intervention will be required to restore confidence and avoid a return to the old model that has proved insufficiently productive, socially divisive, and vulnerable to predictable but uncertain shocks like pandemics. I will argue here, as I did in 2014, that pulling the world out of recession, and generating sustainable, inclusive, and resilient growth path, requires framing a vision of the benefits of government action. The hope is that this time, the opportunity will not be missed.

2 | PLUS C'EST LA MÊME CHOSE—THE SAME CHALLENGES REMAIN

A decade on from the financial crash of 2008, and before the response to COVID-19 set in, growth in advanced economies had been slow. Low productivity growth (Fatás & Summers, 2018) and widening inequality in earnings meant wages for many stagnated (Sprague, 2017). Because the rich in general save a higher proportion of their income than the poor, inequalities tended to contribute to the rise in saving (Koo & Song, 2016; Piketty, 2014). Inflation and nominal interest rates were historically depressed. *Real* rates of interest were also low—near zero—which told that desired investment was weak relative to desired savings (Lukasz & Smith, 2015). I argued in 2014 that the world needed markedly higher investment and that public borrowing funded at favorable rates would play a crucial role in leveraging that investment.[1] That advice holds firm today (Zenghelis & Rydge, 2020).

In the event, fiscal policy was used little at the global level after the first 2 years following the 2008 crisis. The burden of supporting aggregate demand fell largely on monetary policy. Quantitative easing was employed in most countries, and official interest rates were reduced progressively, in due course almost reaching the zero bound (Haldane, 2015). Private sector borrowing, both corporate and personal, expanded on the back of cheap credit, while growing debt leverage supported asset prices.[2] As a result, the rich (who owned most assets) grew wealthier, while the poorest were hit hardest by fiscal austerity, exacerbating inequalities. Low investment in public services and social infrastructure undermined the social contract (OECD, 2020), spawning popular discontent.

At the same time, national recovery packages after the financial crash in 2008 mostly failed to embody sustainability. According to a leading study, only around 16% of global stimulus packages could be classified as "green" (The Energy and Climate Change Committee, 2010). The other 84% helped deliver rising emissions and air pollution in many countries, including China. The opportunity to protect human health, build resilience and respond to climate risk was mostly squandered (Rodrik, 2014).

3 | PLUS ÇA CHANGE…BUT NEW CHALLENGES AND NEW OPPORTUNITIES ARISE

The failures of the past provide salutary lessons for today. Yet despite similarities, no two economic crises are identical and demand different responses. The financial crash of 2008–2009 required measures to extend liquidity and restore the health of the banking system. The COVID-19 crisis and the post-pandemic environment too are likely to prove unique and require responses tailored to the characteristics of the crisis. The banking system and corresponding financial plumbing remains functional, but business activity, human skills and physical supply lines will need rebuilding. Increased corporate indebtedness will exacerbate the strains.

In 2008, bailing out the banks was central to support the continued intermediation process between savers and lenders. By contrast, the impact of the COVID-19 pandemic is being felt directly by households, businesses, and consumers alike. It will also be felt across government, as it takes on higher debt liabilities. Job losses and unemployment will undermine health and wellbeing, stretch public services and spending, and damage skill levels—some of which will be lost irretrievably (DeLong & Summers, 2012). Moving from rescue to recovery will therefore require action, simultaneously to restore *demand* and bolster *supply*.

Yet the news since 2014 is not all bad. Renewable energy has dominated investment in energy generation investment while great strides have been made toward improving efficiency. For example, LED lighting has gone from less than 5% of the global lighting market to 56% since 2014.[3] At the same time, plug-in vehicles in Norway alone have gone from around 5% of sales to nearly 50%[4] and account for all the growth in China's car market. Coal has gone from supplying around 40% of UK electricity to under 5%.[5] There has been a more than doubling of global climate laws to 1900 (Climate Change Laws of the World, 2020). The price of solar photovoltaic (PV) has fallen by 44% in the 2 years to the end of August 2017 (Bloomberg New Energy Finance, 2019) and by 83% since 2010 (Liebreich, 2020), a period over which the price of wind turbines dropped 35%.

