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The impact of COVID-19 fiscal spending on climate change adaptation and resilience

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Government expenditure and taxation have a significant influence on the long-term adaptation and resilience of societies to climate and other environmental shocks. Unprecedented fiscal spending in the COVID-19 recovery offered an opportunity to systematically enhance adaptation and resilience to future shocks. But did the 'build back better' rhetoric manifest in more resilient policy? We develop a dedicated fiscal policy taxonomy for climate change adaptation and resilience (A&R)—the Climate Resilience and Adaptation Financing Taxonomy (CRAFT)—and apply this to analyse ~8,000 government policies across 88 countries. We find that US$279–334 billion (9.7–11.1%) of economic recovery spending potentially had direct A&R benefits. This positive spending is substantial in absolute terms but falls well below adaptation needs. Moreover, a notable portion (27.6–28%) of recovery spending may have had negative impacts on A&R, acting to lock in non-resilient infrastructure. We add a deep learning algorithm to consider A&R themes in associated COVID-19 policy documents. Compared with climate mitigation, A&R received only one-third of the spending and was mentioned only one-seventh as frequently in policy documents. These results suggest that the COVID-19 fiscal response missed many opportunities to advance climate A&R. We draw conclusions for how to better align fiscal policy with A&R.

The COVID-19 pandemic has shown the detrimental consequences of poor preparedness for systemic risks, with a shock to the health system spurring an economic downturn, spiralling debt levels and an unravelling of global supply chains[1,2]. These impacts precipitated many second-order effects, including reduced incomes and reversed progress on development[3–5]. Climate change is likely to pose even greater risks to global systems, with physical climate shocks triggering cascading impacts across interlinked global systems[6–8]. The consequences of climate inaction fall disproportionately on vulnerable populations, with poor and marginalized communities bearing the worst impacts, as with the COVID-19 pandemic[9]. There are currently substantial gaps in the capacity of global human and environmental systems to adapt and be resilient in the face of adverse climate shocks, highlighting the urgent need for investment in adaptation and resilience (see Supplementary Note 1, on defining adaptation and resilience)[10].

Public investment and taxation, hereafter collectively referred to as 'spending', can play an important role in climate change adaptation and resilience (A&R). It can do so through explicit investments in resilient infrastructure and systems, and by influencing future patterns of capital allocation, policy, regulation, law making, business practice or behaviour. Current frameworks for assessing the impacts of government spending on A&R tend to include only policies that explicitly mention adaptation, with an emphasis on physical adaptation actions. As such, there is limited scope to evaluate both the intended and unintended impacts of government spending on adaptation and broader resilience outcomes. To address this gap, we develop a taxonomy that

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scores policy types according to their expected impacts on both 'direct' and 'indirect' climate change A&R. We define direct A&R as explicit efforts to adapt to current or expected climate effects. Indirect A&R refers to efforts that increase resilience or reduce vulnerability to climate change effects, regardless of whether the intention was to directly address climate risks.

The COVID-19 pandemic serves as a unique case for studying the impact of fiscal policy on climate A&R. The level of fiscal spending during the COVID-19 pandemic was unprecedented, in real terms almost four times the amount spent in response to the global financial crisis of 2007–2008[11]. During the initial 'rescue' phase of the pandemic, which focused on immediate protection of lives and livelihoods, 88 governments spent an estimated US$12 trillion on short-term relief measures[11]. The 'recovery' phase saw an additional US$3 trillion allocated to policies aiming to reinvigorate economies in the mid to long term. Together, rescue, recovery and unclear spending totalled US$17.5 trillion. Major fiscal policies were often accompanied by new national development and strategic plans incorporating a wide variety of non-fiscal measures, including industrial, debt and monetary policy[12]. As policymakers directed their attention to pandemic recovery, calls to 'build back better' highlighted the need for public policy to both address climate mitigation and bolster adaptation and resilience to future crises, including those related to climate change[13–15].

Existing research has shown that COVID-19 spending had limited positive impacts on climate change mitigation outcomes such as greenhouse gas emissions, as well as other environmental indicators including air pollution, natural capital and biodiversity[5,16–18]. However, there has been less research into the impacts of COVID-19 spending on climate change A&R. A recent paper demonstrated that relatively few countries explicitly mentioned climate risk management and resilience as a core objective in COVID-19 stimulus plans announced in 2020[19]. The volume and characteristics of climate A&R spending across both the rescue and recovery phases of the pandemic, however, have neither been quantified, nor has the potential 'indirect' impact of broader policies on A&R been assessed. We develop and apply a dedicated climate adaptation and resilience fiscal taxonomy to assess the climate A&R characteristics of fiscal policy and apply it to the COVID-19 fiscal policy database assembled by the Global Recovery Observatory (GRO), which records policies announced by 88 countries (see country list in Supplementary Table 1) over March 2020 to December 2021[11]. We explore regional and country-level variation in A&R spending and compare the relative prioritization of climate change A&R and mitigation in government spending and rhetoric. Specifically, we use techniques in natural language processing (NLP) and deep learning (DL) to evaluate the relative emphasis on A&R versus mitigation in major policy documents. Finally, we draw conclusions for how to better align fiscal policy with A&R.

Climate Resilience and Adaptation Financing Taxonomy (CRAFT)

In this paper, we introduce CRAFT, which provides a framework for evaluating the potential impact of fiscal policy on climate adaptation and resilience (see Methods for details and ref. 20 for the full taxonomy). This taxonomy builds on the methodology of the GRO[11], which classified fiscal policy types into a set of 40 exhaustive and mutually exclusive policy 'archetypes' and 158 'subarchetypes.' The GRO scored each subarchetype for potential climate change mitigation impacts, as well as other environmental and socioeconomic outcomes, and classified it as either a 'rescue' or 'recovery' archetype.

CRAFT refines this original methodology to differentiate between policy types that are relevant to climate A&R, resulting in 42 archetypes and 293 subarchetypes. This extended archetype set was developed by taking the GRO taxonomy and analysing the ~8,000 COVID-19 policies recorded in the GRO database[11] to identify gaps where policies might have A&R characteristics but were categorized to archetypes that would traditionally not be considered A&R-related. For example, while most tourism incentives (archetype S) might be considered poor for A&R, Spain's US$1.62 billion initiative to improve sustainability in the island tourism sector[21] could have positive A&R impacts, hence a new subarchetype, 'Incentives for tourism with A&R conditions', was introduced. Next, the augmented taxonomy was compared to existing frameworks, such as the Intergovernmental Panel on Climate Change's (IPCC) adaptation actions[22] and the European Union's sustainable finance taxonomy[23] to identify further gaps. CRAFT adds depth to these existing approaches by covering policies that improve, reduce or have no impact on A&R (rather than just those that improve) and providing higher granularity (that is, 293 categories, triple the 88 of the European Union).

Each of the 293 CRAFT subarchetypes was scored for its potential impact on direct and indirect climate A&R through a year-long review of existing academic evidence (over 100 studies). Subarchetypes were scored positively (+1) if, on the basis of existing literature, they are expected to enhance direct or indirect A&R; neutrally (0) if they have little relevance to A&R; and negatively (−1) if they are expected to 'lock in' non-resilient infrastructure or promote maladaptation.

After development of the taxonomy and scoring of subarchetypes, we applied CRAFT to the GRO database of ~8,000 fiscal policies announced by 88 governments between March 2020 and December 2021 in response to COVID-19[11]. These fiscal policies include deficit spending, tax cuts and tax deferrals, which we refer to collectively as 'fiscal policies' or 'spending' throughout. Each policy in the GRO was assigned to a CRAFT subarchetype and thus takes on its direct and indirect A&R scores.

