



Uncertainty: A Trigger towards Transformative Policies and Innovation

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Uncertainty: A Trigger towards Transformative Policies and Innovation

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Abstract

The COVID-19 crisis has shifted our world in ways that disrupted the normal functioning of day-to-day practices, and as a consequence, there remain many uncertainties on how the pandemic will shape policies and innovation systems for many years. This paper is concerned with the nexus of complexity and transformation within a policy context, particularly in a post-COVID-19 world. The paper provides empirical examples of the consequences of the pandemic, which includes poverty, inequality, health, and global trade. We provide evidence that COVID-19 has shifted the socio-economic conditions in ways that push more people vulnerable towards poverty, balancing the consequences between the risk of infection versus daily livelihood. Given the urgency of policy responses, the tendency for policymakers has been to rely on 'evidence base' science, to guide action, and reduce the complexity towards quantifiable possibilities. Although techno-managerial approaches are important, they tend to be reductionist in their approach, the benefits of which are limited because the measures border on systems optimisation at best, and at worse, leave a system vulnerable to the next crisis. Therefore, this paper makes the case that rethinking existing policies or new forms of transformative innovation policy approaches are needed. Here we argue that transformative innovation policies could be one of the ways in which policies have an impact on triggering systems changes, such that it addresses issues on the underlying causes of inequality and vulnerability, and ultimately changes towards achieving socio-economic goals that are inclusive, resilient and sustainable.

Keywords: transformative innovation, sustainable development goals, complexity and uncertainty

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1. Introduction

The COVID-19 pandemic has disrupted the normal functioning of innovation systems, endangering key productive and innovation capabilities with lingering uncertainty about its immediate and long-term impacts (OECD, 2021). During these times of crisis, an inevitable narrowing down of solutions to evidence base responses to guiding actions by governments is appealing. Such narrowing down appears to be the dominant approach to policy formulation and implementation. However, in narrowing down solutions, an inherent tendency exists to privilege prediction and technocratic solutions over other possibilities in, for example, surveillance and data gathering, epidemiological modelling, and scenario planning (MacGregor, et al., 2020). A lack of certainty creates particular discomfort among policymakers. Though, failing to embrace an inherently complex and uncertain world reduces policies to only those that address calculable risks (Naidoo, 2020; Scoones & Stirling, 2020) and masks the implicit assumptions that may prove problematic in the long term (Naidoo, 2020). A fallacy thus becomes evident: that policymakers can control the uncertainties purely by appropriate policy choices. Moreover, some scholars suggest that choices associated with both social and technical innovation are not neutral but are accompanied by certain ideas, preferences, values, and interests (Chataway, et al., 2014; Schot & Steinmueller, 2018). These fallacies and polarised contexts potentially obscure the meaningful influence of policies on society, particularly policies that actively respond to multiple uncertainties and systemic changes. Policies that, by design and impact, are transformative and systemic in nature.

The tendency to narrow down policies is also reflected in the linear assumptions between innovation and development. For example, while some innovation leads to socio-economic development, there are also instances where innovation contributes to exacerbating poverty and inequality. The socio-economic impacts of such duality are that innovation may disadvantage the less well-off and marginalised groups. This, in turn, contributes to reinforcing poverty and inequality because of their exclusion from the benefits of socio-technical change (Chataway, et al., 2014; UNCTAD, 2017). For example, as South Africa turns policy attention towards the fourth industrial revolution (4IR), there are some concerns about affordable access to data, highlighting the digital divide (Ting, 2021). Moreover, some scholars have started to analyse the role of transformative innovation in realising systemic changes of nomadic education in Kenya, online learning in Senegal, and the circular economy of e-waste in Ghana (Daniels & Ting, 2019).

This paper is concerned with the nexus of complexity and transformation within a policy context, particularly in a post-COVID-19 world. More specifically, our paper focuses on the need to explore transformative policies in an uncertain world amidst the global pandemic.

First, we analyse some of the consequences of the pandemic relative to issues such as poverty, trade, and health, highlighting the new kinds of issues confronting the scientific and research community. The paper specifically calls for revisiting and reorienting national policy frameworks towards systems change during the recovery period. Here, national policies could be directed towards transformative change (Schot & Steinmueller, 2018),

which is cognisant of inclusion, resilience, and sustainable development. To do so, a suggestion using transformative institutional outcomes that leads to systems change is discussed. Institutional outcomes such as layering, conversion, and displacement, as forms of cumulative incremental shifts towards system change, are discussed (Ting, 2020). These different types of institutional outcomes illustrate that changes may not necessarily be wholesale but can be achieved stepwise, escalating over time. The implication this has on policymakers is that if transformative changes were to be achieved post-COVID-19, using the various institutional outcomes could be one of the ways to do so.

This paper will make the case that unpredictable and uncertain moments, such as COVID-19 and climate disasters, highlight the need for transformative policies focused on systemic outcomes. We argue that policymakers need to embrace complexity, particularly amidst growing global uncertainties. Moreover, the pandemic has intensified the vulnerability of some parts of society due to the widening inequality gap and exacerbated poverty. Thus, we further highlight that existing policies need a reform during the recovery period from the pandemic, which leads to a trigger in systemic and institutional changes. In turn, these transformative changes could accelerate achieving socio-economic goals that are inclusive, resilient, and sustainable.

2. Embracing uncertainty

The pandemic has heightened the vulnerability of some parts of society due to deep-rooted inequalities, which has implications on access to the benefit of technological innovation. Hence, during these uncertain times, fundamental questions are being asked on the adequacy and the inclusiveness of the current socio-technical system to deliver on societal needs. Amidst the COVID-19 crisis, many uncertainties remain that will shape research and innovation systems and the extent to which these systems can help solve societies' grand challenges. Some impacts on the scientific and research community, including further opening up access to data and publications, increased the use of digital tools, enhanced international collaboration, spurred a variety of public-private partnerships, and encouraged the active engagement of new players (OECD, 2021). In the longer term, these developments could accelerate the transition to a more open science and innovation. In the long run, the COVID-19 pandemic presents several significant uncertainties for the future. These can include; (1) the value society assigns to sustainability, inclusivity, and resilience in shaping futures, but also to the role governments should play in supporting those futures, and; (2) social preferences on the importance of inclusive economic and societal outcomes, which may fundamentally change and affect the inclusiveness of innovation processes (OECD, 2021).

Considering these uncertainties, it is necessary to appreciate the complexity and uncertainty that the pandemic has highlighted. In modern society, there are interlinkages between environmental, social, political, and economic systems, which drive the delivery of goods and services. Thus, there is an increasing reliance on interrelated complex systems. For example, in cities, there are interconnections of the provision of energy, mobility, food, health, and financial systems. Inherently, such interrelated systems become vulnerable to

systemic threats, where disruption or stress in one area could prompt cascading damages in another. These systemic threats could be rapid and abrupt shocks or small changes with gradual stress that add up to a major disruption over time (Linkov, et al., 2019). Both threats are often considered difficult to model, and mitigation is usually reduced to a risk-based approach. Here, the philosophy is to prevent, resist, or mitigate the implications of the threats, maintaining the leanest possible operations through efficiency, which ultimately leads to a response that is, at best, system optimisation (Linkov, et al., 2019).