Over the past decade, there has been a near tenfold decline in the cost of both solar photovoltaic generation (Roberts, 2015) and battery storage, necessary to address intermittency of supply. Both sectors benefitted from substantial support in the form or publicly funded R&D and direct deployment support, such as the renewables obligation in the United Kingdom and feed-in tariffs in Germany (IRENA, 2018).

4 | THE NEW GROWTH CHALLENGE

In the short run, the world faces a classic paradox of thrift. This occurs when fear of recession leads business to shed labor and claw back investment, banks to retrench credit and consumers to cut spending. When everyone responds in this way, gloomy expectations become self-fulfilling in generating a downturn. Expectations align around low growth equilibrium and the cycle is entrenched. So the primary macroeconomic task for policymakers is to offset this and stimulate private spending in the short run.

In the long run, the primary objective is to build resilience and capacity by investing in complimentary assets which "crowd in" capacity. These include investment in physical produced capital (IMF, 2014) assets, by locking into future-proofed, resilient and productive infrastructure (, and not using public money to prop up fossil fuel intensive assets with limited productivity potential (Carbon Tracker, 2020). It also requires investment in human capital, by securing the skills and jobs necessary for the 21st century (Robins et al., 2019) and reskilling workers to enable those affected by change to participate in the new economy.

Key to any global low carbon transition will be investment in knowledge capital and innovation. The economy of the 21st century will be shaped by knowledge and innovation. It is the key driver of the growth in total factor productivity and will determine our ability to get more out of the resources we have (resource efficiency) by directing the "eightless" economy to foster dematerialization and decarbonization. Proponents of "degrowth" might argue that the current economic slump is a great opportunity to shrink economic output and move to a quite different kind of economy and society (Jakob et al., 2020). But it is important not to mistake output growth with growth in material inputs such as fuels, minerals, nature-based services and capital equipment (Zenghelis, 2020). Moreover, many of the behavioral responses to COVID-19 have provided an opportunity to embed climate- and productivity positive behaviors (Reeves et al., 2020). These include strengthening connected technologies and promoting virtual learning, healthcare and security as well as smarter "real time" supply chain management, better use of urban space and increased localization.

But these innovations merely scratch the surface. The sheer scale of the low-carbon transition generates substantial network effects (Zenghelis, 2019) and economies of scale in production and discovery (Van der Meijden & Smulders, 2017) These are so large that we invariably underpredict the scope for productivity-augmenting clean innovation. This is true not only within clean sectors, but also though strong evidence of spillovers into other parts of the economy, which are much greater than those associated with more mature fossil fuels investments (Aghion et al., 2012; Dechezleprêtre & Martin, 2017). A study of OECD patent data shows that both wind and solar technologies create knowledge spillovers at the national level (Braun et al., 2010).

It also requires investing in social and institutional capital to deliver effective and functional government, with popular support, rebuilding trust in the social contract (OECD, 2020).[6] It means tackling inequalities, not just in income and wealth, but also in "access" to goods and services such as health, housing, transport, education, and justice—

inequalities exacerbated by COVID-19. Finally, it requires investment in natural capital as biodiversity and habitat loss increase the likelihood of diseases like COVID-19 (Settele et al., 2020). All of this augurs for additional resources for statistical agencies to better measure the stock of broad assets against which to monitor and assess our underlying prosperity (Zenghelis et al., 2020).

Against this framing sustainable, resilient, and inclusive investments have some very appealing short- and long-run characteristics in a recession. In the short run, clean energy infrastructure (such as insulation retrofits and building wind turbines, broadband networks, plant trees, restore wetlands) is labor intensive, but not susceptible to offshoring or imports (Pollin et al., 2008). Consequently, they impart high short run multipliers (Houser et al., 2009; Jacobs, 2012).