We tested the validity of CRAFT's assessment of fiscal policies by conducting a robustness check for a subset of policies for each of the 293 subarchetypes (Methods). For each policy, we manually considered whether the direct and indirect A&R scores assigned at the subarchetype level fit the policy description, examining the source documents where clarification was required. This process helped to address the subjective component of the scoring process. The subarchetype received a 'high' confidence rating if this process revealed scoring inconsistencies for fewer than 10% of policies and a 'medium' confidence rating for scoring inconsistencies for fewer than 20% of policies. Overall, we considered 4,459 policies in our robustness assessments. We found that 97% of total spending was associated with archetypes with fewer than 20% scoring inconsistencies (medium to high confidence). Of all archetypes, 93% were identified as having a medium to high confidence rating. Archetypes such as 'disaster preparedness' and 'natural infrastructure and green spaces investment' were assigned high confidence, while we found lower confidence in 'liquidity support for subnational public entities', for example. Together, these results suggest that the taxonomy is well-suited to assessing potential A&R impacts for policies in well-defined or specific sectors, yet struggles when applied to broad categories with ambiguous boundaries. This is consistent with the subarchetype impact assessments, which are drawn from a literature review of previous studies that tend to be more precise in their results for specific topics compared with broader ones. We report our overall results for A&R spending as a range, with the lower bound including policies in high and medium confidence subarchetypes only, and the upper bound including subarchetypes of all confidence levels.

The A&R characteristics of COVID-19 spending

We find that overall, across both the rescue and recovery phases of the pandemic, governments directed 1.7–2% (US$289–344 billion) of spending to policies with an expected positive direct climate A&R impact (Fig. 1). When indirect A&R is considered, a total of 4.5–6.8% (US$758–1,181 billion) of spending has potentially positive A&R impacts. The rescue phase of the pandemic focused primarily on immediate protection of lives and livelihoods and thus had limited A&R impacts, with 0.1–2.8%

Potential A&R impact		Spending Phase: Rescue (Spending announced during the initial 'rescue' phase of the pandemic, which focused on short-term protection of lives and livelihoods)	Recovery (Spending announced during the 'recovery' phase of the pandemic, which focused on reinvigorating economies in the mid to long term)	Unclear (Spending that does not clearly fit either 'rescue' or 'recovery' phases)	Total (Total spending, including both 'rescue' and 'recovery' phases, as well as unclear spending)
PositiveA&R (Spending with potential positive impacts on direct or indirect A&R)	Direct: Explicit efforts to adapt to current or expected climate effects	$10	$334	$0	$344
	Indirect: Efforts that (intentionally or not) increase resilience or reduce vulnerability to climate effects	$336	$845	$0	$1,181
	Both: Efforts that have either positive direct or indirect potential A&R impacts	$336	$845	$0	$1,181
Negative A&R (Spending with potential negative impacts on A&R)		$0	$831	$0	$831
Neutral A&R (Spending with neither positive nor negative potential impacts on A&R)		$11,589	$1,336	$2,542	$15,466
Total (Total spending, including positive, negative and neutral potential A&R impacts)		$11,925	$3,012	$2,542	$17,478

Fig. 1 | Global spending (US$, billion) during the COVID-19 pandemic, broken down by phase of spending and potential impact on A&R. Spending phases include rescue, recovery and unclear, while potential impact on A&R includes positive (direct, indirect, both), negative and neutral impacts. The 'both' category for A&R impact includes spending with either a positive direct or indirect potential effect. Values displayed are rounded to the nearest integer. All confidence levels are presented; results for high and medium confidence only presented in Supplementary Fig. 1.

(US$10–336 billion) of spending having estimated positive direct or indirect A&R impacts. This spending was dominated by liquidity support to local and regional governments. While this can bolster adaptive capacity[24,25], these archetypes received low scores in the robustness test due to uncertainty around the allocation of funds.

As economies began to shift towards economic recovery, government spending rose to unprecedented levels, raising hopes that 'win–win' initiatives with high economic multipliers and positive climate benefits could help economies 'build back better'[13–16]. We find that only US$279–334 billion (9.7–11.1%) of recovery spending was allocated to direct (explicit) efforts to adapt to current or expected climate change effects. Broken down by policy type (see Table 1), the highest proportion of spending on direct A&R was allocated to disaster preparedness initiatives, natural infrastructure and green retrofitting programmes. When broader resilience impacts are accounted for (indirect A&R), we find that US$748–845 billion (25.9–28.1%) of recovery spending has the potential to positively support indirect adaptation and resilience. In addition to the aforementioned direct policies, indirect A&R recovery spending included communications infrastructure, education and healthcare. Note that all policies with positive scores for direct A&R also have positive scores for indirect A&R due to their broader resilience benefits; total values for direct and indirect A&R spending should therefore not be directly added together.

We find that an estimated 27.6–28% (US$808–831 billion) of recovery spending has the potential to negatively impact climate A&R by 'locking-in' non-resilient infrastructure or promoting maladaptation, particularly through spending on transport, energy and urban development infrastructure without explicit regard for adaptation and resilience (see Supplementary Table 5). Unless climate A&R is explicitly accounted for in infrastructure spending, there is a risk that these assets, which have long lifespans, will be ill-equipped to withstand expected climate impacts[26].

The total of US$289–344 billion allocated to direct (explicit) A&R across both rescue and recovery phases falls below the levels of spending needed to ensure adequate adaptation and resilience to climate change. While estimates of global A&R financing needs are limited and methodologically difficult[27], the United Nations Environment Programme (UNEP) estimates that adaptation costs for developing economies will range from US$160–340 billion per annum by 2030[10], while other estimates[28] range from US$200–250 per year for developing countries, excluding China. These adaptation cost estimates are annual, whereas the fiscal spending policies in our analysis typically come with 5–10-yr implementation horizons. Extrapolating these estimates to 5–10-yr horizons, the range of adaptation costs for developing economies amounts to US$800–1,700 billion over 5 years or US$1,600–3,400 billion over 10 years. These figures probably underestimate the true cost of adaptation[27] and fail to incorporate broader resilience measures and developed economies. Nonetheless, a comparison of these estimates with our findings suggests that government spending on A&R during the COVID-19 pandemic fell substantially below what is needed to adapt and build resilience to climate change. Outside of domestic fiscal spending, international adaptation finance flows to developing countries amounted to only US$28.6 billion in 2020[10]. While this volume continues to rise, there is a clear need both for increased private investment and mainstreaming of A&R into public spending to meet this finance gap, paired with appropriate impact assessment and monitoring.

Variation in A&R spending by region and country

COVID-19 recovery spending on A&R was highly variable across regions (Fig. 2). North America directed the highest absolute volume and proportion of recovery spending to A&R-positive policies, focusing on broadband investment, disaster preparedness, resilient infrastructure and education. Asia Pacific emphasized disaster preparedness, natural infrastructure and broadband, while Latin America and the Caribbean focused on education, broadband and social care. A&R-positive spending in Africa was dominated by disaster preparedness and education. The percentage of low-confidence archetypes as a proportion of overall A&R spending also varies across regions depending on their types of

Table 1 | Recovery spending with potential positive direct A&R impacts, presented by archetype and subarchetype. Upper range of estimate (all confidence levels)

Archetype	Subarchetype	Positive direct A&R (US$, billion)	Positive direct A&R (%)
Disaster preparedness	Other direct climate change adaptation and resilience measures	**84.9**	25
	Investment in emergency response systems	**14.0**	4
	Procurement of emergency response equipment	**0.1**	0
	Investment in risk assessment and early warning systems	**0.1**	0
Natural infrastructure and green spaces investment	Environmental re(building) initiatives including afforestation, reforestation and environmental rehabilitation	**42.3**	13
	Indiscriminate	**33.3**	10
	Environmental protection initiatives including conservation and natural infrastructure resilience	**12.6**	4
Building upgrades and energy efficiency infrastructure investment	Green retrofitting programmes (including daylighting, electricity and electrification, insulation)	**54.5**	16
Other large-scale infrastructure investments	Large-scale regional infrastructure (climate conditions - A&R)	**44.4**	13
	Large-scale urban infrastructure (climate conditions - A&R)	**0.3**	0
Tourism and leisure industry incentives	Incentives for tourism (climate conditions - A&R)	**16.1**	5
Clean energy infrastructure investment	New resilient infrastructure or improve resilience of existing energy infrastructure (clean energy types)	**15.9**	5
Green market creation	Payments and other incentives for ecosystem services	**7.2**	2
Clean transport infrastructure investment	New resilient infrastructure or improve resilience of existing transportation infrastructure and networks	**3.9**	1
Agriculture and fisheries	Investment in forestry (climate conditions - A&R)	**0.9**	0
	Investment in agriculture (climate conditions - A&R)	**0.2**	0
Local (project-based) infrastructure investment	Urban development programmes (climate conditions - A&R)	**0.6**	0
	Sustainable new housing investment (A&R specific)	**0.3**	0
	Investment in local utilities (climate conditions - A&R)	**0.5**	0
Clean R&D investment	Other climate resilience R&D programmes	**0.9**	0
Worker retraining and job creation	Green worker retraining and job creation (unclassified/mixed)	**0.7**	0
	Green worker retraining and job creation (A&R)	**0.2**	0
Education investment	Funding to support understanding of climate change mitigation, adaptation and/or resilience	**0.1**	0
Traditional energy infrastructure investment	New resilient infrastructure or improve resilience of existing energy infrastructure (traditional energy types)	**0.0**	0
Positive direct A&R recovery		**333.8**	

