

PART I: IMPROVING OUR UNDERSTANDING OF PANDEMIC RESPONSE

Epidemiology, Economic models and the cost vs. benefits of social restrictions to control a pandemic

1. It is critical to understand the costs and benefits of different restrictions strategies to inform policy decisions. What are possible strategies and their impacts? What are the impacts of different speeds of introducing and easing restrictions in health and the economy? How fast should restrictions be eased as vaccinations bear down on the spread of COVID-19? How do we trade-off reducing transmission vs. stimulating the economy? Is it possible to prioritise some select sectors for closure to reduce transmission, while minimizing the adverse economic effects? These are critical trade-offs which Imperial researchers have already contributed to and whose findings can be summarized, but further investigation is also warranted. Imperial developed an integrated economic-epidemiological [model](#) to project both health and economic outcomes of alternative control strategies and vaccination allocations.
2. More broadly, policy makers struggle to assess both health and economic effects in a unified approach and more work is needed on how to integrate epidemiological with economic research. So, there is an opportunity for a narrative review of key integrated economic-epidemiological models, i.e., macro-economic models that integrate dynamic disease transmission models where economic outcomes - and often also health outcomes - are endogenously determined.

Managing people and the healthcare system in a pandemic

1. The pressures on health systems have led to many diagnostics and interventions being postponed. At this stage, it is critical to have proper planning to reduce adverse health impacts. Furthermore, after the pandemic eased up, and the healthcare system began scaling up elective surgery, it is similarly critical to optimise scheduling to minimise loss of life. Imperial modelling demonstrated how [optimising scheduling](#) can both reduce costs and lives lost compared to current policies. Proper surge management tools can thus be critical. Imperial further developed the Pandemic Planner (Christen et al), a hospital planning tool designed to estimate how to increase hospital capacity most effectively when patients threaten to overwhelm available capacity.
2. The evolution of the pandemic demonstrated that management of disease has not been uniform, and differs from hospital to hospital, and practical treatment strategies followed as much local practice and understanding as well as insights stemming from global research outcomes. Crucially, insights showed that analytics that venture beyond mere admission and outcomes data, provided much better understanding in how small differences in treatment strategies affected the trajectory of the patients in predictable ways. For example, Imperial set up and led the National Service Evaluation in Critical Care (Patel et al) which collected patient's trajectories and their medical interventions across the country on a day-to-day basis. This delivered a unique snap-shot of actual patient management across the country's healthcare system and its diversity in how it is managed "on the ground". This national, real-time view enabled us to derive personalised healthcare from natural real-world experiments and post-hoc evaluate treatments (e.g. proning of patients) that would not have been subject to specific clinical trials due to time pressures or costs.

3. One important tool to understand and manage the pandemic is strong understanding of its population level impacts. In the UK, the REACT study, which used home testing to understand how the COVID-19 pandemic progressed across England, was quite an important element. Still few other countries were able to do something equivalent. What enabled REACT in the UK but not elsewhere and what can we learn from that in the future?
4. In a pandemic it is equally critical to understand and help manage public engagement. It allows gaining contextual insights into how the pandemic is impacting the population and how to adjust responses to it. The team developed a questionnaire on the impacts of COVID-19 and pandemic control measures in a range of health, social and economic domains, designed to be administered across countries at different levels of income to gain such understanding.
5. One important element of public reaction to the pandemic relates to the social and health inequalities across different socioeconomic groups. It is important to explore and understand how compliance to mobility restrictions during lockdown varied across the country by different socioeconomic groups, and to understand the impact of this variance on health.

PART II: ADDRESSING THE LONG-TERM (UNEQUAL) IMPLICATIONS OF THE PANDEMIC TO HEALTH, HEALTHCARE AND THE ECONOMY TO BUILD NEW RESILIENCE MECHANISMS

Economic Resilience to the COVID-19 pandemic

1. Different countries have experienced different short-term shocks to GDP because of the pandemic crisis. Why do country experiences differ? These variations are not simply due to country differences in the severity of restrictions to non-essential economic activity. The relative importance of, first, demand reductions due to fear of infection or uncertainty about household's economic situation, and, second, supply side shocks due to disruptions to international supply chains is currently unknown. It is currently unclear how long-term these shocks are, and whether countries return to their pre-pandemic growth trajectory or there are long-term scarring effects that will endure for several years. Disentangling this aspect is critical to understand the impact of policy decisions and to better prepare for a future pandemic.
2. One major change in the pandemic has been the growth in working from home and it can be considered an important resilience mechanism in the future. For that reason, it is important to reflect on whether it will remain and also in what ways is it a good or bad thing? How do countries differ in their work-from-home potential, and how does this differ in low- and middle-income countries? In official data, the capital stock used by firms is deployed in the workplace. But working from home shows that some of that capital stock can be deployed outside of the workplace at home. Working from home becomes similar to a return to the pre-industrial revolution time when, before factories, artisanal production was the norm. So, the ability to work from home is in fact a potential source of resilience to the shock of the pandemic that we need to further research.
3. Using cross country data and business surveys it is possible to detail where working from home is likely to become more commonplace and the extent to which domestic capital turns out to be part of the productive capital stock. This has implications for productivity and the future of work.

