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Full Length Article

Why are COVID-19 travel bubbles a tightrope walk? An investigation based on the Trans-Tasmanian case

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ABSTRACT

The COVID-19 pandemic has hit the transportation sector hard; particularly air transportation, as a major mode of long-distance transportation, has been affected tremendously. Since the dawn of COVID-19, politicians and policy makers have discussed the idea of introducing travel bubbles between countries (or states), to allow for a continued exchange of people and goods. The eponymous Trans-Tasman travel bubble is a major example, involving quarantine-free travel between Australia and New Zealand. While both countries have tried to form a travel bubble various times, recurring setbacks and difficulties were faced. In October 2021, this ambitious project presumably has come to an end, with both countries announcing the essential capitulation of their COVIDZero strategies and a planned opening towards broader international travel. In this study, we perform a close investigation of the history behind the Trans-Tasman travel bubble as an on-off relationship, identifying a set of drivers for the serious problems involving a sustainable setup and operation. We develop a framework which represents important factors for successful travel bubbles and believe that the satisfaction of all factors at once is extremely challenging. Our results and insights are not specific to the Trans-Tasman case only, although it is taken as a running example, but can be generalized to various scales and environments. We hope that our study contributes to the literature by improving our understanding of the highly buzzed travel bubble concept, while providing empirical evidence for the troubles that inherently make such bubbles a tightrope walk.

1. Introduction

COVID-19 has become a part of our life for almost three years now, with a total number of 625 million confirmed cases and more than six million reported deaths, as of October 18th, 2022. Many industries have been hit hard (McKibbin and Fernando, 2020), with transportation taking a rather ambiguous role during the COVID-19 pandemic: While our efficient transportation systems largely contribute to the spread of a virus, transportation is probably among the systems affected to the highest degree by COVID-19 lockdowns and border closures. This is particularly true for air transportation, which presumably enabled the transformation of an epidemic outbreak into a full pandemic. The reduction in the number of flights in Murphy et al. (2020) is among the highest-impact events in recent history, leading to grounding of entire fleets and flight cancellations of up to 95% in some markets (Sun et al., 2021a). Soon after, politicians, policy makers, as well as scientists, envisioned so-called travel bubbles as a possible way out of the pandemic. The participating countries of such a travel bubble agree on opening intra-bubble transportation with eased travel restrictions, with the goal to permit mobility and trade, opening pathways for an economic recovery (Iaquinto, 2020; Sharun et al., 2020).

In April/May 2020, the Trans-Tasman bubble was among the first announced in the public, consisting of relaxed travel restrictions between Australia and New Zealand (Krakat, 2020). Singapore and other Asian/Oceanic countries soon considered to join such an undertaking (Wego, 2020). Malaysia and Singapore started a travel bubble which was hoped to lead towards an ASEAN travel bubble eventually (Lim and Kheng, 2020; Furutani, 2020). The so-called Baltic travel bubble was planned to include Lithuania, Estonia, and Latvia (Reuters, 2020). The Atlantic Bubble concerned air travel among the four Atlantic provinces, namely, Newfoundland and Labrador, Nova Scotia, New Brunswick, and Prince Edward Island, in Canada (Linka et al., 2020; Studdert et al., 2020). India has reportedly tried to create travel bubbles with USA, Germany and France (Wego, 2020). Similarly, a Transatlantic air bridge between New York and London was under discussion temporarily (Dailymail, 2020).