Note: Spending presented as recovery phase spending with potential positive 'direct' A&R impacts per subarchetype and as a proportion of direct A&R recovery spending. Only subarchetypes with relevant spending are included; for a complete list of archetypes and subarchetypes, see the full taxonomy in ref. 20. All confidence levels are presented; results for high and medium confidence only presented in Supplementary Table 2. Recovery spending with potential positive 'indirect' A&R impacts presented in Supplementary Tables 3 and 4.

expenditure. For example, Europe had proportionately the largest low-confidence spending because of their investment in archetypes such as green retrofitting and health and science research and development (R&D), which had lower confidence levels.

COVID-19 recovery spending was also uneven across countries (Fig. 3). The Bahamas allocated the highest portion of recovery funds to policies with potential positive A&R impacts (75.4%), amounting to US$300 million. The United States announced the highest absolute amount for policies with likely positive A&R impacts (US$273–277 billion), comprising 39.8–40% of recovery spending.

Research has shown that government spending on climate adaptation and resilience may be influenced by factors such as the country's vulnerability to climate change, their national income, and their social, economic and governance capacity[29,30]. While detailed country-level causal policy analysis to assess the drivers of spending decisions is outside the scope of this paper, we are interested in illustrating the characteristics of spending with respect to economic or institutional factors. To do so, we tested whether there are significant correlations between these factors and countries' spending (absolute and proportional) on climate A&R during the pandemic. We collected gross national income (GNI) data from the World Bank[31] and two indicators developed by the Notre Dame Global Adaptation Initiative (ND-GAIN)[32]: the vulnerability index, which is a compound measure of exposure, sensitivity and adaptive capacity, and the readiness index, which captures social, economic and governance capacity (see correlation matrix in Supplementary Table 6 and Methods for details).

The correlation analysis has several conclusions and implications. First, it suggests that higher-income countries tended to allocate more absolute spending to A&R-positive policies, potentially due to greater financial resources and fiscal capacity. We find a significant positive correlation between GDP and recovery spending on A&R-positive policies (0.83). This suggests that lower-income countries, some of which are the most vulnerable to climate change (0.59 correlation; Fig. 3)[30,33], also spent less on A&R-positive policies in absolute terms.

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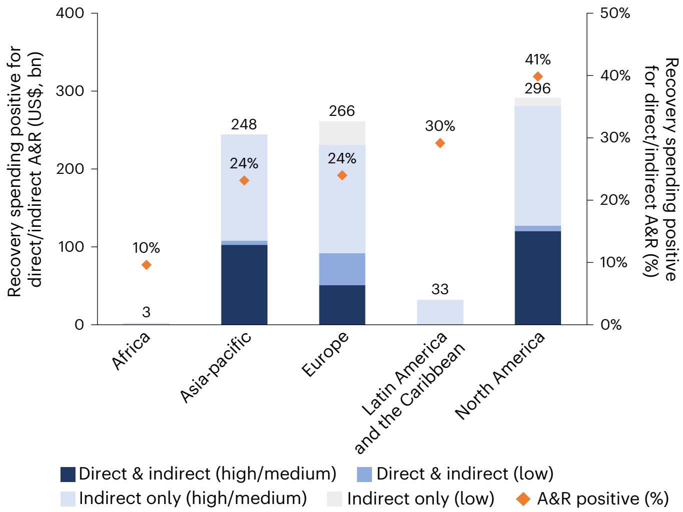

Fig. 2 | Recovery spending (US$, billion) by region, on policies that positively impact direct or indirect climate A&R, broken down by confidence level. Bars give absolute A&R spending (left axis) and points give A&R as a proportion of recovery spending (right axis). The 'direct & indirect' category refers to policies that are scored positively for both direct and indirect A&R, while 'indirect only' indicates policies that are only scored positively for indirect A&R; no policies were scored positive for 'direct only'.

Second, the data show a lack of correlation between GDP per capita and the proportion of recovery spending allocated to A&R policies, indicating variation in the proportion of spending allocated to A&R within income tranches. For instance, we find that many small island developing states (SIDS) allocate a substantial proportion of spending (>30%) to A&R-positive policies, while other lower- and middle-income countries do not (Fig. 3); higher-income countries also diverge in their proportional allocations.

Third, the absence of a correlation between climate vulnerability and A&R spending (absolute and proportional) suggests that cultural factors and differing priorities may influence allocation decisions. Extended Data Table 1 shows that when countries are categorized into GNI per capita quintiles, lower-income countries announced lower A&R-positive spending in both absolute and relative terms, despite having a higher level of vulnerability and exposure. Together with the above findings, these results suggest that spending was influenced by specific national circumstances; generalized conclusions cannot be drawn by dimensions of income or vulnerability.

Finally, the positive correlation between a country's readiness (economic, governance, social) and A&R spending (0.33) and the positive correlation with adaptive capacity implies that countries that are more prepared for climate change tend to invest more in A&R measures, suggesting a policy pathway stickiness or inertia. These conclusions underscore the complexity and context-specific nature of A&R spending decisions.

Relative prioritization of A&R versus mitigation

As countries began to rebuild economically in the wake of the COVID-19 crisis, many governments expressed ambitions to 'build back better', including incorporating climate change mitigation and A&R spending into their recovery plans. While climate change mitigation and A&R have historically been treated separately in mainstream academia, policy and practice[34,35], they are increasingly being considered jointly in recognition of their interconnectedness, particularly for sectors such as energy, infrastructure, buildings, natural capital and agriculture[36,37]. This dual emphasis on mitigation and A&R is evident in international ambitions to achieve a 50:50 balance in climate finance spending on both objectives, as articulated at COP26 and re-affirmed at COP27[38,39].

In this paper, we have focused on adaptation and resilience, which is often underrepresented in climate change discourse relative to mitigation; other papers have analysed mitigation spending in more detail[40,41]. Nonetheless, it is instructive to explore the relative prioritization of A&R versus mitigation in COVID-19 fiscal policy. Previous analysis of the GRO dataset provides data on the potential impact of COVID-19-related spending on mitigation (greenhouse gas emissions)[11]. In this dataset, mitigation-positive spending is that with potential to reduce long-term greenhouse gas emissions compared with a scenario in which the policy was not introduced. Comparing these figures to our own analysis, spending on climate change mitigation in the recovery phase was approximately three times higher than spending on direct A&R; that is, 28.5–30.2% of recovery spending had estimated positive impacts for mitigation, compared with 9.7–11.1% for direct A&R.

This finding mirrors data on broader climate finance allocations between mitigation and adaptation priorities; the Climate Policy Initiative reports that only 8% of global climate finance flows were allocated to adaptation specifically in 2020–2021, compared with 90% allocated to mitigation[42]. This larger gap between mitigation and A&R spending may be because adaptation and resilience spending tends to be more locally focused; it may also be because of our broader definition of direct and indirect A&R. This prioritization of mitigation over adaptation and resilience at both domestic and global levels could be driven by multiple factors, including methodological and data-related issues in quantifying adaptation impacts and tracking financing, domestic or international political economy factors, perceptions of relative urgency and immediate benefits, or weaker knowledge and capability on adaptation[42,43].