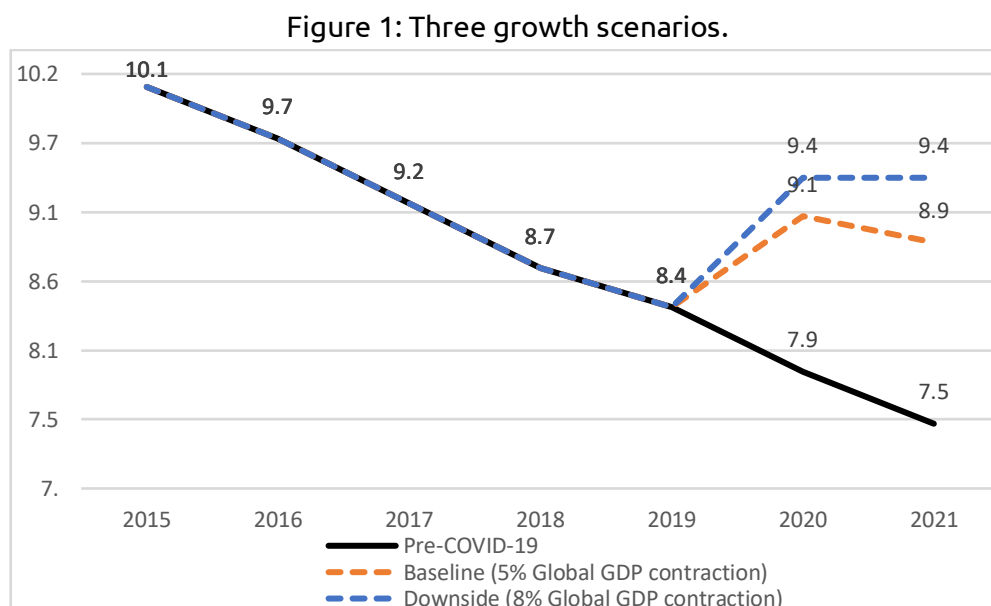
Moreover, minimising risks is often reduced to techno-managerial solutions, mostly placing a privilege on scientific and statistical models, quantifying probabilities, and limiting decisions within a specified timeframe (Mehta, 2020). Top-down approaches can be inadequate in the face of local social dynamics and are often criticised for being short-sighted because, in reality, risks are difficult to predict, measure, or wholly understand and could leave the system susceptible to future disruptions (Linkov, et al., 2019; Mehta, 2020). As an example, where bottom-up approaches became relevant, a group in Delhi, India, that was addressing the implication of toxic pollution in their community. Here transformative change required the use of citizen science, strategic alliances, and negotiation between the state and business. There was a focus on social innovation in ways that focused on political openings to challenge incumbent interests and prevailing politics (Scoones, et al., 2020).

The main point to emphasise is that complexity, presented not only during the time of COVID-19 but also in connection with other systemic threats such as climate change, requires new approaches and new solutions that embrace rather than reduce uncertainty. Thus, Ramos and Hynes (2020) have suggested accepting uncertainty, and even stochastic systemic threats, where disruptions such as climate change or pandemics are likely to compound consequences of impact as the norm. This view could be comparable to seeing systems as in continuous flux, such as a disequilibrium, where an optimum is not reached, and stability is an anomaly (Mahoney & Thelen, 2010; Ting, 2020). In this perspective, a resilience based approach is necessary, where system weaknesses are identified, and the capabilities to absorb, recover, and adapt to the system threats are emphasised. In this way, the approach is “threat agnostic”, in that threats are inherent to the properties of a system (Linkov, et al., 2019, p. 3). Moreover, the system can respond beyond survival towards improvement through broader systemic changes, which can lead to resilience (Linkov, et al., 2019; Ramos & Hynes, 2020).

Putting these academic views into context, the next section turns to the COVID-19 pandemic – which highlights deep systemic complexities that have had far-reaching consequences and revealed the lack of resilience, but also the creative innovations that challenges bring. The paper now turns its attention to some examples of the consequences of the pandemic, discussing issues related to poverty, health, and global trade. These examples are provided as a way to highlight the new kinds of issues that policymakers need to address to adjust to the ‘new normal’ reality amidst the ongoing pandemic.

3. Poverty and inequality implications from COVID-19

Due to COVID-19, the World Bank Global Economic prospects reported that it is likely that the global GDP would contract by 5%, which is one of the worst economic recessions since the Second World War (World Bank, 2020). Faced with this daunting outlook, policymakers are having to respond to multi-dimensional aspects of socio-economic security and recovery. These include health care, macroeconomy, trade, digital connectivity, and inclusive growth, amongst others. A study by Lakner, et al. (2020) reported a reversal in gains against poverty and inequality. Using a global GDP contraction of 5% and 8%, the estimates are that the COVID-19 pandemic is likely to push more than 80 and 100 million people, respectively, into extreme poverty¹, intensifying to as many as 150 million by 2021. Lakner, et al. (2020) has reported that these figures are attributed to an increase in global poverty by more than 1% compared to pre-COVID-19 data (see Figure 1 below). Moreover, the projected estimates are similar to 2017; hence, the impacts of COVID-19 are expected to reverse development towards ending extreme poverty by a minimum of three years.



Source: Lakner, et al. (2020).

Notes: (1) Pre-COVID-19: data from the Global Economic Prospects growth rate projections; (2) Baseline: a predicted 5% GDP contraction and (3) Downside: worst-case scenario of 8% GDP decline.

The UN Economic Commission for Africa (UNECA) has reported similar figures for the continent, where up to 29 million could be further pushed into poverty. Furthermore, Africa's labour force is mostly concentrated in the informal economy (85% of the workforce)², making social distancing and strict quarantine rules a challenging endeavour (UNECA, 2020, p. 14). An inevitable reality is that prolonged lockdown measures force household earners to choose between their health and their livelihood.

¹ Measured using the international poverty line of \$1.90/day.

² ILO, 2018: "Women and men in the informal economy: A statistical picture".

3.1. Pushing people into poverty – the new poor

According to the study conducted by Lakner, et al. (2020), policy options would need to be cognisant of the changing profiles of poverty and vulnerability in what is termed the “new poor” (World Bank, 2020, p. 121). There is evidence to suggest that those who are economically less well-off (e.g. higher dependence on daily income) are most vulnerable to the pandemic since their nature of work (e.g. labour-intensive manufacturing, retails, and restaurants) is less compatible with social distancing and working remotely. The new poor are said to include communities living in middle-income countries, who tend to live in congested informal urban areas and are employed in the non-agriculture sector (e.g. manufacturing, services, and commerce sectors) (World Bank, 2020). Thus, governments are now faced with the task of new kinds of policy options, which require a more nuanced target of vulnerable communities. Specifically, this means protecting households in both existing poorer groups and those which have been pushed into poverty due to the pandemic, living in informal urban areas.

4. Trade implications

The World Trade Organization (WTO) has projected that a decline in world trade of more than 10% to 30% is likely due to the consequence of COVID-19.³ A decline in trade can potentially be detrimental to sub-Saharan economies because most countries are reliant on both industrial inputs and outputs from global trade. As an example, the pharmaceutical trade has been severely disrupted during the pandemic, such that a brief delay in the availability of antiretroviral drugs (ARV) is likely to increase new infections. Moreover, it has been estimated that a six-month delay in ARV production could lead to half a million HIV deaths over the one-year timeframe (Davids, et al., 2020).