In the long term, the economic multipliers are also high, as the operation and maintenance of more productive renewable technologies makes them less labor-intensive, and energy cost savings are passed to the wider economy (Blyth et al., 2014; Hepburn et al., 2020). The boost to innovation across all sectors also has the potential to the productivity of global assets. Previous studies, such as the New Climate Economy and LSE research (New Climate Economy, 2014[7]; Rydge et al., 2018; Zenghelis, 2016a, 2016b) set out the opportunities associated with low-carbon, resource-efficient growth. These include substantial co-benefits from tackling particulate pollution, congestion, ill-health, biodiversity loss, inefficiency and waste and building more attractive, livable cities. But the pandemic gives this vision renewed urgency. For example, COVID-19 has reminded the world of the urgent need to strengthen the quality and resilience of natural assets and broaden access to these assets.

Some will counter that the evidence form green stimulus packages in the past has been patchy (Brahmbhatt, 2014). In the context of facilitating and inducing a structural transformation, where the aim is to generate dynamic returns through economies of scale in production and discovery, the past not an adequate guide to the future (Kattel et al., 2018). Looking at the success or failure of past programs is, therefore, at best only partially informative.

5 | AN OPPORTUNE TIME TO PROMOTE CLEAN INNOVATION

The low-carbon transition is one of many 21st century secular megatrends. AI, automation, machine learning, big data, the internet of things, nanotech, and biotech revolutions have already delivered significant disruption. But, the inevitability of global decarbonization/resource-efficient shift[8] makes it close to a one-way bet which can guide actions and help overcome strategic complementarity problems and inferior Nash equilibria (Zenghelis, 2020). Once again, expectations are center-stage. A policymaker, business or individual is more likely to invest in clean technologies if they feel everyone else will, as they would expect costs to fall, finance to go from niche to mainstem, and new markers to open up. If enough agents invest, then expectations become self-fulfilling as costs fall. The presence of expectations-augmented equilibria on the short and long run are what underly the importance of a clear and credible government vision.

Strong inertia and high switching costs often make it difficult at first to shift innovation from dirty to clean technologies. But with credible policy intervention, once they reach a tipping point, where expectations transition rapidly to the new equilibrium, technologies are enabled to switch quickly from one network to another (Krugman, 1991).

Another feature of network dynamics is that it is easier for countries to become competitive in new green products that require similar production capabilities and know-how to existing sectors (Hidalgo et al., 2007). A firm's choice whether to innovate “clean” or “dirty” is influenced by the practice of the countries where its researchers are located. Moreover, firms tend to direct innovation toward what they are already good at (Aghion et al., 2012). As a result, the clean transition is highly path-dependent: countries and companies that successfully invest early in green capabilities have greater success in diversifying into future clean product markets (Mealy & Hepburn, 2017).

This path-dependency of innovation (Aghion et al., 2014) makes it prone to tipping sets and reinforcing feedbacks (Acemoglu et al., 2012). This explains why conventional economic models, even though they often make unrealistic assumptions about optimal policy applications which ought to understate the costs of decarbonization (Parry et al., 2014), in general systematically overstate the costs of decarbonization (Zenghelis, 2018). It is no coincidence that not a single model predicted the sharp falls in the costs of renewables or battery technologies over the past decade.

It also means that rather than predict the future, our efforts are better spent trying to manage and design the transition. Investments in enabling assets can spur technology tipping points and generate massive network externalities.[9] State-led innovation can take the form of deployment support to create new markets, basic R&D support to stimulate innovation and “research missions” to achieve important economic and social objectives, such as low-carbon innovation across all sectors.[10] This highlights the importance not just of promoting deployment or facilitating private sector R&D spending, but also direct public investment in early stage riskier technologies (Mazzucato, 2014). It also invites

the creation and financing of regional, national, and multilateral investment banks with strong sustainability mandates (Mazzucato & Penna, 2015).

Other important institutional reforms, necessary to prevent a return to the old growth model, include increased localism and devolution of powers the creation of new long-term policy frameworks, such as the UK's Climate Change Act. Such reforms can help mobilize private sector finance by managing and reducing risk, especially policy risk which the private sector does not own.

Strong, credible, and supportive policies can help shift expectations through changing perception of risk, thereby stimulating clean innovation and influencing both the direction and pace of change. At the cost of initial investment, early movers can steer a comparative advantage in clean markets.