To further investigate the discrepancy in policy attention between A&R and mitigation, we compared our findings on spending with a complementary analysis on policy rhetoric. We examined the rhetoric of 11 governments' economic recovery plans using NLP and a simplified Bidirectional Encoder Representations from Transformers (BERT) deep learning model (Methods). We took a set of 78 core policy papers identified by GRO (Supplementary Table 8), framed as plans for economic recovery, covering 11 G20 countries (that is, all those with policy documents published in English). We analysed this corpus for text related to climate A&R and mitigation using a climate dictionary expanded from those of refs. 44,45. The dictionary expansion process used the iterative human-in-the-loop technique introduced in ref. 45 alongside a BERT deep learning model to identify crucial climate terms and concepts in the texts (Methods). With this dictionary, we used basic NLP processes to identify the percentage of clauses in the policy documents relating to climate A&R compared to mitigation. We found that climate mitigation was referenced seven times more frequently than climate A&R in government policy documents (Table 2). This could imply that governments perceive A&R to be a lesser priority, or it may reflect a lack of understanding of A&R and its relevance to bolstering a resilient economic recovery. Combining this with the spending analysis suggests either that A&R is not as politically salient or there are knowledge gaps among policymakers. This conclusion is further supported by the fact that direct (explicit) A&R spending in the recovery phase was substantially (1.5×) lower than estimated indirect adaptation and resilience benefits. This could suggest that positive A&R impacts might often be an unintended side effect of spending rather than a core objective.

An additional reason for the divergence in mitigation and A&R spending could be a perception that the two are distinct or even competing objectives. With scarce resources and political capital, particularly for countries with fiscal constraints, difficult decisions must be made. In this final section, we explore where there are 'triple benefits' to A&R, mitigation and economic recovery, and where there could be trade-offs.

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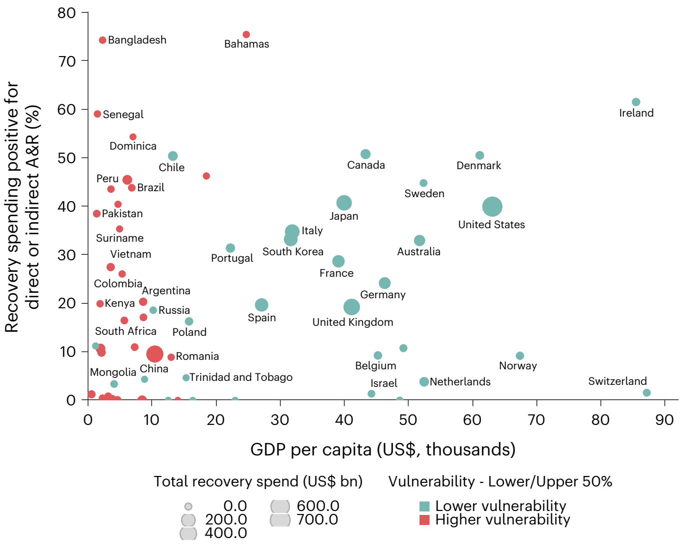

Fig. 3 | Proportion of recovery spending with potential positive impacts on direct or indirect climate A&R against GDP per capita. Size of circles indicates COVID-19 spending during the recovery phase (US$, billion). Circles are coloured on the basis of whether countries are in the upper or lower 50% of the ND-GAIN vulnerability index. Not all circles are labelled. The upper range estimate is presented (all confidence levels); results for high and medium confidence only presented in Supplementary Fig. 2.

While the majority of COVID-19 fiscal policies are estimated to have neutral impacts for both climate change mitigation and A&R (Extended Data Fig. 1), we do find some policy types for which there are potential trade-offs. Integrating the data categorization of ref. 11 on mitigation, we group recovery policies with positive A&R scores on the basis of those with potential to have a negative, neutral or positive climate mitigation impact (Fig. 4). We find that policies aiming to enhance the resilience of traditional energy infrastructure may also prolong greenhouse gas emissions from these facilities[46]. Compared with new traditional energy infrastructure investment, however, the impact of prolonging existing facilities is expected to be lower on an emissions basis. Moreover, only one COVID-19 policy, worth US$33 million, was allocated to this archetype, suggesting that trade-offs of this nature were limited[47]. By contrast, investment in mitigation-oriented infrastructural projects (for example, rail construction and electric vehicle charging infrastructure), which are implemented without A&R conditions, are expected to have positive long-term mitigation impacts and negative A&R impacts by encouraging 'lock in' of non-resilient infrastructure. This amounts to US$232 billion (7.8%) of recovery spending, indicating a need for policymakers to explicitly integrate adaptation and resilience planning into climate mitigation-oriented projects.

Importantly, we find that 24 recovery subarchetypes, amounting to US$119–216 billion (4.1–8.5%) of recovery spending, are scored positively for both mitigation and A&R. This spending was dominated by natural infrastructure investment (for example, environmental rehabilitation and conservation), resilient clean energy infrastructure and payments for ecosystem services. Additional spending on worker retraining for A&R jobs and investing in climate change educational programmes also contributed to both mitigation and A&R objectives. Policies such as natural infrastructure investment, green worker retraining, clean energy infrastructure and education have previously been identified as having moderate to high long-run economic multiplier effects[16], making these 'triple benefit' investments that help to achieve goals of economic recovery, climate change mitigation, and adaptation and resilience.

Table 2 | Percentage of clauses related to A&R and climate mitigation in policy documents of 11 nations in the G20

	Climate clauses as percentage of total clauses		
	General climate (%)	**Mitigation specific (%)**	**A&R specific (%)**
Australia	0.5	1.2	0.3
Canada	2.0	1.4	0.1
European Union	5.8	1.2	0.5
France	3.2	0.8	0.6
Germany	2.7	2.4	0.0
India	0.9	4.8	0.1
Italy	1.9	1.4	0.1
Korea	4.6	5.1	0.4
South Africa	0.3	0.8	0.0
United Kingdom	1.2	2.4	0.1
United States of America	3.1	2.4	0.9
Mean (equal weighting)	2.4	2.2	0.3
Median	2.0	1.4	0.1

In summary, while we identify some trade-offs, these mostly stem from a failure to explicitly integrate A&R into mitigation-oriented infrastructure projects. Most importantly, there are 'triple benefit' policies that support A&R, mitigation and economic recovery. Policymakers would benefit from integrating A&R more holistically into policy measures and emphasizing these 'triple benefit' projects.

Discussion

COVID-19 underscored the importance of A&R and provided an opportunity to 'build back better' for future shocks, including climate-related ones. However, despite considerable spending, this analysis suggests that the opportunity to enhance climate A&R was not fully utilized. Specifically, based on an analysis using the CRAFT tool on the GRO dataset, A&R spending during the economic recovery was low, requiring substantial additional investment if identified needs for the coming decade are to be met[10,28]. Comparing A&R to mitigation figures, governments allocated only one third as much to A&R and mentioned A&R topics only one-seventh as often in policy documents.

This suggests insufficient emphasis among national policymakers on the benefits of integrating A&R considerations across various spending areas. Given the rhetorical emphasis on 'building back better' over the COVID-19 period, this result is particularly concerning and suggests that emphasizing the benefits of A&R to policymakers should be an urgent priority. This is particularly critical at a time when the public is increasingly recognizing that the threats posed by climate change are no longer theoretical, but immediate and material. Calls to mainstream climate A&R are not new, but our evidence suggests that it is not yet happening and quantifies the gap. Moreover, our results underscore the importance of recognizing the potential negative impacts that government spending can have on adaptation and resilience if these factors are not urgently and holistically accounted for in policy planning.