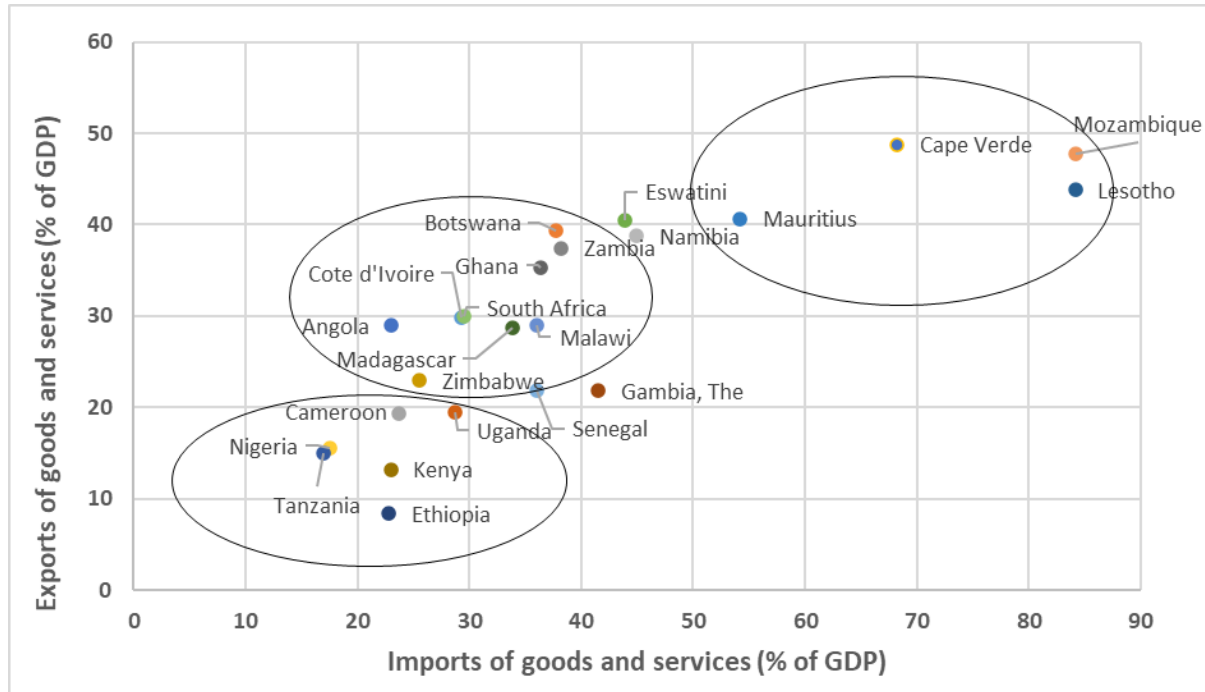
There are primarily three concerns for sub-Saharan Africa (SSA) countries because of a decline in world trade. Firstly, this includes a decrease in both domestic sales and African exports due to a decline in production and a shortage of supplies (Hartwich & Hedeshi, 2020; Kassa, 2020). Moreover, many micro and small enterprises will be under severe strain, leading to income insecurity. Secondly, there will be disruption in global value chains (GVCs), leading to a curb in production in export-oriented sectors. Lastly, trade partners have a significant role to play in foreign direct investments (FDIs), leading to a fall in FDI flows (Kassa, 2020).

To illustrate these trade flows, it is worth noting that, in SSA countries, the share of imports and exports of goods and services as a percentage of GDP is around 30% (Figure 2 below). The lower the percentages in both exports and imports, the less the global trade participation and integration of a given country. Countries that are overly reliant on either export or import are highly imbalanced. For example, LDCs are mostly dependent on the exports of primary commodities, leading them vulnerable to a widening trade deficit under

³ WTO (2020) Trade falls steeply in first half of 2020, https://www.wto.org/english/news_e/pres20_e/pr858_e.htm

reduced global trade. Moreover, SSA is reliant on trade with a few countries, such as China, India, the Netherlands, the U.S, and South Africa.

Figure 2: Sub-Saharan African dependence on international trade, using exports and goods and services as a % of GDP.



Source: Hartwich & Hedeshi (2020).

To lessen the pandemic's effects in SSA, there is a need for both short- and longer-term measures. The former can include debt relief or subsidies to SMMEs, or support for continued employment of particularly women, who represent most of the labour in the informal sector (Hartwich & Hedeshi, 2020). For longer recovery measures, it is necessary to develop new kinds of business models such as circular manufacturing as well as infrastructure and skills that can handle future crises. One of the outcomes of the pandemic is that some countries move towards trade protectionism, e.g. the restriction of exports such as medicines, medical equipment, and essential food products, in order to maintain their own countries health and food security.⁴ Further, there are cases where developed countries are reshoring their production and manufacturing closer to home, reducing sourcing suppliers from distant places.

Thus, some developing countries could have reduced participation in GVCs, and even worse, this could lead to deindustrialisation (Hartwich & Isaksson, 2020). Domenech and Fokeer (2020) have called for a regional industrial revival through more integrated supply chains and circular manufacturing. They argued that a globalised production system has led to a disconnect between research, innovation, and manufacturing. Instead, they advocate for the development of research, design, and manufacturing as a co-evolution with local innovative networks, capacities, and needs (Domenech & Fokeer, 2020). They noted that

⁴ <https://www.weforum.org/agenda/2020/04/protectionism-africa-pandemic-coronavirus-covid19>

countries, where manufacturing is firmly entrenched in domestic and regional networks, can respond and be more flexible at times of uncertainty. For example, Turkey and China are using local manufacturing capacities to repurpose production for essential items such as personal protective equipment (PPEs), diagnostic equipment, and clinical care equipment.⁵ Therefore, a move away from linear manufacturing is an important part of recovery post-COVID-19, particularly if there is an emphasis on local capacity building and less reliance on a few trade partners or suppliers (Domenech & Fokeer, 2020; Kassa, 2020). Some demonstrated models already exist through eco-industrial parks, where collaboration is taking place between local capacities (private sector and local government), infrastructure, and exchange of materials (e.g. water, energy, waste). To do so, a rethinking of policies and regulation is needed to create conditions that go beyond optimising the status quo post-COVID-19 but one in which the change brings about a transformative manufacturing sector.

5. Health implications from COVID-19

The United Nations Economic Commission for Africa (UNECA) has indicated that a quarter of the continent's population lives in informal urban areas (UENCA, 2020, p.12). These households primarily contain the only bedroom with few accesses to potable water. Thus, with limited access to handwashing facilities, and a prevalence of overcrowding in informal areas, containment measures considering a pandemic become challenging. Added to this are underlying health conditions which are widespread, and these include tuberculosis, malaria, malnutrition, and HIV/AIDS, rendering communities vulnerable to an epidemic. Therefore, mitigating the virus in these conditions simply cannot be a wholesale lockdown approach but requires balancing the repercussions in both health and economic outcomes.

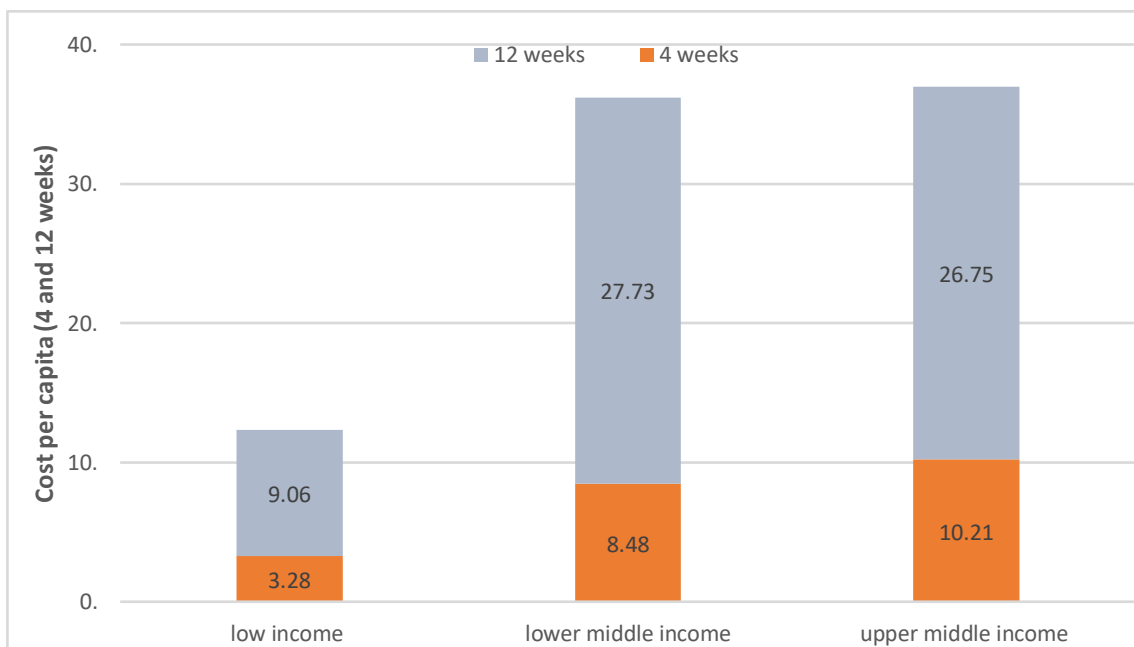
The impact of COVID-19 on Africa's health care system has demonstrated the stark inequality between access to quality primary care between the private and public systems. As an example, a study by Naidoo, et al. (2013) reported that there are 5000 intensive care unit (ICU) beds available in South Africa, of which 75% is derived from private hospitals. The implications of COVID-19 are additional stress in an overly burdened system. Moreover, there are already cases where the focus on COVID-19 has diverted attention away from delivering on other essential services, such as immunisation and non-communicable diseases (Davids, et al., 2020; Tan-Torres Edejer, et al., 2020). In South Africa, theatre admissions have been reduced, existing staff have been redeployed to manage the pandemic, and have delayed treatment such as hypertension and diabetes, which have a detrimental impact, particularly for low- and middle-income countries (Davids, et al., 2020). The question remains if there are additional resources that would attend to the current pandemic and perhaps strengthen the resilience of communities to handle future ones while simultaneously protecting and maintaining existing health services. At present, early response measures seem to reveal that existing resources are downscaled, redirected, or repurposed, given the urgency and broad scale of the crisis. However, what would be helpful is to ensure that countries are better able to respond to a future crisis, particularly attending to the more vulnerable, less-resourced groups of society.