A few studies have provided preliminary discussions on the concept of
travel bubbles; mostly published in early 2020, when the concept of a travel bubble was still a mostly theoretical one, with lack of actual empirical evidence throughout the COVID-19 pandemic; see Table 1 for an overview. These existing studies can be summarized as follows. Sharun et al. (2020) listed several proposed travel bubbles and concluded that travel bubbles should be considered as an effective compromise in the preventive strategies. At the same time, the authors highlighted the need for strict prevention and control measures at the travel bubble interface, and also emphasized that bubbles would likely work out for countries with a similar COVID-19 incidence. Other researchers have highlighted a strong dominance of government policy in response to COVID-19, compared to earlier pandemics in the past century (Beirman, 2021). In this context, it has been argued that the functionality scores of country policies, composed of entry rules, quarantine rules, social distancing rules, and testing rules, could be used to estimate the success of a bubble. The rationale is that a lower functionality score leads to a higher probability of failure. Beirman (2021) quantified the functionality score of the Trans-Tasmanian travel bubble as 9.5/10, as of the rules active in October 2020, concluding that the bubble is not mutually beneficial. Edwards (2020) states that the success of Australia and New Zealand in fighting COVID-19 could lead to a carefully managed pathway - a bubble - to allow the tourism, particularly in the context of its Pacific neighbors, given that Australia and New Zealand control largely the indirect accessibility for international travelers to many Pacific islands (Blackman, 2021).

Based on survey data for Hong Kong residents on potential travel bubble destinations, Luo and Lam (2020) found that fear of COVID-19, travel anxiety and risk attitude negatively impact travel intention inside a bubble. It should be noted that the term bubble is used in slightly different COVID-19 contexts as well. For instance, Yu et al. (2021) analyzed the drivers and effects behind the tourism bubble policy, including travel decisions and physical/mental health assessment. Dave et al. (2020) reported that the establishment of a ground transportation-based travel bubble in India based on the health vulnerability indices alone would discard the en-route epidemiological travel risk; a problem not directly present in air transportation. Berger and Reupert (2020) reported that the establishment of domestic bubbles in Australia often come with inconsistent rules and descriptions. This effect is exacerbated by the fact that different states have largely different restrictions, mainly induced by their heterogeneous epidemic situation. For instance, the state of New South Wales has seen many more infections than Western Australia, presumably because of the higher population density and higher degree of international connectivity of Eastern Australia; see the effect of special health accommodation in Fotheringham et al. (2021). A few studies have aimed to formally solve the network revision problem by making epidemiologically driven decision making, e.g., see Ding et al. (2021) for air transportation, Guillot et al. (2022) for bus networks, and Qu et al. (2022) for an overview discussing the need of informed modeling and data acquisition. In this context it is important to understand that our transportation systems are built around efficiency and resilience, where redundancy is an important aspect for well-functioning (Ezaki et al., 2022). In order to create pandemic-resilient systems, one needs different approaches.

In this study, we investigate the troubles and challenges inherent to travel bubbles, mainly from a retrospective. The first part of our work is concerned with a dissection of the Trans-Tasmanian travel bubble comprising Australia and New Zealand. This bubble project is unique in several aspects. Australia and New Zealand have a rich history in cooperation: their shared ecosystems make them natural allies and intensive trade partners (Hennessy et al., 2007; O’Sullivan, 2011). Their geographical location, being largely accessible by air transportation only, provides them with an excellent opportunity to seal of their borders against unwanted immigration and intrusion, compared to countries which must secure land-side borders of hundreds or thousands of kilometers (Murphy et al., 2020). The political leaders in both countries have very early indicated the intent to open a travel bubble, in order to resume trade and mobility (Sharun et al., 2020; Berger and Reupert, 2020; Edwards, 2020). Finally, both countries followed a rather strict strategy of COVIDZero (or maybe better called low-COVID), with widely recognized success throughout the year 2020 and parts of 2021 (Baker et al., 2020; Chang et al., 2020; Price et al., 2020). The emergence of COVID-19 cases with the delta variant in Australia has significantly changed this plan recently (Bennett, 2021); as counter measures against the variant were likely implemented too late, despite of concerns having been raised rather early (Sun et al., 2021b). The fact that - despite factoid mostly positive prerequisites - the bubble did not work out, calls for scientific investigation from a retrospective, as insights from this failing partnership can shed light on other travel bubble projects with worse prospects.

Based on the discussion of the Trans-Tasmanian travel bubble project, we propose a set of drivers for the tremendous problems involving a sustainable bubble setup and operation. We develop a framework which represents important factors for successful travel bubbles and believe that the satisfaction of all factors at once is extremely difficult, leading to a walk on the tightrope. Our framework and discussions only hold for the specific case of the Trans-Tasmanian travel bubble but can be extended to other bubble setups at different spatial scales. We hope that our study contributes towards a better understanding of travel bubbles together with their inherent troubles and challenges.