6 | MULTIPLIED BENEFITS

So how big are investment multipliers? The answer is: helpfully big. Studies from NBER (Auerbach & Gorodnichenko, 2012) and the IMF (Blanchard & Leigh, 2013) suggest that fiscal multipliers (Christiano et al., 2009) associated with government spending range from near zero when the economy is operating close to capacity to about 2.5 during recessions. That is, a dollar of investment from public borrowing can generate 2.5 dollars of extra output. Government spending in a slump not only generates positive benefits, it also prevents negative hysteresis (DeLong & Summers, 2012) effects on future supply, whereby capital is scrapped and labor skills are lost as a result of protracted under-utilization. Llewellyn Consulting conclude, on the basis of three quite different models for the United Kingdom (by the IMF and by the OECD), that under circumstances such as those prevailing at present, debt-financed fiscal injections probably have UK multiplier effects in a (narrow) range of 2.5–3.0.[11] Another IMF study found that in the medium run (3 years), the average multiplier for the EU is about 1 in normal times, but between 1.6 and 2.8 when interest rates are close to the zero bound, as they presently are (Amendola et al., 2019). The OECD estimates a similar range (Mourougane et al., 2016). The latest IMF Fiscal Monitor (October 2020) reaffirms these findings. It argues that each dollar of increased public borrowing used to invest in "job-rich, highly productive, and greener activities" can generate a multiplier of 2.7.

This evidence suggests growing out of recession is a better route to debt sustainability than attempting to balance budgets prematurely. Low interest rates and the willingness of financial institutions to lend to the government without charging interest make debt dynamics currently very favorable.[12] All else equal, if an economy grows faster than the rate of interest charged on its stock of debt, its debt to GDP ratio will fall. This is because the numerator (debt) grows more slowly than the denominator (GDP).

But growth also drives the debt/GDP numerator. For example, if targeted investment generates a multiplier of 3, then 1% of GDP in extra borrowing can be expected to raise GDP by 3% thereby generating public revenues sufficient to reduce the public deficit by around 1% of GDP. This combined effect on both the numerator and denominator of the debt/GDP ratio explains why, under the right conditions, borrowing to invest can be so much more sustainable in terms of public debt management than seeking to directly target balanced budgets. It also generates more jobs, higher productivity and better wages and a more content citizenry.

7 | GROWTH-ENHANCING CLEAN INVESTMENTS

The evidence outlined above clearly suggests that now is a good time for governments to prioritize investment in creating enduring, resilient jobs in and productive sectors of the economy. These range from: broadband and smart connectivity[13]; investment in accessible EV charging networks; renewable energy and battery storage (which will require significant investment worldwide to upgrade and extend electricity grids, though distributed energy could play a vital role in electrifying remote rural regions), and other climate-smart technologies such as hydrogen, carbon capture, and laboratory produced meat.

Building net zero buildings while upgrading and retrofitting existing buildings and investing in energy and heat networks will also generate short run activity strengthen an economies ability to proposer in the 21st century, as will investment in efficiency and the circular economy (reducing recycling and reusing material inputs). Natural improvement projects such as planting trees, protecting rainforest, restoring wetlands, greening cities and improving biodiversity and adopting restorative agriculture techniques also offer enduring growth prospects (RSPB, 2016). Supporting