4. As well, as working from home accounting for cross-country variation, different countries experienced very different infection and mortality trajectories during the pandemic, which reflected difference in the organisation of countries, e.g. national vs regional management of research and regulation leading to slower vs faster speed of adoption/trials/etc (e.g. Germany vs UK) but conversely differences in the scale and speed of vaccine rollouts being faster in monolithically organised countries over more regional/federal ones. This points to important differences in how future responsiveness should be shaped based on national characteristics and there is no one-size fits all solution. It also highlights the key issue of the role of centralised vs decentralised action from governments.

Addressing the unequal impacts of the pandemic through health and healthcare

1. COVID-19 pressures led to a massive decrease in hospital care, with significant asymmetries in impact across income and ethnicity. This reduction in care will have further knock-on effects on the demand for healthcare in the future, further exacerbating health inequalities.
2. The response to the pandemic was to shut down the economy, leading to income drops for various groups of people, which in turn hurt health, particularly of vulnerable groups and low income/poor health communities. This will again exacerbate health inequalities.
3. Many of these changes to health will take time to evolve and are not easy to predict. Large shocks such as previous world pandemics have brought about significant changes to relative labour and capital prices (think of the Black Death in the UK); it is too soon to establish these.
4. Thus, we need to understand much better worldwide the distributional impacts for users of care of these massive cuts to healthcare supply during the pandemic and prepare adequate responses as part of the recovery and building back a more resilient society. Some of these must be flexible enough to accommodate emerging and unanticipated change.
5. In any case, healthcare productivity needs to improve. Some changes involve pushing gains at the margin, using digital and remote tools, as well as rethinking regulation, which often holds back productivity improvements, for example allowing digital consultations. We need to respond to the important changes that will 'shock' healthcare systems by pushing new forms of delivery and to spur innovation.
6. A post pandemic response requires recognizing and addressing these inequalities more broadly as well, beyond decision on resources and organization of the healthcare system, and extending into investments in individuals and communities, as well as changes to the nature of jobs, food prices etc. Health resilience will be built up also by a focus on provision of 'good' jobs and community investment, so that individuals do not become marginalized.

PART III: COVID-19 AND THE DRIVE FOR A NEW HEALTH INNOVATION PARADIGM

Fostering an innovative response

1. We have witnessed an unprecedented effort to develop technological solutions to help mitigate the spread of COVID-19 and mitigate its consequences. This effort has come from traditional healthcare industries such as pharmaceuticals, medical devices and diagnostics, but also global tech giants, as well as a wealth of ground-up activity,

including hackathons and open innovation models, 'frugal innovation' and hospitals using crowdsourcing and 3D printing to tackle equipment shortages.

2. Healthcare has fast forwarded digital technologies, their deployment and acceptance by up to a decade. Moreover, the stake holders and society in general have seen the impact of digital technologies as part of the ammunition to fight the pandemic and remote care – telehealth, telemedicine – are coming of age.
3. But these efforts will eventually run up against the old challenges associated with healthcare innovation: the need to navigate the complex ecosystem of organisations, regulations, evidence requirements, payment and reimbursement models, and professional silos to shepherd their innovation to successful adoption.
4. A question is thus whether we can build on recent experience and find more efficient, speedier ways of ensuring that innovative new technologies can be brought into practice. For example, how can regulatory bodies such as the FDA and MHRA better support innovation in light of their pandemic experiences?
5. We supported innovators to understand key regulations and processes to comply with ([Albert-Smet et al](#)), and how these changed during a public health emergency via dedicated exemptions. The work has served as a guide for those wishing to act quickly but with uncertainty of the legal and regulatory pathways that allow a new device or service to be fast-tracked.
6. We have now realised how we can speed things up in healthcare innovation in general. This is based on what has worked well during the pandemic, and could inform our understanding of how, beyond the pandemic, we can help further unlock innovation potential from innovators who were wary of entering a potentially highly-regulated healthcare technologies market that may have appeared difficult to navigate to many.
7. We can learn from the differences in the speed of adoption and trials when comparing national/regional management of research/regulation.
8. New approaches to modelling and simulation leverage emerging data sources and data analytics tools to conduct natural and other experiments (causal inference on retrospective data) to support innovation impact studies and potentially speedier adoption by avoiding time consuming and costly randomised controlled trials.

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