The remainder of this study is structured as follows. Section 2 discusses the background and evolution of the Trans-Tasmanian travel bubble in detail. Section 3 develops a framework with drivers for successful travel bubble projects. Section 4 concludes this study and proposes a set of directions for future work.

2. Trans-Tasmanian travel bubble

This section investigates the development of the Trans-Tasmanian travel bubble project as a response to the COVID-19 outbreak. Australasia consists of Australia, New Zealand and a collection of tropical islands; see (Hennessy et al., 2007) for a broad geographical and socio-economical overview on the region. The geographical proximity and shared ecosystems make them natural allies and intensive trade partners, but far from being a static relationship (O’Sullivan, 2011). Notable steps in the two neighbors’ recent geopolitical evolution were the New Zealand Australia Free Trade Agreement (in 1966), Trans-Tasman Travel Arrangement (in 1973) and the Closer Economics Relations agreement (in 1983), targeting the establishment of a free trade zone with border-less service and travel; see Lloyd (1995) for a review and discussion.

Given the strong economic ties, the high degree of social homogeneity (Robinson, 1969), and the geopolitical ramifications during COVID-19, it is not surprising that Australia and New Zealand were among the first countries to consider the idea of establishing a travel bubble to re-instantiate movement of people and goods. The attempt to establish

### Table 1
Overview on closely related literature.

| Reference            | Result                                                                 |
|----------------------|------------------------------------------------------------------------|
| Beirman (2021)       | Mutuality scores of a travel bubble might give an indication of potential for success. |
| Berger and Reupert (2020) | Domestic bubbles in Australia often come with inconsistent rules and descriptions. |
| Dave et al. (2020)   | Discussion of ground transportation-based travel bubbles in India.      |
| Edwards (2020)       | Early lessons for the COVID-19 recovery in terms of bubble agreements are evaluated. |
| Fotheringham et al. (2021) | The role of special health accommodation in New South Wales, Australia. |
| Luo and Lam (2020)   | Fear, travel anxiety, and risk attitude can negatively impact travel inside a bubble. |
| Sharun et al. (2020) | Early risk assessment for the COVID-19 recovery in terms of bubble agreements. |
| Sun et al. (2022)    | Data-driven analysis on the extent of travel bubbles in global air transportation. |
the travel bubble, however, faced several setbacks since its conception and could possibly be best described as an on-off relationship; see Table 2 for a brief review of the Tasmanian travel bubble history during the COVID-19 pandemic. The public discussion about the project started in April 2020, when New Zealand officials raised the idea of establishing the bubble with Australia. It took about half a year until the long-expected travel bubble was opened eventually between New Zealand and the state New South Wales. After two days, it was revealed that several New Zealanders violated the travel bubble rules in Australia by visiting regions outside the travel bubble, leading to a cancellation of the travel agreement eventually. In early 2021, the outstanding epidemic situation in both countries led to further attempts to re-establish travel. The first attempt in February 2021 failed within a few days (the actual reason could not be tracked) and the second attempt, which came into order in April 2021, lasted for three months eventually. In July 2021, New Zealand - again - canceled the travel bubble agreement due to the worsening epidemic situation in Australia. In October 2021, both countries made independent media statements concerning the worsening epidemiological situation in both countries, mainly citing extreme difficulties to handle the delta variant contagion. Given the - by now - advanced vaccination process of both countries, it was announced that they plan to soon re-open their international borders. This step is presumably the final burst of the Trans-Tasmanian travel bubble dream, since with an opening of international borders, the uphold of a travel bubble relationship is likely pointless (by definition of the travel bubble concept). One could imagine that both countries still agree on easier entry/test restrictions, but this likely leads to a concept quite different from the originally envisioned autarkic travel bubble, the main subject of our study. The remainder of this section investigates the epidemic situation and mobility patterns of Australia and New Zealand during the first one and a half years with COVID-19, until both countries achieved significant vaccination rates (40% and 50%, respectively). Such an analysis is instructive, because it highlights the real-world ramifications encountered within a travel bubble agreement.

