Understanding Elementary Statistics on COVID-19: Many Pandemic Research Questions Generated & A Couple of Potential Answers Found!

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Introduction

In the last year, I wrote two educational memos aimed at trying to understand and provide some perspective on the COVID-19 pandemic as it developed on a biweekly basis. These interpretations were based on: 1) academic experience teaching and using statistics analyzing differences across countries over many years; 2) comments from relatives, friends and colleagues; and 3) relevant information in the press and academic sources as the pandemic evolved. The first memo covers the period September 4 – December 11 2020 (http://econweb.umd.edu/~betancourt/development/Elementary%20statistics%20on%20COVID%2019.finalformatupdates.pdf). A second revised version covers the period December 25- March 19 (http://econweb.umd.edu/~betancourt/development/Elementary%20statistics%20on%20COVID%2019.%20New.finalformupdates.pdf).

Towards the end of March 2021, I decided to stop the biweekly interpretations for various reasons indicated at the end of the second memo above. At least a year has passed since the pandemic got started almost everywhere around the globe, albeit at different paces. Thus, it seems useful at this point to take stock of what the educational knowledge acquired implies, if anything, for ongoing and future research on the pandemic since the latter is far from over everywhere as well as likely to continue, perhaps for years, in some places. In the present essay, I identify patterns arising from the evolution of the COVID-19 pandemic as described by the biweekly data and its interpretation. These patterns allows countries' classification into two different groups in terms of an observable approach towards COVID-19. This classification and patterns revealed by a further exploration of the data and connections with the literature identify various explicit and implicit strategies employed by countries or spatial units that lead to various health and economic outcomes. These strategies are worth highlighting in designing current and future policies to address a pandemic. In the next section, I develop the basic classification and its rationale. In the subsequent section, I identify the basic long term strategies pursued by various countries or spatial units, implicitly or explicitly, their potential feasibility over time and some of their main economic consequences. In the last two substantive sections, I apply the final classification and the long- term strategies identified to an extension of the analysis in two dimensions: over time for the three biweekly periods between April 30 2021 and May 28 2021 to the initial spatial units and over a new set of twenty countries over the same period. A brief section concludes.

I The classification

The first step in the classification is a dichotomy based on the ability of a spatial unit to attain a level of transmission rate, or positivity rate, such that infections are not increasing exponentially. In terms of the epidemiological literature, one may think of this number as the Effective R^0, or Effective R 'naught', that can bring the pandemic under control. If the Effective R^0 is below or equal to unity, there is no pandemic; if the Effective R^0 is above unity, there is an ongoing pandemic. Unfortunately, the Effective R^0 is not directly observable at any point in time after a pandemic starts for two very different reasons.

1) R 'naught' or R^0 is the basic reproduction rate, which is a term used by epidemiologists in their models to capture the basic reproduction rate of a disease that determines its evolution into a pandemic. Just as

in the case of Effective R^0, values of R^0 below unity imply that transmission declines because each infected person transmits the virus to less than one other person in a population and there is no pandemic. Values of R^0 above unity imply that transmission increases because each infected person transmits the virus to more than one person. Values of R^0 equal to unity imply the disease will stay alive and stable but there will be no pandemic. Hence, the first reason the Effective R^0 is not directly observable is that R^0 itself is not directly observable once the pandemic starts. Because it depends on the intrinsic nature of the pathogen and the characteristics of the host population during 'normal times', i.e., before the pandemic starts (see Ives and Bozzuto 2021 for a formal definition and an attempt at estimation using county level data on death rates for the US). 2) A second reason the Effective R^0 is not directly observable is that, at any point in time after a pandemic starts, it depends on how the host population responds to the pandemic, to its non-pharmaceutical intervention policies (NPI's) and to the effectiveness of pharmaceutical interventions (PI's) available to the population. Hence, it will be constantly changing as these responses and interventions change, i.e., it is continually evolving.