⁵ <http://www.unido.or.jp/en/news/6936/>

To provide a more nuanced view of the kinds of capabilities needed to prepare and respond effectively to the pandemic, Tan-Torres Edejer, et al. (2020) conducted an epidemiological study of 73 low income and middle-income countries. These scholars had projected cost estimates according to nine pillars from WHO’s strategic preparedness and response plan (WHO, 2020). The study had noted that the epidemiological model had some limitations, given that projections for many countries are “fraught with uncertainty” (2020, p. 7), and therefore assumptions had to be made. To do so, the epidemiological model was restricted to shorter time frames (4 and 12 weeks), and the transmission rate had to be kept constant at different intervals.

Tan-Torres Edejer, et al. (2020) demonstrate that the major cost items to mitigate the pandemic were highly sensitive to the availability of human resources in the frontline, which are needed in case management, essential health services, surveillance, and rapid responses. The study has also shown that the typical costs in 4 weeks are between USD 3.28 per capita for low-income countries to USD 10.21 per capita for upper-middle-income countries. These costs escalate over time, as can be shown in 12 weeks (Figure 3 below). For comparison, WHO indicated that total health expenditure had ranged from USD 130 to USD 471 per capita for low- and middle-income countries, respectively, for 2017 (WHO, 2019). This would indicate that the budget required for mitigating COVID-19 is an additional burden to the healthcare system.

Figure 3: The cost per capita for COVID-19 response by country income group over 4 and 12 weeks.



Source: Tan-Torres Edejer, et al. (2020).

The study by Tan-Torres Edejer, et al. (2020) illustrates the difficulty in modelling scenarios that are unpredictable and with targets that are constantly moving. It is worth noting that using these kinds of quantitative methods is often limited to a specific period (4-12 weeks).

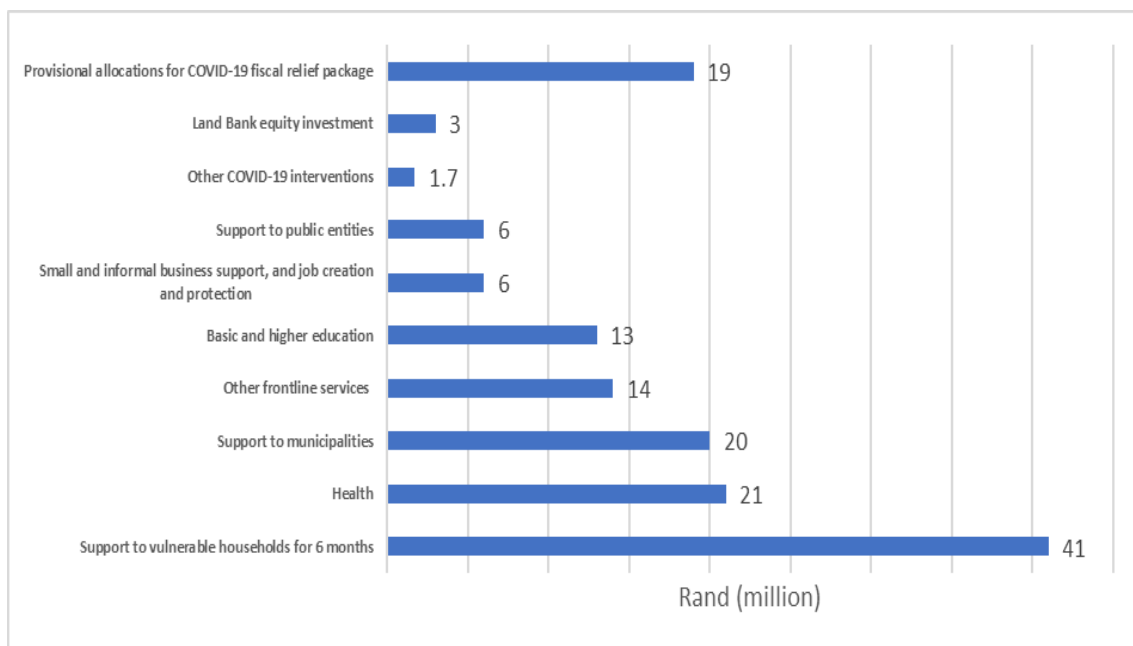
Nevertheless, governments continue to rely on this evidence base type of research to inform their strategic preparedness and response plans.

To illustrate the complexity of issues in which the government had to overcome during the early stages of the pandemic, Box 1 (below) analyses South Africa’s response to the COVID-19 pandemic, highlighting issues of fiscal constraints and the important socio-economic issues of balancing between lives and livelihoods.

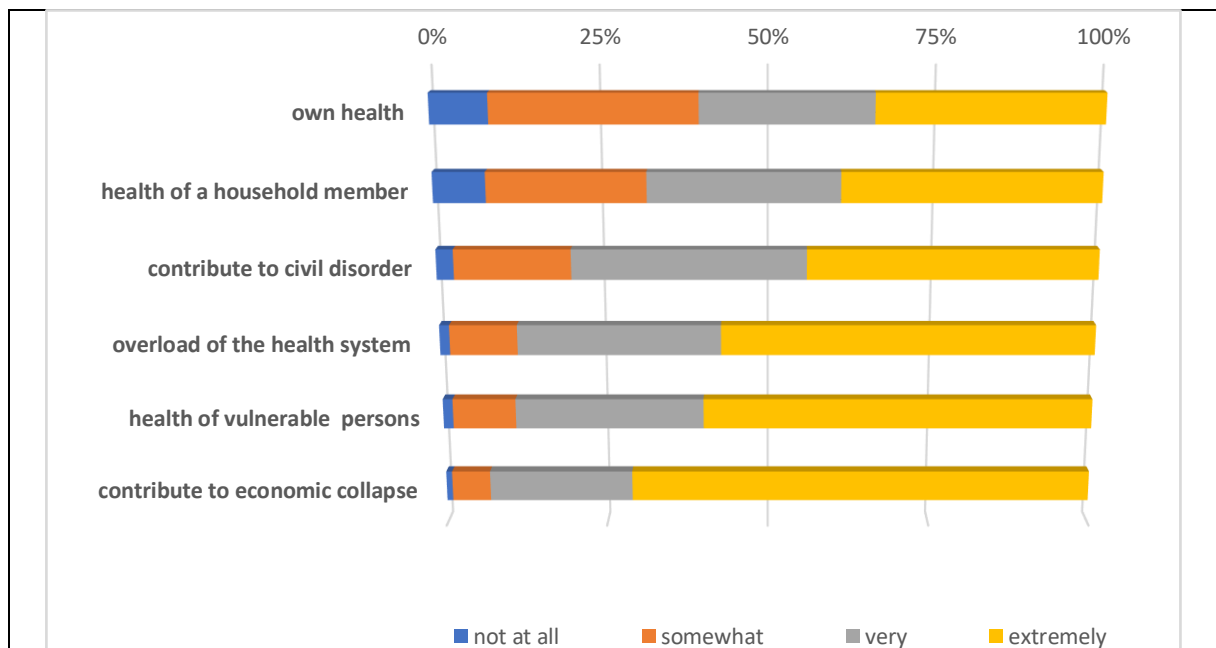
Box 1: South Africa’s response to the COVID-19 pandemic