Fig. 1 reports the temporal evolution of COVID-19-related performance indicators for both regions of interest, Australia and New Zealand, respectively. The first wave of COVID-19 sets off in Murphy et al., (2020) at about the same time in both countries; to a larger magnitude in Australia. An additional major flareup can be found in Australia in August 2020 and July 2021. At that time, New Zealand had already committed to an extremely strict strategy to handle COVID-19 and, accordingly, the large outbreaks can be seen in Australia only. These two major outbreaks led to New Zealand canceling the travel bubble, respectively. While additional local-scale outbreaks happened in other countries, it was possible for the governments to quickly constrain the spread of the virus at these times. Regarding the number of confirmed deaths, both countries have seen very few fatalities over time, mainly due to their quick response regarding confirmed cases. In total, New Zealand has reported 27 deaths related to COVID-19, which is orders of magnitude smaller than most other countries in the world. Finally, it can be seen from Fig. 1 that both countries started vaccination efforts rather late (February 2021) with a similar performance, in terms of the vaccination ratio, achieved over time. Notably, both countries have been repetitively named as role models for handling the COVID-19 pandemic in the past. It should be noted, however, that Australia’s image as a COVID-19 paragon is increasingly questioned, given recent outbreaks caused by the delta variant and increasing unhappiness of Australia’s population about strict, seemingly never-ending lock downs. On the other hand, it is worth noting that the situation inside Australia is largely heterogeneous, with most cases being reported in the highly populated and more internationalized states in Eastern Australia; a fact not visible from Fig. 1.

Fig. 2 reports the temporal evolution of monthly international flights for both countries, respectively. The reduction of flights between Australia and New Zealand coincides with the major global disruption of international flights, at the end of March 2020. Afterwards, the number of flights remains at a rather low level for about one year; Australia revealing a slightly larger trend in the rising number of flights in this transition period. Finally, starting from April 2021, a significant increase in the number of international flights can be found.

3. Factors for successful travel bubble projects

Based on our retrospective analysis of the Trans-Tasmanian travel bubble in Section 2, we propose and discuss a set of potential success factors. Most of these factors are directly derived from the experience with Australia and New Zealand, enriched by insights from other travel bubble projects and more general considerations. The overall framework, coined TIGHTROPE, based on the success factors’ initial letters, is summarized in Fig. 3. Each factor is discussed in detail below.

### 1) Throughput

The first factor influencing the success of a travel bubble is the magnitude of flow within the travel bubble, here labeled as throughput. If the throughput is too small, meaning that there are few travelers between the participating countries, the administrative overhead to set up the actual bubble could be considered too high, in other words, the amortized cost per traveler is not acceptable. If, on the other hand, the throughput is too high, then the risk of disease spreading/leakage by human mobility inside the bubble increases significantly. Australia and New Zealand have a long history in profligate cross-country mobility, with around 100,000 monthly people exchanges before COVID-19. For instance, the connection between Auckland Airport (AKL) and Sydney Airport (SYD) has more passengers than any other international flight from New Zealand, and ranked even among the top connections when considering domestic flights within New Zealand. Such a high flow between the bubble partners gives rise to specific probabilities of transmission, which can be estimated through models and simulations, and even small numbers of cases in either country can lead to a travel bubble leakage in the long run. Moreover, in theory, the very first traveler inside the bubble could always be Patient 0 worst-case-wise. Accordingly, the judgment of travel bubble prospects highly depends on common agreements for acceptable travel bubble leakage probabilities, which grow significantly with the number of passengers.
2) Isolation: Another success factor inherent to the travel bubble concept is the degree to which the partners are connected to the rest of the world, i.e., the exchange flow. The concept of a bubble presumes that the mobility is potentially high (= normal) inside the bubble, but significantly reduced towards exterior places. The magnitude of the reduction and the asymmetry of connectivity between travel bubble partners has significant effects on the success of a travel bubble project. In general: The more connected one of the partners is to the rest of the world, the more likely the partner will have a negative effect on the bubble through leakage. Accordingly, an agreement for travel bubbles between partners should not be made without clear statements on how to deal with the respective exterior connectivity. Without a common understanding, one of the partners will likely make the bubble burst. Australia and New Zealand had ideal prerequisites regarding a potential for isolation, but chose different degrees of external connectivity, which presumably led to Australia repetitively importing new COVID-19 cases via international mobility. Naturally, such an imbalance of isolation increases the likelihood of propagation to New Zealand - which isolated itself rather strictly. In such a setup, it is very likely that the isolated party raises anxiety and discontent, which puts the travel bubble at high risks.