Nevertheless, one can obtain estimates of the actual transmission rate for a country at any point in time by calculating it as the positivity rate (POR) or the ratio of the cumulative infection rate to the cumulative testing rate at a point in time, which is the definition used in this essay. The cumulative positivity rate over the 16 biweekly observations covering the period September 4 2020 to April 02 2021 for an idiosyncratically selected group of 18 countries and two spatial units (US states) within a country as well as the definition of the basic pandemic statistics used is available in Appendix 1. The latter reproduces the data in the second of the educational memos. In addition, I also include the 16^{th} biweekly observation (April 02 2021) for completeness sake. They will provide the basic data for the initial classification. An interesting research question is— **Can a sensible classification for policy purposes be used or developed during a pandemic?** My answer will be -- **Yes, provided we don't insist that a country's classification is immutable throughout the pandemic.** The rest of the section provides the argument.

Of course, the positivity rate estimates are subject to errors in both the numerator (the infections rate) and the denominator (the testing rate). Hence, it is useful to discuss briefly their nature. Tests are not perfect indicators of the disease as they yield both false positives (you have COVID-19 when you are free of it), and false negatives (you are free of COVID- 19 when you do have it). Second, testing rates vary across countries and over time for a wide variety of reasons. For instance, one that leads to a systematic underestimation bias in the positivity rate is testing the same person in a given time period more than once. Some other issues such as irregular reporting of test results or irregular fluctuations in testing periods disappear when using cumulative measures as we do here. Nonetheless, many other issues, for example tests availability and their composition and nature, remain even if one uses cumulative measures; similarly, stages of the pandemic can also affect the reporting of infections by health agencies, e.g., medical personnel taking care of patients in emergencies will prioritize patient care, as they should, over recording data. Thus, in principle, there can be overestimation or underestimation of the actual effective rate of transmission at any point in time. In any event, these considerations suggest a classification in terms of range of values of the positivity rate. Moreover, they also suggest considering additional information besides the positivity rate to check on the reliability of any initial classification.

Initially I settled on a classification of countries into two groups according to the range of values taken by the median positivity rate (MPOR) of these16 biweekly measuring points for 20 spatial units between September 4 2020 and April 2 2021. This initial classification is available in column 1 of Table 1 ordered by the value of the median positivity rate. Thus, if the MPOR fell in the range, .000 < MPOR ≤ .015, the spatial unit was classified as a **suppressor.** If the MPOR fell in the range .015 > MPOR ≤ 1, it was classified as a **mitigator**. The choice of a median less than or equal to .015 as a dividing line is somewhat arbitrary but it has three attractive features. First, medians are less sensitive than other measures of central tendency to extreme values. Second, the dividing line itself allows for possibilities of mistakes and their reversals by policy makers or measurement observers with no razor edge implication for the pandemic to increase or decrease as a choice of .010 would have when using the median as an estimator of the Effective R^0. Finally, it allows validation by considering the behavior of other statistics such as the range of values or of other variables that may be indicative of the spread of the pandemic, e.g., death rates changes. **Suppressors** are countries or spatial units that try to prevent or contain the epidemic from spreading fast enough to take hold in a country or area within a country. **Mitigators** are countries that for one reason or another (including willful or unwitting ignorance of its existence) fail at suppressing the epidemic before it embeds itself within a country or a substantial part of a country. Once the epidemic becomes endemic, what is feasible from a health perspective, especially in the absence of vaccines, is to mitigate or ameliorate its spread and effects until it runs out of new victims to infect exponentially or effective treatments and vaccines are developed and made available to the population.

Since the epidemiological literature cited above relies on the death rate as the most accurate basis for the estimation of R^0, column 2 presents the median value of the percentage change in the death rate in the biweekly period over the 16 periods for each spatial unit. Column 3 presents the vaccination rate on April 15 2021 available in a reliable source for 17 of the countries and the two US states in the table as an indicator of a pharmaceutical intervention that lowers both death rates (directly) and positivity rates (indirectly)[1]. Column 4 provides an opportunity for checking the initial classification using the median of the positivity rate against the actual value generated by the statistic for April 16 2021. The latter is the first out of sample period in the classification mechanism. Column 5 plays a similar role with respect to column 2. The only classification contradiction appearing in Table 1 when contrasting column 4 with column 1 is for the case of Cuba. Its median value (.010) is well within the suppressor category range. Yet, its actual value on April 16 2021 (.028) is 2.8 times its median value and well above the lower bound of the mitigators category (.015).