In the face of adverse climate impacts, there is a need for enhanced spending on both direct adaptation and broader resilience topics, balancing immediate and longer-term resilience needs. More broadly, there is a need to rethink the modern economic structures and incentives that have enabled climate change to continue at pace for decades and that fail to adequately incentivize private capital into climate investment. For recessionary economic policy, perhaps this means moving beyond a fixation on economic growth and towards a more

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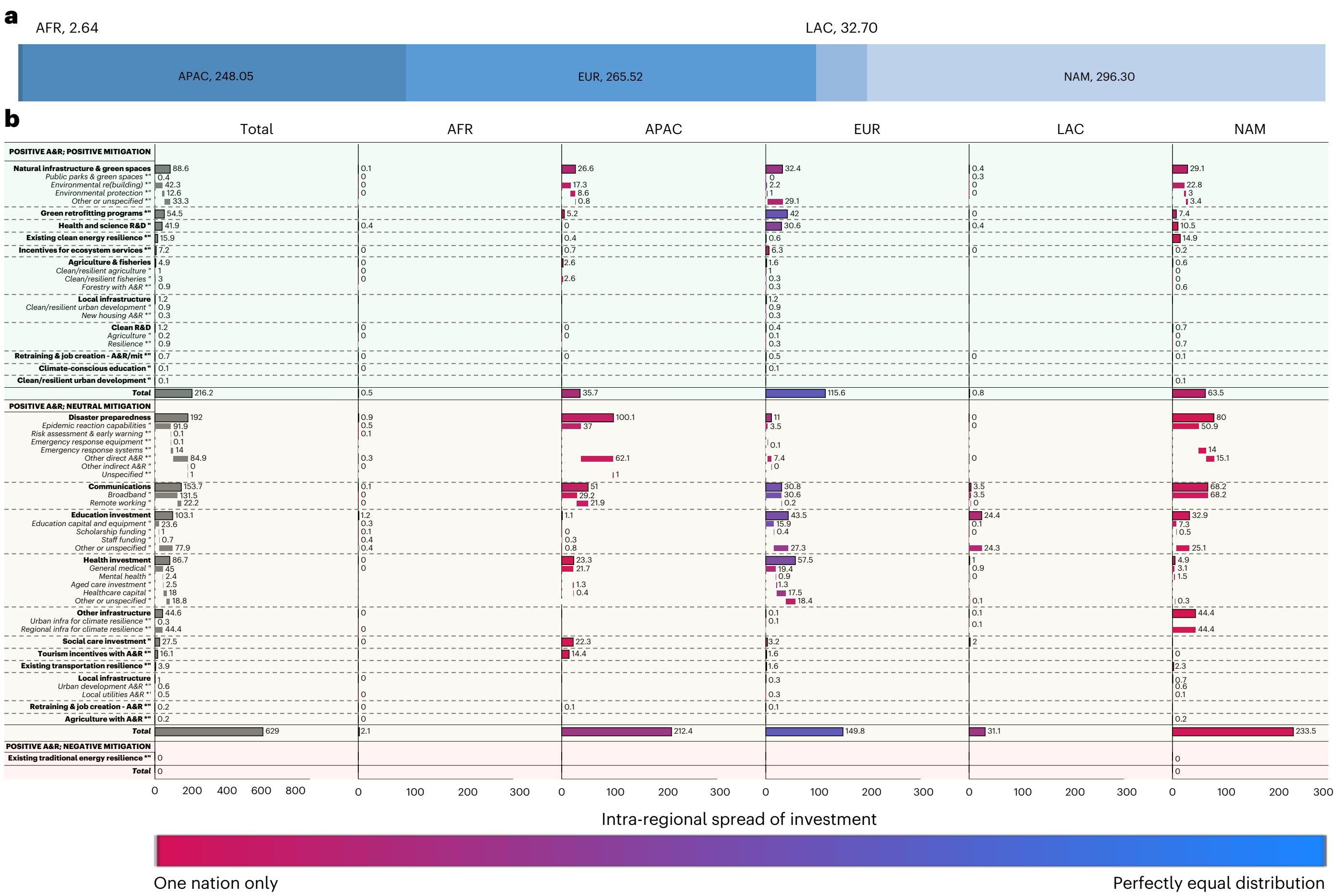

Fig. 4 | Total recovery spending with positive climate A&R characteristics, presented by subarchetype and region. a, Total positive A&R recovery spending (US$, billion) in each region. **b**, Total recovery spending by subarchetype, grouped by expected mitigation impact (negative, neutral, positive). Bold text in a row indicates archetype level, non-bold text indicates subarchetype level. Blank values indicate exactly US$0. Zero values indicate minor spending, between US$0 and US$50 million. AFR, Africa (11 countries); APAC, Asia and the 140 Pacific (23 countries); EUR, Europe (19 countries); NAM, North America (23 countries); SAM, South America (12 countries); *, subarchetype positive for direct A&R; ", subarchetype positive for indirect A&R.

holistic approach that embeds adaptation and resilience as well as other factors core to human well-being[48,49].

While there are some trade-offs, we found that several policy types have 'triple benefits' for climate A&R, mitigation and economic recovery. These synergies are particularly important for countries with high vulnerability and low fiscal space. It is crucial to prioritize A&R investment in low-income countries, which are often more vulnerable and in greater need. Despite the challenges posed by the current economic environment, including high inflation and energy/war shocks, preparing for climate impacts remains essential.

There remain persistent gaps in the literature on the climate A&R impacts of different fiscal policy types. Future spending should be paired with robust evaluation processes to better understand how different kinds of spending impact climate A&R over all time frames, as well as interdependencies between climate resilience and other forms of resilience.

Methods

This paper used multiple methods to analyse the potential impacts of COVID-19 fiscal spending on climate change adaptation and resilience (A&R). First, we expanded an existing taxonomy of fiscal spending to incorporate A&R-relevant policy measures[50]. Second, we applied this taxonomy to a database of ~8,000 policies implemented by 88 countries during the pandemic and analysed the A&R characteristics of this spending. Third, we used techniques in NLP and DL to consider how A&R versus mitigation themes feature in broader policy planning in a subset of 11 countries. Figures of country spending were created using Tableau 2021.4 and tables were generated using Excel 2016.

CRAFT

To assess the potential impact of fiscal policy on climate change adaptation and resilience, we developed a policy taxonomy, organized around the likely impacts of fiscal archetypes on climate A&R. We developed the taxonomy by expanding the original archetype set established by the GRO[50], conducting an extensive literature review, and drawing upon existing adaptation and resilience frameworks, as outlined below.

The GRO is a policy database developed by the Smith School of Enterprise and the Environment at the University of Oxford, which tracked COVID-19 fiscal policy in 88 countries from March 2020 to December 2021 (see Supplementary Table 1 for a list of all included countries)[11]. In the database, policies are categorized into exhaustive and mutually exclusive subarchetypes, which are each associated with one overarching archetype and designated as functioning either for 'rescue' (that is, initial pandemic relief) or economic 'recovery'. An additional 'indiscriminate' archetype captures spending that does not clearly fit into specific archetypes, typically due to a lack of specificity of the policy descriptions provided by governments. Indiscriminate archetypes are classified as 'unclear', rather than being allocated to either the 'rescue' or 'recovery' phase. The original GRO included 40 archetypes and 158 subarchetypes.

Each subarchetype was assessed in ref. 11 for its potential impact on short- and long-term greenhouse gas emissions. Other potential environmental, social and economic impacts were defined for an adapted archetype set in ref. 50. Archetypes were also tagged by sector. The archetypes were developed from first principles and tested against a preliminary set of 2,000 observed policies. Archetypes were developed with a focus on fiscal policy in contractionary macroeconomic environments.

We took the GRO taxonomy and analysed the ~8,000 COVID-19 policies recorded in ref. 11 to identify gaps where policies might have A&R characteristics but were categorized to archetypes that would traditionally not be considered A&R-related. For example, while most tourism incentives (archetype S) might be considered poor for A&R, Spain's US$1.62 billion initiative to improve sustainability in the tourism sector (special attention to Balearic and Canary Islands) could have positive A&R impacts, hence a new subarchetype, 'Incentives for tourism with A&R conditions', was introduced[21].

Next, the augmented taxonomy was compared to existing adaptation and resilience frameworks, such as the IPCC's adaptation actions[22] and the European Union's sustainable finance taxonomy[23], to identify further gaps. Various classification approaches already exist in climate A&R scholarship; however, they operate at a coarser level. The European Union's taxonomy for sustainable economic activities uses a sectoral classification approach to account for A&R activities alongside other sustainability criteria[23]. The United Nations Office for Disaster Risk Reduction (UNDRR)'s climate resilience classification framework follows a similar sectoral approach[51]. The CRAFT framework adds a level of granularity by categorizing policies according to the type of activity they represent (rather than the sector), which incorporates both cross-sectoral and sector-specific policies, resulting in 293 subarchetypes (42 archetypes), triple the 88 of the European Union taxonomy.