South Africa’s response to the COVID-19 pandemic entailed a major reprioritisation of its fiscal budget. The National Treasury expects the economy to contract by 7%, placing the government with a difficult balance between essential public health measures (e.g. stringent lockdown) and potential economic implications (e.g. job losses, lower tax revenue, and higher poverty) (National Treasury, 2020). The country’s response is informed along with frontline functions focusing on health, peace and security, and social development. The National Treasury 2020 supplementary budget allocation prioritised support to vulnerable households, health, and support to municipalities (see Figure below).

It is worth noting that the National Treasury had indicated that the spread of COVID-19 remains uncertain, and therefore mitigation and treatment gives rise to complex decision making for business, government, investors, and households. In the interim, rapid surveys are used to inform policymakers of potential economic scenarios and socio-economic implications. However, more importantly, given the uncertainty, relying on future economic estimations is becoming “exceedingly difficult” (National Treasury, 2020).



Statistics South Africa conducted a rapid online survey (April 2020) to measure the impact of COVID-19 on households in the country (StatsSA, 2020). The survey revealed that respondents had greater concerns over the country’s economic collapse than the consequences of the health of the household members or a vulnerable person. Interestingly, the concerns also included civil disorder, indicative of coercive state measures such as enforcing strict lockdown measures, particularly in overcrowded informal settlements across the country (see Figure below).



While South Africa’s mitigation of the impacts of COVID-19 has included both social and economic measures, there are some scholars who have critiqued the lack of engagement from social scientists.⁶ Currently, the country’s ministerial advisory committee is mostly composed of medical doctors, public health scientists and pathologists. Conversely, Germany is one of the few countries that have included humanities scholars into the government’s circle of expert advice, i.e. philosophers, jurists and theologians. In this extended circle with a transdisciplinary perspective, Otfried Höffe, a professor in philosophy, advocated raising complex questions which could go unnoticed and provided the example that a lockdown strategy may provide governments with an opportunity to hoard power, which could result in executive overreach⁷ (i.e. crossing the line between protecting citizens versus eroding civic rights). Indeed, some of this executive overreach has started to manifest, with South Africa’s Minister of Health indicating that imposing strict regulations that limit citizens movement and behaviour is necessary beyond COVID-19.⁸ However, some arguments suggest that coercive measures are less effective than those which use ethical norms in society. In a highly unequal country, and with rising unemployment, the significance of socio-economic inequity becomes critical to the pandemic response. What can be learnt here is that we cannot simply narrow solutions into a technical fix; rather, we must open up the potential solutions towards embracing the complexity, particularly through transdisciplinary research, and use the crisis as a way to place countries in a better position to handle future contagions.

6. Transformative innovation policy

In this section, we now turn our attention to the new kinds of innovation policies that are applicable in addressing the post-COVID-19 reality. Policymakers are grappling with ideas on reorienting policy goals towards sustainability, inclusiveness, and resilience in the recovery period. This will require altogether different policy frameworks and practices, which deploy a range of novel and emerging frameworks and concepts. Some frameworks have been at the fringes of innovation policy for a decade or more but have yet to be

⁶ <https://www.universityworldnews.com/post.php?story=20200429090356725>

⁷ <https://www.leadersleague.com/en/news/germany-s-extended-circle-of-coronavirus-experts>

⁸ <https://www.news24.com/news24/southafrica/news/mkhize-wants-powers-to-restrict-citizens-behaviour-and-movements-beyond-a-state-of-disaster-20201014>

mainstreamed. The socio-technical transitions literature which emerged in sustainability research in the 2000s is a prominent example (OECD, 2021). More recently, the transformative policy, building on sustainability transitions, from Schot and Steinmueller, 2018 has begun to be developed. Here, an emerging research agenda called 'transformative innovation policy', an initiative between academics and policymakers, is finding new ways to frame innovation policies that are relevant to achieving the UN Sustainable Development Goals (Diercks, et al., 2019; Kuhlmann, 2018; Schot & Steinmueller, 2018). In this frame, instead of focusing on innovation policies that address market failure, the emphasis is on the quality of growth, specifically directed towards societal needs (Schot & Steinmueller, 2018).

Sustainable development is a crucial issue amongst this transformative innovation policy community, and there is a critical reflection on the role of current innovation policies, which may be the source of externalities such as climate change and exclusive economic growth.⁹ In some of the emerging studies, for example in Ghana's electronic waste sector, a broad range of actors is being consulted during policy formulation. These include e-waste collectors in the informal sector, scrap dealers, small scale entrepreneurs, amongst others (Quaye, et al., 2019a; Quaye, et al., 2019b). The broad participation reveals some conflicts and trade-offs, which the business as usual-approach does not raise (Daniels & Ting, 2019). This study has shown that the power dynamic between regulators, which dominate the policy space, versus the less powerful groups (e.g. beneficiaries) threatens the policy implementation because of a lack of buy-in from users (Daniels & Ting, 2019). There are also transformative policy cases in Kenya, where mobile schools have been introduced into the nomadic community (Ayisi, et al., 2019). At present, the norm is to deliver classes with inflexible classrooms, timings, and locations. However, mobile schools adapt to the nomadic community in ways that complement their way of life and economic livelihood (Ayisi, et al., 2019; Ndakala, et al., 2019). Here, the Kenyan case study has shown that transformative innovation policy may not necessarily be dominated by a focus on economic growth or national competitiveness. Instead, the emphasis is on a flourishing Kenyan society because mobile schools are having a positive impact on the nomadic community through improving peace, security and stability in the region (Ayisi, et al., 2019; Daniels & Ting, 2019). Moreover, this emphasis on policy outcomes other than economic gains justifies the relevance of diversity in values and capacities for change, which may often be overlooked or undervalued in traditional policy formulation. Another example is the establishment of a Virtual University of Senegal (UVS) as a way to address equitable and affordable higher education in the country. The UVS takes into consideration the population growth and rapid trends in ICT, which will require new ways of equipping students in the digital age (Daniels & Ting, 2019). The UVS system has several transformative implications, such as reduction of gender inequalities with access to education, and system-level impact, because of a strong emphasis on regional development, such as revitalising community development by ensuring that students are local agents for change (Cissé, et al., 2019; Diallo, et al., 2019).

In all three examples, transformative innovation policies contained elements of democratised policy formulation (broad participation of actors), inclusion (addressing

⁹ Transformative Innovation Policy Consortium (TIPC). <http://www.tipconsortium.net/>

issues of capacity and access), and social justice (addressing issues relative to vulnerable and marginalised groups). There is a growing understanding in this community that technological choices are not neutral, but instead, they are a socially driven co-evolutionary process. Moreover, sustainability transition scholars argue that a truly transformative innovation is achieved through broad systemic change in user practices, cultural meanings, industry structures, markets, policies, technologies, and supporting infrastructures (Geels & Schot, 2010). COVID-19, climate change, and biodiversity system collapse establish a new premise for transformative change – the need for urgent innovation imposed on society to respond to systemic vulnerabilities. In that way, uncertainty has offered a useful and important trigger to reconsider societal functions, which has the potential for inclusivity but also raises questions for societal rights and liberties in some instances.