3) Goal: A travel bubble should be established with a goal in mind. Here, the short-term goal is often an envisioned opportunity to revive mobility, trade, and economics between the partners. The factor of a goal, however, should be understood beyond such rather trivial and short-sighted definitions. Instead, one should consider it as part of a long-term strategy and exit plan from an epidemic outbreak or a pandemic. Australia and New Zealand have frequently emphasized the short-term goal, without having a clear long-term strategy on how to deal with the pandemic; except from making a transient commitment to COVIDZero. The early lack of significant vaccination efforts in New Zealand is just one striking example here. The absence of a long-term strategy - together with evolving epidemiological properties in the partners regions - can be considered a major factor that set an end to the dream of the Trans-Tasmanian travel bubble.

4) Homogeneity: A travel bubble involves multiple parties: All partners need to make balanced contributions, where the benefits and obligations should be roughly equally distributed. This has been highlighted in the literature, e.g., by referring to mutuality scores (Beirman, 2021). Such scores could measure a wide range of policies and rules. For instance, one could consider entry rules, quarantine requirements and environments, social distancing, and testing rules. If the mutuality score is too different between participating parties, then one of
the partners might have incentives to leave the bubble, if it can be established in the first place. Moreover, homogeneity also refers to the underlying long-term goals and the epidemiological status of the partners; see the discussion in the previous paragraph. A travel bubble needs to maintain a high degree of homogeneity, in order to develop as a unified entity. Australia and New Zealand do have a shared ecosystem and they followed similar COVIDZero strategies, albeit New Zealand stricter than Australia.

5) Test&Track: The concept of a travel bubble envisions a completely free travel between partners. Whether a travel bubble can sustain such a fully relaxed environment can be doubted, at least. Especially under ramifications of a COVIDZero-based approach, the free travel between partners requires an enormous amount of trust. Once one of the partners discovers local infections, the question will come up whether these cases were induced by the travel bubble and through which path. Accordingly, we presume that a successful bubble will still require a kind of testing/tracking measure. On the other hand, if the partners of a bubble do not follow strict containment strategies (for instance, due to a high degree of vaccination), then one could possibly imagine a relaxed test and track environment. Overall, uncontrolled border traffic between local subpopulations is presumably increasing the likelihood for the mutation and spread of new variants. It has been shown that routine asymptomatic testing can lead to an effective strategy lowering passenger risk infection (Kiang et al., 2021).

6) Resilience: Given the inherent difficulty of establishing a working travel bubble, both partners need to have a high degree of resilience towards the project. The major risk is presumably related to infection events within either of the partners’ areas, once occurring, following strict COVIDZero policies, the travel bubble will likely be immediately closed by other partners. For the Trans-Tasmanian travel bubble, this happened multiple times. Over time, especially if the source of the trouble is always the same partner (e.g., Australia), the other partner needs to be very resilient to make efforts for reestablishing the travel bubble again. A striking example of this factor is the statement of New Zealand’s prime minister Jacinda Ardern about Australia in context of the discussed travel bubble: “We’ve seen the dire consequences of taking too long to act in other countries, not least our neighbors.” (Dyer, 2021).

7) Operability: The rules associated with the travel bubble should operable. Throughout the time with COVID-19, several bubble projects got stuck in the development of actual rules and implementation. A travel bubble should allow populations to lawfully participate in travel between the partners. Without a clear set of feasible rules, properly communicated to the population, such an endeavor will not work out, partially because the people will not make use of the travel bubble for the sole reason of hesitation. In the case of Australia, it was reported that the population is often not sure what rules are active at a specific time and to which regions these rules apply. The number of Trans-Tasmanian travel bubble announcements and retreats led to further hesitancy and confusion.