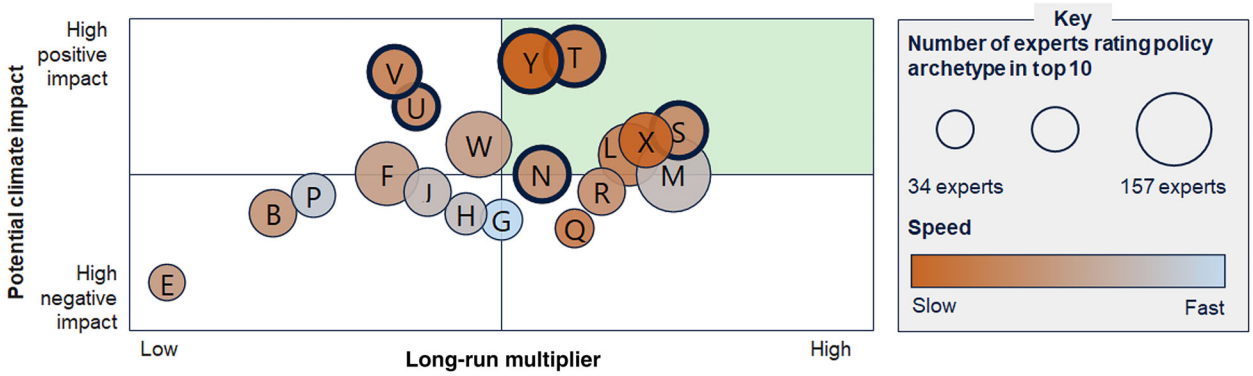
adaptation and resilience, including water management, flood protection, heat attenuation and the preservation of non-renewable natural capital also scores well against these criteria. Finally, expanding rail and bus transport to better connect low-income regions while investing in compact connected cities (Stern & Zenghelis, 2018) can increase productivity, drive innovation and enhance liveability while complementing post-COVID behavioral change by exploiting local supply lines and encouraging virtual working.

In the 2008 recession, the main problem was a lack of "shovel-ready" climate-related investments. Today, Paris-aligned Nationally Determined Contributions (NDCs) mean many countries have already prepared "shovel-ready" projects. In lower- and middle-income countries, these NDCs are predominantly oriented toward infrastructure (Hepburn et al., 2020).

Post-COVID bailouts should be conditional on improvements against climate-positive criteria, including requirements to embrace newer, yet proven, standards, technologies and business models. Mandatory disclosure and stress testing under (The Task Force on Climate-related Financial Disclosures, 2019) by COP26, and commitment to collaborate through global R&D partnerships, for example in aviation and shipping should also be included. Experience shows that attaching efficiency and emissions targets to financial support can give corporations a competitive edge. To do this governments could offer loans, guarantees, capital injections, and wage subsidies. With time, burdensome debt can be traded for public equity stakes, provided conditions are met. If they not, bailout funding would be converted to equity at today's very low stock market spot prices.

The policy mix must be broad, comprehensive and coherent, if it is to guide investment and rapidly scale up financial flows. Most importantly, it must be clear, credible, and enduring. This is the most effective way to generate investor confidence to kick start the clean innovation machine (Aghion et al., 2009). There are reasons to be confident that policymakers and business expectations are aligning around the view that policies with the highest impact and highest growth multipliers tend to be the cleanest and most sustainable.

We recently conducted a survey of 231 finance ministry and central bank officials as well as senior economists (Hepburn et al., 2020). They found the investments with highest impact and highest multipliers are in many cases the cleanest and most sustainable (Figure 1). These included clean R&D spending, clean energy infrastructure, connectivity infrastructure building upgrades and energy efficiency and investment in green spaces. With a bit of policy leadership following COVID-19, the task of steering an expectations and generating low cost finance for clean investment will be less challenging than it once was, especially as financial institutions seek to limit exposure to potentially stranded assets.



Policy archetypes

B Assisted bankruptcy (super Chapter 11)	M Healthcare investment	T Clean energy infrastructure investment
E Airline bailouts	N Worker retraining	U Buildings upgrades (energy efficiency)
F NFP, education, research, health bailouts	P Rural support policies	V Green spaces, natural infra investment
G Reduction in goods & services taxes	Q Traditional transport infra investment	W Disaster preparedness, capacity building
H Income tax cuts	R Project-based local infrastructure grants	X General R&D spending
J Business tax relief for strategic adj.	S Connectivity infrastructure investment	Y Clean R&D spending
L Education investment		

FIGURE 1 Global survey (April 2020, survey of 231 finance ministry/central bank officials/senior economists [representing 53 countries incl. all G20]: perspectives on COVID-19 fiscal recovery packages; Hepburn et al., 2020) identifies policies that perform well on both economic and climate metrics