[Place Table 1 here]

[1] Incidentally, in Cuba's case the lack of data in the basic source on vaccination rates used for column 3 is to a large extent the result of a policy decision by the Cuban government. It chose to develop its own vaccines and not to participate in COVAX or buy vaccines from other countries. It has two vaccines in stage 3 trials, Soberana 2 and Abdala, according to an interview with the Director of the Finlay Institute reported in Nature (https://www.nature.com/articles/d41586-021-01126-4). For Soberana 2, he expects a grant of emergency use authorization in Cuba during the month of June. This vaccine is a new variant of protein subunit vaccines (one of the four types in use for COVID 19). It conjugates protein fragments that are safe but can generate weak immune responses with a tetanus toxoid to generate an increased immune response. Starting in May 14 2021, there is an entry in our basic source for Cuba, presumably counting the participants in the trials and others vaccinated before formal approval as in China.

Looking more generally at other values of MPOR in Table 1, one notices that there is a substantial jump in MPOR between the last pair of suppressors [Denmark (.011), South Korea (.013)] and the first pair of mitigators [Canada (.036), the UK (.038)]. Similarly looking at values below Cuba one notices that the MPOR for Australia (.003) is 3 times lower than the one from Cuba. If one looks at the whole range of values of the POR over the 16 periods, one notices that for Cuba it goes from .008 on October16 2020 to .026 on April 2 2021, revealing an increasing trend since January 08 2021. On the other hand, in Australia the range of values goes from .004 to .002 over the period, revealing a constant or decreasing trend over the whole period since September 4 2020. In Denmark, the range of values peaks at .016 on January 22 2020, exhibiting a systematic decreasing trend thereafter until reaching .009 on April 2 2021. Thus, it makes sense to move Cuba over Denmark using the range and its pattern instead of the median as a criterion. When we look at South Korea, its range peaks at.015 on January 8 2021, decreasing slowly or staying constant until reaching a value of .012 on April 02 2020. Hence, it also makes sense to place Cuba above South Korea in the classification based on the range statistic. Finally, the range of the POR for Canada fluctuates during the period between .070 and .022, reaching a secondary peak at .044 on January 8 2021. From there it decreases slowly to a value of .036 on April 02 2021, which is substantially higher than Cuba's at .028.

A similar analysis of column 2 as an alternative indicator of the spread of the pandemic is available as Appendix 2. It leads to the same conclusion: namely, placing Cuba in the **mitigators** category. In subsequent sections, we employ this 'final' classification. We conclude this section, however, by noting one more feature of Table 1. More specifically, the substantial decreases in the biweekly per capita death rates associated with increased vaccinations in the UK. Column 3 reports the number of administered doses of vaccines per million persons in the population, or the vaccination rate in a country, as of April 15 2021. It shows the second highest value for the vaccination rate is for the UK (60.30). Furthermore, the UK has the highest percentage decrease from the median positivity rate to the first out of sample positivity rate of any country in the table. It decreases from .038 to .031 (or .007/.038 = 18%) and the highest percentage decrease from the median percentage change in the two week death rate (.009) to the first out of sample change in the two week death rate (almost.000). It goes from .009 to almost .000 or almost 100%. This suggests that vaccination campaigns, despite all their difficulties, can control the pandemic, at least at observed transmission rates below 5%. **Does this result hold at higher levels of transmission rates?**

While Chile has the highest vaccination rate in the table (66.6), it also has a high positivity rate (i.e., three times that of the UK). That is, Chile's POR decreases from a median of .098 to a first out of sample period of .091 for a decrease of 8.1% (.008/.098x 100), but in contrast to the UK there is a percentage increase between the median death rate (.005) and the out of sample first period change in the death rate (.007). This shows that the effect of vaccination rates on death rates varies rather widely with the level of positivity rates. Thus, it suggests following the pattern of vaccination rates to understand patterns in positivity rates and in death rates during the rest of the pandemic's duration.[2] Hence, in Table 3 we follow the biweekly evolution of the pandemic in terms of three variables: POR, % ΔDR (L2wks), and the vaccination rate, using our 'final' classification. It starts with the biweekly period that ends on April 30 2021 and, initially, stops with the one that ends on May 28 2021. The simple analysis