Existing approaches to categorizing A&R spending tend to emphasize physical adaptation actions, failing to consider the broader impacts of spending on climate resilience. The assessment framework developed by multilateral development banks for aligning activities with the Paris Agreement, for example, focuses specifically on policies that 'manage physical climate change risks'[52]. More broadly, A&R frameworks tend to evaluate only actions that are explicitly oriented towards adaptation and resilience. For example, the World Bank[53] proposes six priority adaptation policy actions, spanning: inclusive development; facilitating adaptation and protection against shocks for firms, peoples, land and public assets; managing economic and financial risk; and monitoring of interventions. Similarly, the UNDRR's Budget Tagging guide for Disaster Risk Reduction and Climate Change Adaptation focuses only on activities explicitly oriented towards these objectives. CRAFT, by contrast, includes policies that are explicitly targeted at climate change adaptation actions (which we classify as 'direct' A&R), alongside policies that are not explicitly climate-oriented, but which may have positive implications for climate adaptation or resilience (identified as 'indirect' A&R). Importantly, CRAFT adds depth to existing approaches by covering policies that improve, reduce or have no impact on A&R, rather than focusing solely on actions that explicitly aim to enhance A&R, allowing us to provide a more holistic picture of the proportion of fiscal spending with potential positive, neutral and negative impacts on climate A&R.

Through an extensive literature review, each existing and new subarchetype was assessed for its potential impact on climate A&R. Archetypes were scored using a 3-point Likert scale (negative, neutral, positive) for two dimensions: 'direct' and 'indirect' climate A&R. We defined direct A&R as explicit efforts to adapt to current or expected climate effects, that is, policies that aim to implement direct adaptation actions. Examples of policies with potential positive impacts on direct climate A&R include the construction of seawalls or efforts to secure coastal ecosystems by planting mangroves[54,55].

We defined indirect A&R as efforts that increase resilience or reduce vulnerability to climate change effects, regardless of whether the intention was to directly address climate risks. For example, policies that build capacity for local utilities were identified as having a potential positive impact on indirect climate A&R, because utilities provide services (water supply, waste and sanitation, energy distribution) that are crucial to the functioning and adaptive capacity of individuals, communities and systems[24]. Similarly, spending on education, even that which is not climate-specific, has been found to increase adaptive capacity and thus was scored positively for indirect climate A&R[56,57]. Healthcare systems are also crucial to ensuring the ability of populations to adapt and be resilient in the face of climate change[58]. Other policies that have expected positive impacts for indirect climate A&R include capacity building for subnational public entities, supply chain resilience measures, increasing social and political inclusion, enhancing managerial capacity, and providing access to institutions and information[59].

All subarchetypes with a positive direct impact also have a positive indirect impact. This is because specific adaptation actions have broader impacts for climate change adaptation and resilience. For example, the construction of a seawall is also expected to enhance the economic resilience of coastal communities, hence this subarchetype, which was scored positively for direct A&R, was also scored positively for indirect A&R. By contrast, not all policies that were scored positively for indirect A&R were scored positively for direct A&R. For example, education investment that did not specify adaptation or resilience measures was not scored positively for direct A&R, even though it has a positive impact on indirect A&R by enhancing adaptive capacity more broadly. By scoring policies for both direct and indirect A&R impacts, we recognize that climate A&R extends beyond physical adaptation actions and intersects with social, political, economic and environmental resilience[60,61]. Supplementary Table 9 outlines all policy archetypes with a positive score for either direct or indirect climate A&R, while a literature review and justification for each score is provided in ref. 20.

Policy archetypes that are not expected to have a positive impact on direct or indirect A&R were treated in two ways. Policies that have little relevance to climate A&R were scored as neutral (0). For example, general tax cuts and interest rate reductions do not contribute to direct climate adaptation, and their short-term nature means that any savings they create for individuals or businesses do not contribute to climate resilience by building adaptive capacity. Some policies were scored as neutral for climate A&R because their impacts are limited to the COVID-19 pandemic. For instance, the provision of basic needs (shelter, food, social services), if secured beyond the pandemic, would contribute to adaptive capacity. However, short-term provision of basic needs, delimited to the pandemic, were scored as having a neutral climate A&R impact.

By contrast, policies that entail 'lock in' of non-resilient infrastructure or promote maladaptation were scored as having a negative climate A&R impact. For example, spending on general transportation, energy and urban development infrastructure without regard to resilience is likely to result in 'lock in', whereby assets with long lifespans are maladapted to changing and uncertain local climate conditions[26]. There are a few exceptions, whereby infrastructural policies that are non-resilient are counterbalanced by the positive adaptation and resilience impacts of that archetype. For example, education and healthcare infrastructure constructed without regard for resilience may have lock-in potential; however, these impacts are counterbalanced by the adaptive capacity benefits of strengthening education and healthcare facilities, resulting in a neutral score. We did not score any liquidity policies negatively, as we do not expect this short-term funding to result in long-term infrastructure investments with lock-in potential.

Policies that are positive from a mitigation standpoint, such as the construction of renewable energy infrastructure, without consideration of infrastructure resilience, are not always positive for climate A&R. In terms of indirect A&R, clean energy infrastructure provides sustainable jobs and enhances access to energy, both of which are crucial to adaptive capacity[24]. However, these positive impacts are outweighed by the vulnerability of these facilities to future climate impacts if the new infrastructure is constructed without resilience in mind[62,63]. On balance, these policies are thus expected to have a potential negative impact on indirect climate A&R, despite their positive impact on mitigation.

We recognize the distinction in the literature among the three dimensions of resilience: absorptive capacity, adaptive capacity and transformative capacity[64]. However, we did not score policy archetypes for their distinct impacts on each of these dimensions. As ref. 64 highlights, specific interventions are likely to have impacts on multiple dimensions, depending on the intensity of the disturbance and the time of exposure. Policies tend to vary widely on these dimensions for any given subarchetype, such that it would appear misleading to score a policy archetype for a specific dimension.

The CRAFT framework includes 42 archetypes and 293 subarchetypes. This represents a step forward in granularity of taxonomies for assessment of adaptation and resilience impacts of policy interventions. The European Union's taxonomy for sustainable economic activities incorporates only 88 policy types, while the UNDRR's Budget Tagging guide for Disaster Risk Reduction and Climate Change Adaptation classifies activities into 20 'broad areas', further broken down into 77 'action areas'. CRAFT therefore offers more specificity in its assessments than existing approaches. Nonetheless, a taxonomic approach can never replace the specificity of individual policy-level impact assessments; necessarily, there will be variation in the types of interventions assigned to specific categories. For example, even within the subarchetype of agricultural investment with A&R conditions, there will probably be variation in the extent of impact of individual policies that cannot be captured through our Likert-scale assessments of positive, neutral and negative direct and indirect A&R impacts. Only impact evaluations at the policy level can truly capture the potential impact of specific policies on A&R; however, this is not always feasible for policymakers or researchers. A taxonomic approach thus enables an approximate assessment that is scalable, feasible and replicable. While there is likely to be some variation in policy impacts within subarchetypes, CRAFT offers a higher level of granularity than existing assessment approaches, thus offering useful insights for policymakers and researchers alike.

The new policy taxonomy developed for assessing potential A&R impacts was applied to the GRO database[11]. The GRO database records all fiscal policies implemented by 88 countries over the period of March 2020 to December 2021. Each policy is assigned to a subarchetype and thus takes on the direct and indirect A&R scores, which are implemented at the subarchetype level. Policy names, descriptions, local currency amount (and US$ equivalent) and several other fields are captured for each policy, enabling aggregations at the country and archetype level.

To test the validity of the taxonomy for the GRO, we conducted a robustness check for a subset of policies per archetype. We manually reviewed 4,459 policies out of a total set of 8,037 policies to ensure a 95% confidence interval at 5% margin of error for every archetype. The sample was randomly selected per archetype, with a minimum of 10 policies selected per subarchetype (unless the subarchetype contained less than 10 policies, in which case we reviewed every policy) to ensure coverage of all subarchetypes. For each selected policy, we evaluated whether the direct and indirect A&R scores assigned at the subarchetype level fit the policy description, examining the source documents where clarification was required. We assigned a confidence rating of 'High' where the percentage of inconsistencies in the random sample was between 0–10%, 'Medium' for 10–20% and 'Low' for 20–100%. We found that 97% of total spending and 96% of recovery spending were associated with archetypes with fewer than 20% scoring inconsistencies (medium to high confidence) (Extended Data Table 2). We also found that 93% of all archetypes and 94% of recovery archetypes were identified as having a medium to high confidence rating. We report our results as a range, with the lower bound referring to high and medium confidence subarchetypes only, and the upper bound including subarchetypes of all confidence levels, except where all policies are high and medium confidence, in which case only one figure is reported.