Building on the transformative innovation community, the next section discusses suggestions for systems change during the recovery period of the pandemic. The motivation for a systems change is that the 'new normal' cannot go back to a socio-technical system that could be the source of reinforcing inequality, heightened vulnerability, and an even wider gap in access to the benefits of technological change. Instead, a system change must embrace issues of inclusion, resilience, and the broader agenda on sustainable development, as will be discussed in greater detail in the following.

7. Triggers for systemic changes

Different country and institutional responses to COVID-19 offer an important reflection on how societal triggers may contribute to essential systemic changes. COVID-19 responses differed vastly across the globe. The narrative of transformative innovation offers a useful basis for reframing complexity as a basis for triggering systemic change. Innovation and its influence on the newer field of sustainability transitions studies offer useful constructs for framing the basis and evolution of systemic changes. Specifically, technological advancements led to five successive revolutions between the 1770s to 2000s: each following a familiar pattern (Perez, 2002). Starting from 1771 in Britain with the industrial revolution, followed by steam and railways, then innovations in steel, electricity, and heavy engineering, which then led to oil, automobile, and mass production innovations. The last technological revolution revolved around information and telecommunications, which started in 1971. Though the information and telecommunications revolution is still rife, a parallel green and clean revolution represented by electric vehicles and renewable energy is also emerging (Mathews, 2015).

Perez's pattern for technological revolutions include periods of great excitement in the new technology described as "frenzy" at first when it becomes a direct contribution to real growth. As maturity sets in, the new technology begins to decouple from the economy and stagnate. Perez's framing of the technological revolutions also includes a useful provocation that systemic changes have certain characteristics. For example, there is a temporal nature to change; and it has a disruptive effect on the status quo. These characteristics of change are very important for understanding the requisite policy and financial response. The reality of the situation should thus determine the nature of the

response. The technological revolutions were largely voluntary and not mandatorily imposed or decided upon as a result of broader societal challenges. Innovation transformed how societies engaged with the economic mechanism, resulting in various technological improvements.

Paradoxically, the reality of COVID-19 and the growing evidence of climate change and biodiversity systems collapse coupled with deep social unrest represents a volatile and urgent social context for innovation to offer transformative and urgent solutions. The nature of innovation should be purposeful, with specific economic, social, and environmental outcomes. Within the sustainability transitions research community, a similar narrative is unfolding, focusing on the characteristics of transitions that allow for understanding what the requisite economic, social, and environmental responses should be. The field follows on the premise that modern societies consistently face structural challenges, many of which are attributable to unsustainable production and consumption problems. Historically, societies have responded by enabling innovation at the level of process and products, aimed at tweaking specific elements to derive cleaner options (Elzen, et al., 2004). However, such tweaks are inadequate to address the structural challenges of the present-day – of which COVID-19, climate change, energy transitions, and biodiversity systems collapse are but a few. Innovation needs to contribute directly to creating new ways in which society functions so that environmental and social outcomes are at the forefront of innovation. In addition, such societal shifts should fundamentally be just and inclusive, not perpetuating existing inequalities (Jasanoff, 2018; Swilling & Annecke, 2006).

Characterising the deliberate shift and transition that society needs to embark on is essential for understanding the quality of transformation that innovation needs to achieve. Such quality is best considered in light of the characteristics of the sustainability transition process, which should ideally inform the quality of the innovation, its ultimate impact and the nature of financial innovation and policy responses that ensue (Naidoo, 2020). Firstly, there is a temporal reality which refers to the time-based nature which is either extended or accelerated. Secondly, the transition process has a directionality – there is a simultaneous shift away from unsustainable and towards sustainable practices and norms. Thirdly, uncertainty, creativity, and disruption are fundamental coexisting features of transition processes. Fourthly, social contestation is inevitable as new change agents emerge, such as communities affected by the disruptive forces of change and the intergenerational effects of change. Finally, the transition process necessitates experimentation; innovation needs to be iterative, learning-based, and embody a willingness to experiment.

8. Triggers for institutional change

Addressing the urgency of deep systemic changes also necessitates innovative policies that focus on transformative changes at an institutional level. Systemic changes can be framed by using the theoretical underpinnings from sustainability transitions and transformative innovation. Socio-technical systems are characterised as stable and path-dependent because they are constituted from a co-evolutionary accumulation and alignment of the following: (1) incumbent actors which have become vested in maintaining the status quo,

(2) a network of actors that represent organisational capital, (3) regulations and standards that enable continuity of the regime, (4) cognitive routines and practices that can blind actors to realities outside of their focus, and, lastly, (5) material elements such as infrastructure that enable lock-in due to sunk investments (Verbong & Geels, 2007). The QWERTY keyboard is an example of long-lasting technological path dependency because the design achieved a dominant market position early on, leading to economies of scale and crowding out alternative designs that followed. This example elucidates how, once an initial choice gets locked in, a change is challenging even if there are more efficient technologies available (Thelen, 2003). Thus, socio-technical systems which are locked in can pose considerable challenges to policymakers who set out to contribute to unlocking path dependencies.

In the context of uncertainties and systemic shocks such as COVID-19, the relative flexibility and adaptability of institutions became particularly evident. As the socio-economic context evolves, (e.g. political, financial, and cultural) as highlighted by the consequences of the pandemic, so will policies and institutions. However, these changes may not necessarily be wholesale but can be achieved through escalated interactions between the institutional changes over time. Drawing on the work on institutional theory from Mahoney and Thelen (2010) and Ting (2020) on sustainability transitions, there are various mechanisms in which institutions can change in response to the dynamic systemic changes. Three types of institutional changes in response to transformative shifts are possible, i.e. layering, conversion, and displacement.

- Changing institutions through layering is a form of incremental adjustment in which emerging innovations are developed within the existing incumbent selection environment. Layering is feasible when an institutional environment is not conducive to radical disruption, therefore allowing new and old institutions to coexist over time. An example of layering is the introduction of renewable energy in South Africa which was introduced as a way to diversify the country's coal-based electricity. The layered process was done in a stepwise, fit and conform strategy. Similarly, the implications from the global pandemic may necessitate changes, which are not outright radical but can be 'layered', leading towards systemic changes (Ting, 2020).
- Conversion defines institutions as 'multipurpose tools', which means they can be used at differing ends, depending on who is powerful enough to utilise them in their favour (Hacker, et al., 2015). In this way, new institutions are not created, but instead, existing ones are repurposed to serve new goals or interests. Further, incumbents could draw strengths from existing organisational networks and capabilities. Examples of conversion are the efforts of South African coal base towns undergoing threats of stranded assets due to emphasis on lower carbon emission, which are repurposing infrastructures to serve the local community in a more sustainable way (Strambo et al., 2019). Related to COVID-19, Domenech and Fokeer (2020) noted that countries where manufacturing is firmly entrenched in domestic and regional networks can respond and be more flexible at times of uncertainty. For example, Turkey, China and other countries are using local manufacturing capacities to repurpose production for essential items such as personal protective equipment

(PPEs), diagnostic equipment, and clinical care equipment.¹⁰ Therefore, a move away from linear manufacturing is an important part of recovery post-COVID, particularly if there is an emphasis on local capacity building and less reliance on a few trade partners or suppliers (Domenech & Fokeer, 2020, Kassa, 2020).