8) Principledness: The setup and operation of a travel bubble should be designed and manifested through following objectively designed standards and rules. If the desired travel bubble is driven by an illusionary motivation, then the result is unlikely to turn out well. The necessity and the ramifications of the bubbles, together with the exact, science-based conditions for adaptations, need to be carefully designed beforehand. Overall, the rules and legislations should carefully consider what matters most: the tourism stakeholders’ values (Puste-Forne and Michael, 2021; Puste-Forne and Hussain, 2022) and past travel habits (Yao et al., 2022), potentially through personalized modeling (Lyu et al., 2022).

9) Epidemiology: Last, but not least, the epidemiological properties of the spreading disease need to be considered when making decisions regarding travel bubbles. The Trans-Tasman travel bubble project is very instructive here. While the original strain of the virus could be controlled by Australia and New Zealand, both countries faced tremendous difficulties once being confronted with the delta variant. Under presence of the delta variant, the traditional lock downs, repetitively used on both countries upon resurgences, did not lead to significant containment. Ultimately, in October 2021, both countries publicly decided to give up their COVIDZero strategy and indicated future ambitions to reopen (all) their borders for intentional travel, once a sufficiently high degree of immunity among their own populations is achieved.

We have presented a set of factors that we believe are critical for a successful establishment of travel bubbles. These factors can be found along the whole process of travel bubble agreement and implementation, from the necessary condition of mutual goal setting and enablement, towards the successful operation and mutual long-term vision. Satisfying most of these success factors individually is already far from trivial. The much higher degree of difficulty to satisfy all these factors at once makes the establishment of successful travel bubbles a walk on a TIGHTROPE.

4. Conclusions

Travel bubbles have been proposed - and partially hyped - with the aim to revive human mobility and economic growth during all parts of the COVID-19 pandemic. This study is not simply a discussion on the benefits of establishing travel bubbles, an aspect which has been covered in the recent literature. On the contrary, we combine various unique aspects into a comprehensive analysis of travel bubbles. The discussion on the eponymous Trans-Tasmanian travel bubble provides insights regarding the actual development and presumed failure of travel bubbles as a pandemic management concept. This specific example is of high scientific interest, given the overall belief that these two countries had rather good prospects in establishing a bubble; mainly due to its geographical isolation as islands. Our discussion on a framework for successful establishment and maintenance of travel bubbles, coined TIGHTROPE, shows that there are many factors involved, beyond the simple facet of isolation. In total, a collection of nine factors highlights the extraordinary difficulty of such an undertaking. Satisfying all factors at once is highly challenging for any two selected countries. Given the current pandemic situation, with active reported cases in most countries of the world, the opening of Australia’s and New Zealand’s international borders will let the travel bubble project fail ultimately.

Our study leads to several policy insights and directions of future work. First, a strict prerequisite for COVIDZero travel bubbles is full isolation. If one of the partners choses to remain its international connectivity, the infection risk of other partners is increased significantly. This holds even more, of the travel bubble partners do not establish costly testing procedures among their incoming passengers and own population. A real-world example for the extent of isolation, which is needed for really eliminating imports, is China (Zhang et al., 2020, 2022). According to the changing epidemic regulations, travelers to China must undergo quarantine stays for 7–14 days, depending on the final destination, where each traveler is strictly isolated in specifically reserved hotels or quarantine facilities. Throughout the week-long quarantine period, up to ten COVID-19 tests are performed; once a single case is verified, the closer travel group of the case will be all quarantined and treated further. While China has been largely able to eliminate COVID-19 from the mainland of China, at least in comparison to other countries, it still has to fight against recurrent small-scale outbreaks which are often attributed to leakage. For instance, it was reported that an international traveler returning from Singapore developed COVID-19 symptoms after more than 30 days inside China - despite undergoing all entry requirements, checks, and quarantine. Needless to say, the very strict regulations implemented in China will unlikely be implementable in many other countries. Understanding and explaining such developments better is crucial for the research community, particularly in light of travel restrictions.