In analysing the GRO data, we also evaluated correlations between A&R spending, country income levels and the vulnerability indicators developed by the ND-GAIN[32]. ND-GAIN defines vulnerability as the 'propensity or predisposition of human societies to be negatively impacted by climate hazards'[32]. This vulnerability index is a compound measure of exposure, sensitivity and adaptive capacity. Exposure is defined as 'the physical factors external to the system that contribute to vulnerability'. Sensitivity is the 'extent to which a country is dependent upon a sector negatively affected by climate hazard, or the proportion of the population particularly susceptible to a climate change hazard'. Adaptive capacity indicates the 'availability of social resources for sector-specific adaptation', which can include sustainable adaptation solutions[32]. We extracted the indicators for our 88 studied countries for the year 2020. We also extracted World Bank[31] data for country income levels (GDP per capita and GNI per capita) for 2020.

A&R versus mitigation themes in core policy documents

To assess how A&R themes feature in broader policy planning, we first identified a set of 78 core policy papers (Supplementary Table 8) that were framed as plans for economic recovery, covering 11 of the G20 countries (that is, all those with policy documents published in English). The policy paper corpus was selected from source documents provided by the GRO, supplemented by key-term database searches to add missing budget documents. We analysed the English corpus for text related to A&R and climate mitigation using a climate dictionary expanded from previous papers with techniques in deep learning. The corpus was limited to English documents as vocabularies differ considerably across languages; we leave this exercise to be repeated by future works in other languages, but do not expect the direction of the results to change.

Creating bespoke dictionaries for NLP analysis is notoriously difficult[45,65]. The objective is to identify a complete set of terms that are broad enough to capture all mentions of a particular theme but precise enough to exclude irrelevant themes. One method for dictionary creation involves surveying subject matter experts, but experts are prone to missing important terms[45,65,66]. Supervised and active unsupervised methods both offer useful advances[44,67], but previous applications struggle to fully address the limits of setting an appropriate starting dictionary. Reference [68] build on ref. 66 to demonstrate a classification approach that iteratively identifies keywords relevant to the emergent themes of a prescribed document set. In our case, where A&R is often a very minor theme in the policy documents and the corpus is small, the classification approach is unlikely to generate substantial additional terms. Instead of a classifier approach, we adopted the method of ref. 45 to iteratively expand a starting dictionary on the basis of embedding models of the target corpus itself; this is a similar method to the later work of ref. 69. The dictionary expansion process began with the full set of policy papers. From these papers, terms (words, bigrams and trigrams) were embedded using the 'word2vec' neural network model, resulting in three separate 100-dimensional embedding spaces. In each space, every term (1:n) was combined with every other term, resulting in a total of n factorial possible term pairs. The vectorized positions of each pair were then averaged and the term closest to this average position was added to the dictionary. An initial set of vectorized A&R terms served as a starting point for this search.

Once added, these new terms were manually reviewed. This procedure was iteratively performed until no additional terms emerged. Similar to the classifier approach, the method is somewhat limited by the low overall prevalence of A&R discussion in the policy paper corpus (topic model available in Supplementary Information; also see Extended Data Figs. 2 and 3).

As an alternative approach to dictionary building, we experimented with deep learning BERT[70], expanding and categorizing lists of climate A&R and mitigation terms sourced from ref. 45. The transformer architecture is unique in its use of self-attention to differentially weight the significance of input data, processing an entire input simultaneously rather than sequentially. This allows for better contextual learning than previous approaches such as Recurrent Neural Networks[71]. BERT is the preeminent transformer model, pretrained on a corpus of 3.3 billion words to understand how English words relate to each other. It learns a target word's meaning on the basis of the full sentence in which it occurs, whereas a popular alternative, Generative Pretrained Transformers, learns meaning from words that occur only earlier in a sentence than the target word. BERT has been applied to countless topics, including climate mitigation issues (see ClimateBert in the study of refs. 72,73 on electric vehicles), but not, so far as we know, to questions of climate A&R.

We used BERT to identify terms relevant to concepts of climate A&R and mitigation, supplementing language from ref. 45 and that provided by experts. To do so, we fine-tuned a BERT model using policy names and descriptions provided by the GRO dataset of ~8,000 COVID-19 fiscal policies. The model was subsequently trained to identify fiscal provisions that supported direct and indirect adaptation on the basis of policy titles and descriptions. The trained model was then applied to the policy document corpus to identify language consistent with strong climate A&R and mitigation. A subset of selected clauses was manually reviewed to identify new terms for the base dictionary. Dictionary terms were categorized into those that support adaptation, mitigation and both/unclear using the climate A&R taxonomy impact assessment matrix, CRAFT[20]. The full dictionary and categorizations are included in Supplementary Table 10, and Extended Data Figs. 2 and 3.

Applying the BERT-supplemented dictionaries, we used basic NLP techniques and manual sorting to categorize all 124,593 clauses in the 78 policy papers into those that pertained to topics of general climate, climate mitigation, climate A&R, other forms of A&R and other. Table 2 provides a preliminary statistical account of term usage across the policy papers. These results are helpful for direct comparisons within a country or proportional comparisons between countries. They are unsuitable for direct comparisons between countries as the typology of policy documents vary considerably. Recorded mentions of non-climate A&R are likely to underestimate usage as the dictionaries were developed to target climate topics.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

For Climate Resilience and Adaptation Financing Taxonomy (CRAFT), the taxonomy and literature review providing justification for each of the direct and indirect A&R scores can be accessed at https://doi.org/10.6084/m9.figshare.21598779.v3 (ref. 20). The Global Recovery Observatory dataset (that is, COVID-19 spending data) can be accessed at https://figshare.com/s/ddb3c8e7a9e7ae7bd3ab (ref. 11).

Code availability

Descriptive and statistical analyses were completed in Excel and MATLAB using basic custom code, which will be made available following publication of other studies reliant on this code.

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Author contributions

The study was conceived and designed by A.S., B.O'C. and N.R. Data analysis was conducted by A.S., B.O'C., N.R. and F.M., and results were also discussed with S.F. The writing of the paper was led by A.S., B.O'C. and N.R., with revisions and edits provided by S.F. and F.M.

Competing interests

The authors declare no competing interests.

Additional information

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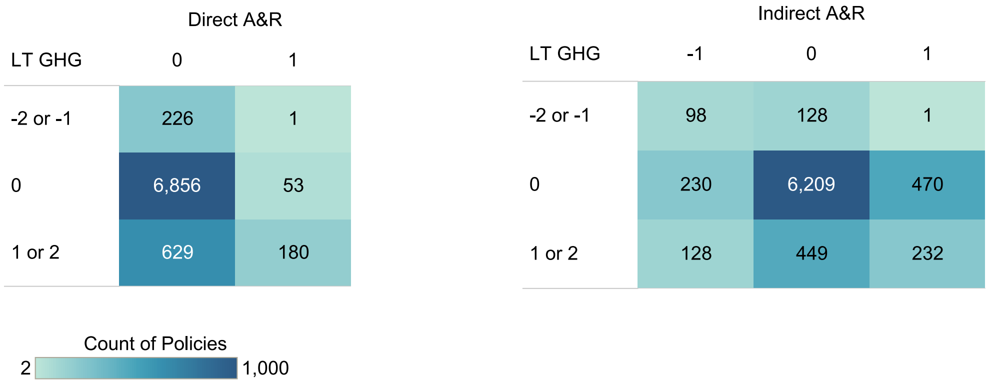
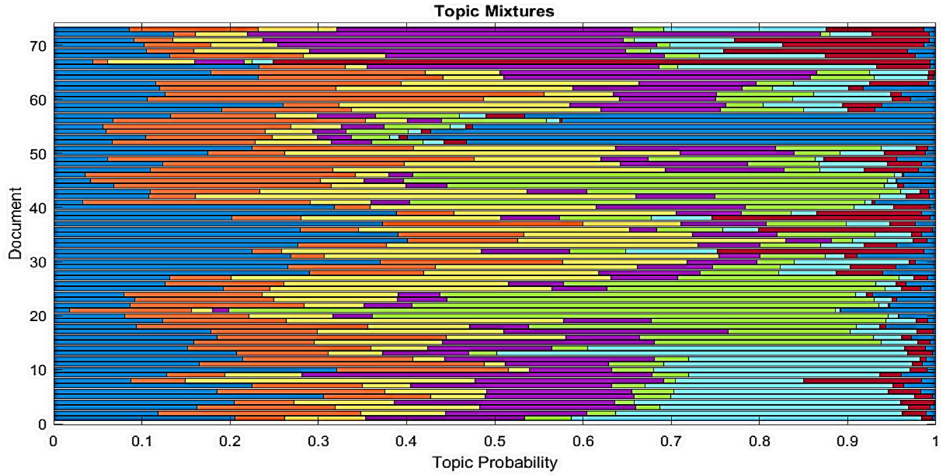