- Displacement is the most radical institutional change because there is purposeful alteration, rejection, or dissolution in existing rules (Ting, 2020). We would argue that the impact of COVID-19, particularly on exacerbating the deteriorating conditions in socio-economic status, such as widening inequality in some countries, may require improved capacities to enact stronger policies directed towards transformative changes. Here we can draw on literature, such as phase-out policies (Rogge & Johnstone, 2017), creative destruction (Kivimaa & Kern, 2016) and 'discontinuation governance' (Stegmaier et al., 2014). These are the kinds of policies that are aimed at enhancing the decline and destabilisation of existing innovation systems. For example, in sustainability transitions, policies of control (e.g. regulation), restriction (e.g. setting carbon emissions), reduction (e.g. stricter reduction in carbon emissions), or more gradual measures such as phase-out (e.g. declining use of internal combustion engines to favour electric vehicles) (Ting, 2020).

Each of these different types of institutional changes is to appreciate the dialectic nature of an innovation system. Additionally, these changes are not deterministic or mutually sequential. Likewise, there is a need to recognise feedback loops and learn as the process unfolds in implementing policy interventions. It is worth noting that transformative innovation that leads to systemic changes is often challenging and rarely occurs wholesale. For example, in South Africa's electricity system, the transition cannot directly be from coal to renewables, which could be characterised as a wholesale change. There need to be more nuanced changes, taking into consequences of such transition, which could include incremental changes over time.

Thus, introducing innovation into a system, which may have resistant incumbents, or may not be conducive to radical changes, could be addressed in incremental shifts. We would argue that in a post-COVID world, policy responses can no longer be limited to systems optimisation but needs to be transformative, such that deep structural shifts are taken seriously.

9. Discussion and conclusion

The pandemic has shown the heightened vulnerability of some parts of society due to deep-rooted inequalities, which has implications on access to the benefit of technological innovation. Hence, during these uncertain times, fundamental questions are being asked on the adequacy and the inclusiveness of the current socio-technical system to deliver on societal needs.

¹⁰ <http://www.unido.or.jp/en/news/6936/>

In this paper, we interrogated if current national policies are appropriate in engaging with increasing complexities, particularly post COVID-19. We began by analysing the implications of the pandemic on poverty, inequality, health, and global trade. It was evident that COVID-19 has shifted the socio-economic conditions in ways that push more vulnerable people towards poverty, balancing the consequences between the risk of infection versus daily livelihood. We also discussed that some countries in sub-Saharan Africa are at peril of early deindustrialisation because of reduced participation in global value chains. Significantly, the responses to the pandemic require much more nuanced approaches, particularly in the African context, where the socio-economic context requires a balance of trade-offs and synergies amongst multiple priorities, such as inequality, job creation, and poverty reduction. Thus, there is an increasing expectation from the science and research community to provide solutions, such as new kinds of innovation policies in products, processes, and business models that attend to the new socio-economic reality. The pandemic is a wake-up call for all and highlights the need to recalibrate national policies to better equip governments with the instruments and capabilities to point innovation efforts towards the goals of sustainability, inclusivity, and resiliency. In this paper, we suggest the use of transformative innovation, which is analogous to deep systemic change needed across economic, social, political, financial, and other structures which address underlying causes of vulnerability (e.g. inequality, lack of capabilities).

Given the urgency of policy responses, the tendency for policymakers has been to rely on 'evidence base' science, to guide action, and reduce the complexity towards quantifiable possibilities. These kinds of approaches tend to be reductionist in their approach and deterministic, such as the linear assumption that innovation leads to economic development. Although these techno-managerial responses are important, the benefits are limited because the result borders on systems optimisation at best, and at worse, leaves a system vulnerable to the next crisis. Our paper argues that the implication of COVID-19 on exacerbating vulnerability requires a rethinking of the linear assumptions between innovation and development (Chataway, et al., 2014; Schot & Steinmueller, 2018). Moreover, there is a need for rethinking or revisiting policies and regulations to create conditions, which support development that goes beyond optimising the status quo post-COVID and one in which there are transformative changes.

Further research, particularly exploring more empirical examples from the Global South, is essential. Such research could involve cross country comparisons across the African continent, building case studies that compare different types of policy frameworks focused on transformative impacts. Although the discussion in this paper relies upon nascent empirical examples, particularly given the pandemic's recent impact, we are able to extract several messages for policymakers. Specifically, they need to engage and appreciate the complexity presented not only during the time of COVID-19 but also in connection with other systemic and pending threats such as climate change and biodiversity systems collapse.

The following are key messages:

- The COVID-19 crisis has obliged governments to engage in “forced experimentation”, from organising new ways of working from home to using new data, policy tools, and partnerships to formulate, design, and implement policies (OECD, 2021).
- Challenge the linear assumptions between innovation and development, where key questions can be asked, such as, what kinds of innovation should be pursued, in what direction, and for whose benefit?
 - Moreover, social dimensions (trust, diversity in participation, access, inclusion, etc.) and technical solutions are equally important.
- Consider a resilience based approach, where system weaknesses are identified as well as the capabilities to absorb, recover, and adapt to future system threats.
 - In this way, the approach is ‘threat agnostic’, in that threats are inherent to the properties of a system.
- Reorientate policy goals and use innovation policies to trigger systems change during the recovery period from the pandemic. These innovation policies should enable and accelerate in achieving socio-economic goals that are inclusive, resilient, and sustainable. This will require new forms of policy frameworks and practices (e.g. the transformative innovation policy approach to policymaking).
- Transformative changes can be achieved through stepwise or incremental institutional outcomes, using strategies such as layering, conversion, and displacement. Rooted in sustainability transitions and institutional literature, these kinds of institutional outcomes pay special attention to deep-seated structural change, which fundamentally challenges the status quo.

Embracing complexity and uncertainty is a necessity in an increasingly interrelated complex system. The COVID-19 pandemic shows that in the wider, long run and real-world of human affairs, control does not exist (Scoones & Stirling, 2020). In a post-COVID world, we have a need for policies that are innovative and focus on transformative change. These transformative changes can include innovative policies in education, trade, or health, as examples discussed in this paper. Recalling Minsky (1986:4), we further remind ourselves that one cannot deny the underlying characteristics of the economic mechanisms that gave rise to problems, for which theories need to offer useful guides wherever possible. The paper reflects on the complex policy challenges due to the COVID-19 pandemic and suggests, at least theoretically, that uncertainty and systemic shocks may trigger positive fundamental societal changes.

References

- Ayisi, J., Ndakala, F., Owuor, R., Nyanga, R., Daniels, C., Boniface, W., & Ting, M. B. (2019). *Nomadic Education in Kenya: A Case Study of Mobile Schools in Samburu County, As A Transformative Innovation Policy*. TILH report, TIP Africa.
- World Bank. (2020). *COVID-19 to plunge global economy into worst recession since World War II* [Online]. Available: <https://www.worldbank.org/en/news/press-release/2020/06/08/Covid-19-to-plunge-global-economy-into-worst-recession-since-world-war-ii> [Accessed].
- World Bank. (2020). *Poverty and Shared Prosperity 2020: Reversals of fortune*.
- Chataway, J., Hanlin, R., & Kaplinsky, R. (2014). Inclusive innovation: an architecture for policy development. *Innovation and Development*, 4, 33-54.
- Cissé, F., Diémé, J. S., Assion, L., Sy, M., Daniels, C., & Ting, M. B. (2019). *ICT in Higher Education in Africa: Example of the Virtual University in Senegal*. TILH Report, TIP Africa.
- Daniels, C., & Ting, M. B. (2019). *Transforming Science, Technology And Innovation Policies In Africa: Insights from Ghana, Kenya, Senegal, and South Africa*. TIPC Policy Brief. University of Sussex: Transformative Innovation Policy Consortium (TIPC).
- Davids, R., Ahmed, N., & Shead, D. (2020). Cry the Beloved Non-COVID Country: A Review of South African Health Care's Response to COVID Pandemic. *Journal of Critical Care*, 6.
- Diallo, M., Dasyuva, J., Cissé, F., Sy, M., Ting, M. B., Daniels, C., & Diémé, J. S. (2019). *Senegal's Virtual University, a Case Study on Transformative Innovation Policy*. <http://www.tipconsortium.net/senegals-virtual-university-a-case-study-on-transformative-innovation-policy/> [Online].
- Diercks, G., Larsen, H., & Steward, F. (2019). Transformative innovation policy: Addressing variety in an emerging policy paradigm. *Research Policy*, 48, 880-894.
- Domenech, T., & Fokeer, S. (2020). *Why innovative manufacturing and circularity are key for resilient manufacturing industry post-COVID-19*. UNIDO.
- Elzen, B., Geels, F. W., & Green, K. (2004). *System Innovation and the Transition to Sustainability: Theory, evidence and policy*. Edward Elgar. The United Kingdom.
- Geels, F. W., & Schot, J. (2010). The Dynamics of Transitions In: Grin, J., et al. (Eds.) *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*. Taylor & Francis Group.