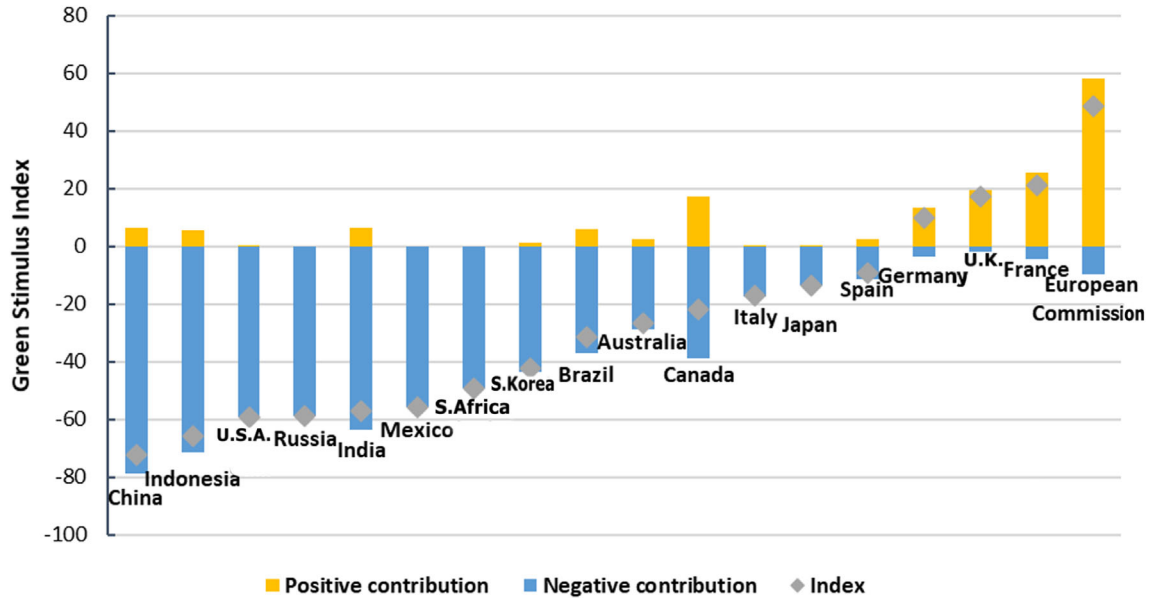


FIGURE 2 Vivid Economics Green Stimulus Index

Source: Vivid Economics, 2020 (The Green Stimulus Index [July 2020 version] examines 17 major economies and the European Commission to assess the green vs. brown orientation of their stimulus funding based on: the scale of funds flowing into environmentally relevant sectors; the existing green orientation of those sectors, and the efforts to steer stimulus toward [or away from] sustainability. What is being captured in the index to date is a flow of rescue funding into existing sectors, which, for many countries, reinforces a status quo that is significantly tilted toward brown)

8 | SECURING A JUST AND INCLUSIVE TRANSITION

The adjustment to a low-carbon economy will inevitably be uncertain and complex. There will be winners and losers. Many of the behaviors, technologies and infrastructural networks of the last century look set to be devalued or stranded. Ensuring a just transition will be crucial for maintaining social cohesion and economic justice. This emphasizes investment in adaptive and flexible human capital, including the training and retraining of current workers and the provision of continuing education. A just transition also requires policy responses to compensate consumers who disproportionately face higher costs (e.g., with fewer options to substitute to efficient low carbon heating or vehicles) and policy support for people living in less dynamic smaller towns and peripheral regions whose older, less educated and less connected demographics render them less suited to adjust flexibly and profitably to a rapidly changing economy.

Avoiding protracted depression and making progress on climate change will depend significantly on policy choices in the coming 6 months. EU has shown the way (Figure 2). Of the €750 billion (US$830bn) package, 30% will be directed toward "green" initiatives. The Just Transition Mechanism (European Commission, 2020) will help mobilize at least €100 billion over the period 2021–2027 (Zenghelis & Rydge, 2020). Furthermore, all recovery loans and grants to member states will be attached to "do no harm" environmental safeguards.

There is however a real risk that recovery packages try to return the economy to the old model that has proved unproductive and dangerous (including in the sense of making pandemics more likely). This would make climate action much more challenging in the years and decades ahead.