Extended Data Fig. 1 | Count of policies scored negative, neutral, or positive for climate mitigation and climate A&R (direct and indirect). Policies in the Global Recovery Observatory were scored on a 5-point Likert scale for their potential impact on short-term and long-term greenhouse gas emissions (GHG), and scored on a 3-point Likert scale for their potential impact on direct and indirect A&R. Policies are counted according to their potential long-term GHG and direct (left) and indirect (right) A&R impacts.

Extended Data Fig. 2 | Naturally emerging topics in policy paper corpus. Naturally emerging topics in policy paper corpus using lda modelling, 8 topics, a word concentration of 10, preprocessing, and no lemmatisation.

https://doi.org/10.1038/s41893-024-01269-y



Extended Data Fig. 3 | Spread of topics across the policy paper corpus.

https://doi.org/10.1038/s41893-024-01269-y

Extended Data Table 1 | Comparison of A&R spending to climate adaptation characteristics by national income quintile

Income Quintile (GNI per capita)	Average total A&R-positive spending (USD, bn)	Average % A&R-positive spending out of total spending	Average vulnerability score	Average exposure score	Average adaptive capacity score	Average readiness score
0-20	1.5	3.8%	0.49	0.46	0.61	0.31
80-100	41.0	5.5%	0.31	0.41	0.25	0.69

Adaptation index scores from ND-GAIN; lower scores for vulnerability, exposure, and adaptive capacity are better, while higher scores for readiness are better. Only top and bottom quintiles displayed. Only countries with A&R spending > 0% were included in calculations. Further details provided in the Supplementary Information (Table 7).

 https://doi.org/10.1038/s41893-024-01269-y

Extended Data Table 2 | Results of robustness test, by number and value of archetypes

Spending Phase	Confidence Rating	Threshold	Number of archetypes (% archetypes)	Value of archetypes (% spending)
Rescue	High	<10%	82 (87%)	11,502 (96%)
	Medium	10-20%	3 (3%)	26 (0.2%)
	Low	>20%	9 (10%)	397 (3%)
Recovery	High	<10%	120 (87%)	2620 (87%)
	Medium	10-20%	10 (7%)	265 (9%)
	Low	>20%	8 (6%)	127 (4%)
Total	High	<10%	203 (87%)	16,663 (95%)
	Medium	10-20%	13 (6%)	291 (2%)
	Low	>20%	17 (7%)	524 (3%)

Not all archetypes received a confidence rating, as some archetypes (n=60) had no allocated policies. Percentage figures are therefore calculated as the number of subarchetypes assigned to a given confidence level, as a proportion of the total number of subarchetypes for that spending phase (for example 120 subarchetypes had high confidence out of 138 recovery subarchetypes, resulting in 87% of all recovery archetypes having high confidence).

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Software and code

Policy information about availability of computer code

Data collection	All COVID-19 spending data was previously collected by O'Callaghan (2023) (see Data section below). COVID-19 policy documents were identified using the "source" field in the data of O'Callaghan (2023) and supplemented, when necessary, with systematic desktop research. Text extraction was completed using basic MATLAB R2022b functions for querying web pages, like "urlwrite" and for importing text data, like file data stores ("fds").
Data analysis	Figures of country spending were created in Tableau 2021.4. Descriptive and statistical analyses were completed in excel and MATLAB R2022b using basic custom code. Topic modelling was completed with MATLAB's fit latent Dirichlet allocation (LDA) model ("fitlda") and visualised with custom code and the "wordcloud" function. The MATLAB pretrained BERT transformer model was fine-tuned using data from O'Callaghan (2022) and toolboxes including the Deep Learning Toolbox and the Text Analytics Toolbox. Dictionary terms were embedded from policy papers using the word2vec neural network model. Pre- and post-processing was completed with basic MATLAB text analysis functions. Statistical analyses within the corpus was completed with MATLAB natural language processing functions and custom code.

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Climate Change Adaptation and Resilience Scores: The full taxonomy and literature review providing justification for each of the direct and indirect A&R scores can be accessed at: https://doi.org/10.6084/m9.figshare.21598779.v3
Global Recovery Observatory: The Global Recovery Observatory dataset (i.e. COVID-19 spending data) can be accessed at: https://figshare.com/s/ddb3c8e7a9e7ae7bd3ab

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	Not applicable. Information on sex and gender has not been collected or reported on.
Population characteristics	Not applicable. No primary data was collected from participants, thus no population characteristics were reported on.
Recruitment	Not applicable. No primary data was collected from participants, thus recruitment was not required.
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Study description	We use quantitative data from the Global Recovery Observatory (GRO), a policy database developed by the Smith School of Enterprise and the Environment at the University of Oxford, which tracked approximately 8,000 COVID-19 fiscal policies in 88 countries from March 2020 to December 2021.
Research sample	We use quantitative data from the Global Recovery Observatory (GRO), a policy database developed by the Smith School of Enterprise and the Environment at the University of Oxford, which tracked approximately 8,000 COVID-19 fiscal policies in 88 countries from March 2020 to December 2021. We analysed the entire set of policies, so sampling is not applicable in this context. For the natural language processing analysis, we identified all English-based policy documents that were included in the GRO database.
Sampling strategy	We use quantitative data from the Global Recovery Observatory (GRO), a policy database developed by the Smith School of Enterprise and the Environment at the University of Oxford, which tracked approximately 8,000 COVID-19 fiscal policies in 88 countries from March 2020 to December 2021. We analysed the entire set of policies, so sampling is not applicable in this context.
Data collection	We use quantitative data from the Global Recovery Observatory (GRO), a policy database developed by the Smith School of Enterprise and the Environment at the University of Oxford, which tracked approximately 8,000 COVID-19 fiscal policies in 88 countries from March 2020 to December 2021. The data is publicly available, so the data collection process for this study involved accessing the publicly available spreadsheet of recorded policies. All 8,000 policies were analysed for this study.
Timing	We use quantitative data from the Global Recovery Observatory (GRO), a policy database developed by the Smith School of Enterprise and the Environment at the University of Oxford, which tracked approximately 8,000 COVID-19 fiscal policies in 88 countries from March 2020 to December 2021.
Data exclusions	No data were excluded from the analysis.

Non-participation	Not applicable; data was secondary quantitative data on COVID-19 fiscal policies from the Global Recovery Observatory. No participants were involved in the study.
Randomization	Not applicable; data was secondary quantitative data on COVID-19 fiscal policies from the Global Recovery Observatory. We analysed all 8,000 policies included in the dataset, so randomization was not used in our primary analysis. We conducted a robustness check to ensure the validity of our Climate Resilience and Adaptation Financing Taxonomy (CRAFT) framework for use with the GRO. For the robustness check, we randomly selected at least 10 policies per subarchetype, ensuring a 95% confidence interval at 5% margin of error for every archetype. For each randomly selected policy, we manually reviewed whether the taxonomy score assigned at the subarchetype level was valid by reviewing the policy description and, where necessary, the source documentation.

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