Hacker, J. S., Pierson, P., & Thelen, K. (2015). Drift and conversion: hidden faces of institutional change. In: Mahoney, J., & Thelen, K. (Eds.) *Advances in comparative historical analysis*. Cambridge: Cambridge University Press.

Hartwich, F., & Hedeshi, M. (2020). *COVID-19 effects in sub-Saharan Africa and what local industry and governments can do*. Vienna, Austria: UNIDO.

Hartwich, F., & Isaksson, A. (2020). *Managing COVID-19: Why poorer countries may drop out of industrialization*. UNIDO.

International Labour Organisation (ILO). (2018). Women and men in the informal economy: A statistical picture.

Jasanoff, S. (2018). Just transitions: A humble approach to global energy futures. *Energy Research and Social Science*, 35, 11-14.

Kassa, W. (2020). *COVID-19 and Trade in SSA: Impacts and Policy Response*. June, 2020 Issue 1, No. 1. Office of the Chief Economist, Africa Region, World Bank.

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, 45, 205-217.

Kuhlmann, S. (2018). Introduction to discussion paper on 'Three Frames for Innovation Policy: R&D, Systems of Innovation and Transformative Change'. *Research Policy*, 47, 1553.

Lakner, C., Mahler, D. G., Negre, M., & Prydz, E. B. (2020). *How Much Does Reducing Inequality Matter for Global Poverty?* World Bank.

Linkov, I., Trump, B. D., & Hynes, W. (2019). *Resilience-based Strategies and Policies to Address Systemic Risks*. Paris, France: OECD.

Macgregor, H., Ripoll, S., & Leach, M. (2020). Disease outbreaks. Navigating uncertainties in preparedness and response. In: Scoones, I., & Stirling, A. (Eds.) *The Politics of Uncertainty. Challenges of Transformation*. Routledge.

Mahoney, J., & Thelen, K. A. (2010). *Explaining institutional change: ambiguity, agency, and power*. Cambridge: Cambridge University Press.

Mathews, J. A. (2015). *Greening of Capitalism: How Asia is driving the next great transformation*. Stanford University Press.

Mehta, L., & Srivastava, S. (2020) Uncertainty in modelling climate change. Chapter 7 in Stirling and Scoones (eds), *The politics of uncertainty, challenges in transformation*. Earthscan, Routledge.

Minsky, H. (1986). *Stabilizing an unstable economy*. Yale University Press. New Haven and London.

Naidoo, C. P. (2020). Relating financial systems to sustainability transitions: Challenges, demands and design features. *Environmental Innovation and Societal Transitions*, 36, 270-290.

Naidoo, K., Singh, J., & Lalloo, U. (2013). A critical analysis of ICU/HC beds in South Africa: 2008-2009. *South African medical journal/Suid-Afrikaanse tydskrif vir geneeskunde*, 103, 751-753.

National Treasury. (2020). *Supplementary Budget Review*. Pretoria, Republic of South Africa. Available at: <http://www.treasury.gov.za/documents/National%20Budget/2020S/review/FullSBR.pdf>

Ndakala, F., Nyanga, R., Ayisi, J., Owuor, R., Wanyama, B., Ting, M. B., & Daniels, C. (2019). *Analysis Of Transformative Components Of Mobile Schools For The Nomads In Kenya*. TIP Africa Research Brief.

OECD. (2021), *OECD Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity*, OECD Publishing, Paris, France.

Perez, C., (2002). *Technological Revolutions and Financial Capital*. Edward Elgar Publishing Ltd, Cheltenham, UK.

Quaye, W., Akon-Yamga, G., Daniels, C., Ting, M. B., & Asante, A. (2019a). *Transformation Innovation Learning History of Ghana's E-Waste Management System TILH Report*, TIP Africa.

Quaye, W., Akon-Yamga, G., Daniels, C., Ting, M. B., Asante, A., & Antwi, D. O. (2019b). *Research Brief On Transformative Innovation Policies: Lessons From Ghana's E-Waste Management System*. TIP Africa Research Brief.

Ramos, G., & Hynes, W. (2020). *A systemic resilience approach to dealing with Covid-19 and future shocks*. Paris, France: OECD.

Rogge, K. S., & Johnstone, P. (2017). Exploring the role of phase-out policies for low-carbon energy transitions: The case of the German Energiewende. *Energy Research & Social Science*, 33, 128-137.

Schot, J., & Kanger, L. (2018). Deep transitions: Emergence, acceleration, stabilization and directionality. *Research Policy*, 47, 1045-1059.

Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, 47, 1554-1567.

Scoones, I., & Stirling, A. (2020). *The Politics of Uncertainty: Challenges of Transformation*.

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy*, 41, 1025-1036.

Smith, A., Voß, J.-P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research Policy*, 39, 435-448.

StatsSA. (2020). *Behavioural and health impacts of the COVID-19 pandemic in South Africa*. Pretoria, South Africa: Statistics South Africa.

Stegmaier, P., Kuhlmann, S., & Visser, V. R. (2014). The discontinuation of socio-technical systems as a governance problem. In: Borrás, S. & Edler, J. (Eds.) *The Governance of Socio-Technical Systems: Explaining Change*. Cheltenham: Edward Elgar.

Stirling, A. (2010). Keep it complex, *Nature*, 468, 1029-1031.

Strambo et al. (2019). *The end of coal? Planning a just transition in South Africa*. Stockholm Environment Institute (SEI), February 2019.

Swilling, M., & Annecke, E. (2006). *Just transitions: explorations of sustainability in an unfair world*. University of Cape Town Press.

Tan-Torres Edejer, T., Hanssen, O., Mirelman, A., Verboom, P., Lolong, G., Watson, O. J., Boulanger, L. L., & Soucat, A. (2020). Projected health-care resource needs for an effective response to COVID-19 in 73 low-income and middle-income countries: a modelling study. *The Lancet Global Health*, 8, e1372-e1379.

Thelen, K. (2003). How institutions evolve. In: Reuschemeyer, D., & Mahoney, J. (Eds.) *Comparative Historical Analysis in the Social Sciences*. Cambridge: Cambridge University Press.

Ting, M. B. (2021). Inclusive energy transitions: an analysis of the potential for a digital revolution in South Africa's electricity system. Chapter 11, in *Leap 4.0 African perspectives on the Fourth Industrial Revolution*.

Ting, M. B. (2020). *Socio-technical transitions in South Africa's electricity system*. The University of Sussex.

UNCTAD. (2017). *New innovation approaches to support the implementation of sustainable development goals*. Geneva, Switzerland: United Nations Conference for Trade and Development.

UNECA. (2020). *Impact of COVID-19 in Africa*. United Nations Economic Commission for Africa.

Verbong, G., & Geels, F. (2007). The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960–2004). *Energy Policy*, 35, 1025-1037.

WHO. (2019). *Global Spending on Health: A world in transition*. Geneva, Switzerland: World Health Organisation.

WHO. (2020). *COVID-19 Strategy update, 14 April 2020*. Geneva, Switzerland: World Health Organisation.

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