9 | CONCLUSION

A clear macroeconomic vision is required to restore confidence, create jobs and grow the economy out of post-COVID recession and debt by supporting activity in the short term and expanding productive capacity in the medium term. There will be a need to ensure fiscal and monetary policy work together to guide liquidity and savings toward the growth of productive sectors. Properly managed and implemented, it can simultaneously reduce existing welfare inequalities that will be exacerbated by the pandemic and improve economic and social resilience to future shocks.

There is a unique opportunity for the world to rebuild to last after COVID-19, put unemployed resources to good use and generate employment and activity that locks in inclusive, resilient and sustainable growth. Failure to grasp the opportunity means a legacy of the COVID-19 pandemic which could lead to a series of damaging social, environmental and economic emergencies. The consequences of a prolonged global depression would be profoundly damaging; the consequences of environmental degradation and dangerous climate change could be catastrophic. The period after the crash of 2008 was mostly wasted. This may be our last chance.

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CONFLICT OF INTEREST

The author has declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Dimitri Zenghelis: Conceptualization; formal analysis; investigation; visualization; writing-review & editing.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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ENDNOTES

[1] Laurence Summers various blog pieces on "secular stagnation." Available at: http://larrysummers.com/category/secular-stagnation/

[2] At the time of writing (July 2020) and despite a second corona virus wave hitting major economies, the S&P 500 index stands at 3245, a mere 45 shy of its all-time high.

[3] https://www.grandviewresearch.com/industry-analysis/led-lighting-market

[4] https://cleantechnica.com/2018/01/04/50-new-car-registrations-norway-2017-plug-vehicles-hybrids/

[5] OFGEM Electricity generation mix by quarter and fuel source. Available at: https://www.ofgem.gov.uk/data-portal/electricity-generation-mix-quarter-and-fuel-source-gb

[6] See https://read.oecd-ilibrary.org/view/?ref=119_119674-tbcxotkmhb&title=Coronavirus_(COVID-19)Joint_actions_to_win_the_war

[7] See https://newclimateeconomy.report/

[8] The reason decarbonzaition in "inevitable" is because it is the stock of GHGs that causes warming and not the flow of emissions. To stabilize the climate at any temperature, emissions must fall to net zero. Either emissions come down through managed reductions or humanity creates such a hostile climate that the emissions come down through depopulation and deindustrialization. But down emissions will come.

[9] For example, once electric vehicle infrastructure is rolled out, the incentives to conduct research and development on electric cars increase relative to combustion engine, or fuel cell, vehicles. Volvo will stop producing combustion engine cars from 2019 and start focusing its R&D on electric vehicles; others are sure to follow.

[10] See LSE Growth Commission (December 2018) *Sustainable growth in the UK: Seizing opportunities from technological change and the transition to a low-carbon economy*.

[11] Llewellyn focuses only on model results in which spending was additional and funded by new borrowing. The OECD, averaging across three different model estimates, has estimated that a sustained increase in public investment in the United Kingdom of ½ percentage point of GDP leads to a long-term output gain (potential GDP) of around 1.5% of GDP (i.e., a 3% increase for a 1% increase in investment). See OECD (November 2016) *Can an increase in public investment sustainably lift economic growth?*, paragraphs 26–31., and Figure 8. The IMF has estimated similar figures, with the caveat that underlying economic conditions affect the value importantly: "The macroeconomic effects of

public investment shocks are very different across economic regimes (Figure 3.6, panels 1 through 4). During periods of low growth, a public investment spending shock increases the level of output by about 1.5% in the same year and by 3% in the medium term, but during periods of high growth the long-term effect is not statistically significantly different from zero." See IMF (2015). Elsewhere the IMF has found statistical evidence for a value of 2.5: see IMF (2015, May) *The Macroeconomic Effects of Public Investment: Evidence from Advanced Economies*, especially p. 19.

[12] As the standard equation for debt dynamics illustrates: Change in $d = -p + (r - g) * d(-1)$, where d = debt/GDP, p is the primary balance (public borrowing after interest payments), r is the rate of interest, and g the rate of nominal GDP growth.

[13] See BT Digital impact and sustainability https://www.btplc.com/Digitalimpactandsustainability/

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