Second, the travel bubble concept is mostly constructed around the
idea of pursuing COVIDZero inside the bubble, independent of the epidemic situation exterior to the bubble. The increase in vaccination opens the pathway towards travel bubbles which are not constructed around COVIDZero, but other possible goals and survival strategies. For instance, countries with mutually-high rates of vaccinations consider to fully open for human mobility and exchange. Such instance, however, usually do not refer to mutual bubble agreements, but rather a generic opening based on selected criteria, e.g., vaccination rates. The major question is what could be the rationale for locking parts of the (international) mobility, if very high fractions of the population is vaccinated. One such concern could be the importation of new variants of concern, which could still spread freely if reactions come too late (Sun et al., 2021b). Here, particularly, there is a significant risk of importing a variant which can gradually adapt towards breaking through vaccinations, especially if one allows interchange with various strains developed in different parts of the world - which will necessarily happen if all borders are reopened. Accordingly, the community needs to develop better models for variants of concern and how probabilities for emergence - if quantifiable - lead to optimal (partial, temporary) border closures or travel bubbles.

In this context, one should not neglect the fact that for most vaccines, the level of immunity is gradually reducing over time, which leads to the requirement of having booster shots. Even if one succeeds in building a highly vaccinated population - aiming to reopen all travel, the problem is presumably postponed. In most developed countries, it seems like the time of reaching a level close to herd immunity coincides with the time the earliest vaccine recipients require their first booster shots. This leads to a vicious cycle and highly unfair distribution of vaccines globally. The effects of the skewed vaccination might lead to severe troubles, not only in the developing countries with extremely low vaccination rates. For instance, the countries in Africa are reported by the WHO to be far from average vaccination levels of the developed countries. Nevertheless, as long as human mobility exists - and it seems clear after experiencing COVID-19 that it is infeasible to freeze the whole world for a given amount of time - there is a risk of further developing more long-term aggressive variants of concerns between highly vaccinated populations and more vulnerable ones. The scientific community needs to prepare solving this problem. Ultimately, travel bubbles can be understood as a rather local measure - where two or more partners agree to be special and leave the pandemic to bubble-external parties. This local strategy did not work out during COVID-19. Our study provided a retrospective glimpse of potential reasons, based on the failed Trans-Tasmanian travel bubble. We hope that considerations of travel bubbles during future epidemic outbreaks will be made more informed and science driven (Sun et al., 2021c).

Finally, we should discuss a set of limitations inherent to our study. First, this study has a strong topical focus on the Trans-Tasmanian case. While this discussion is instructive, a dissection of other travel bubble projects could lead to additional and complementary findings. Accordingly, future studies may investigate other cases. Second, and relatedly, the concept of a travel bubble is rather vague and might have different connotations for various stakeholders from different domains. Therefore, it would be of importance to derive a formal set of criteria and terminology for the future analysis of travel bubbles and related concepts. Finally, our study is a collection of impressions and interpretations based on the existing travel bubble experiments, without further analysis of the underlying data. Future work could analyze the actual extent of travel bubble materializations in different projects and verify a formal set of data-driven explanatory variables based on our framework.

Replication and data sharing

The results and figures in this study, as presented in Figs. 1 and 2, can be reproduced with our replication package. Data concerning the number of COVID-19 cases, deaths, and vaccination efforts can be obtained freely from Our World in Data (https://ourworldindata.org/coronavirus).

Commercial data concerning air transport connectivity can be obtained from various sources, we have used data from Sabre Airview Market Intelligence in this study (https://www.sabre.com/products/market-intelligence/). The aggregated data underlying Fig. 2 is included in the replication package for the sake of reproducibility.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Replication and data sharing

The results and figures in this study, as presented in Figs. 1 and 2, can be reproduced with our replication package. Data concerning the number of COVID-19 cases, deaths, and vaccination efforts can be obtained freely from Our World in Data (https://ourworldindata.org/coronavirus).
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