[2] Incidentally, it would be naïve to expect or assume this 'final' classification to remain immutable throughout the rest of the pandemic for any particular country. Yet, by performing an analysis similar to the one in this section and in Appendix 2, one can easily evaluate whether or not there is a need to reclassify a spatial unit at anyone point.

here, however, already raises additional important questions for future research. If countries end- up as mitigators, whatever the reason --. **Is it possible to contain the virus in a year or so through vaccination campaigns regardless of the transmission rate experienced in the initial stages? Are there transmission thresholds, or ranges for the observed POR, when it becomes futile to do so for epidemiological or economic reasons and, if so, what are they?** We will present additional information relevant for these questions in Sections III-V.

II. Basic Long Term Strategies Responding to the Pandemic.

In order to gain insights into successes and failures of policy responses to the health aspects of the pandemic, we will use the information in Table 2 below to identify three basic strategies relied on, explicitly or implicitly, to respond to the pandemic by our original twenty spatial units during 2020 and 2021. This approach, however, requires defining what we mean by basic strategies that are available at a given stage of the pandemic to any one spatial unit.

In the early stages of a pandemic, a country's potential policy response is limited to non-pharmaceutical interventions (NPI's). In the case of respiratory diseases such as COVID-19, the two basic type of policies available are population-based policies (PBP) and case-based policies (CBP). The former include mask wearing, hand washing, social distancing and lock-downs of the population varying in extent, severity and effectiveness. The latter also include lock downs of varying extent, severity and effectiveness but, in addition, they stress testing, contact tracing and subsequent quarantine and isolation restrictions based on test results (e.g., see https://theconversation.com/how-taiwan-beat-covid-19-new-study-reveals-clues-to-its-success-158900). We have direct statistical information available on testing rates. The latter are important for successful implementation of CBP. If a country is unable to test, it has to rely on population-based policies. Of course, countries that are able to test can also rely on population-based policies. Indeed, Taiwan's initial success in controlling the pandemic in the citation above stresses that it used both while providing evidence of the greater effectiveness of the population-based policies.

Lock-downs are short-term policies that can be very effective if severe enough and wide enough in relevant population coverage, especially at the beginning of a pandemic. Unfortunately, they are not that feasible and effective in practice. This is especially the case in their most draconian forms as long-term policies (more than a year continuously, for example) due to fatigue and/or severe negative economic consequences. Hence, the basic long- term population- based policies included, as a strategy pursued (implicitly or explicitly) by a country or spatial unit, will be mask wearing, hand hygiene and social distancing. Similarly, with respect to cased-based policies, the testing rate will be the basic case-based policy used, since we have no direct information on contact- tracing or on the effectiveness of quarantine and isolation policies actually implemented across countries.

Finally, among the pharmaceutical policy interventions (PI's), we have vaccines and treatments. We have statistical information on vaccination rates but none on treatments. While the latter certainly affect death rates as a curative strategy, I will focus on vaccination rates, which affect death rates directly as well as positivity rates indirectly as a preventive strategy. Moreover, we have excellent data on this policy across countries. Thus, we will view vaccine- based policies (VCP) as the main long-term PI policy that a country adopts, explicitly or implicitly, at any point in time and not consider treatment explicitly. Summing up, we will classify each country in Table 2 into one of the above 3 basic categories of policies PBP, CBP and VCP during 2020 and 2021. This information is available in the last column of both Table 2, where the entry indicates our policy classification judgement for 2020 and 2021.

[Insert Table 2 here]

The basis for our judgement is a set of characteristics of the country (or spatial units) helpful in identifying potential policies and their impacts during the pandemic. While all strategies are employable simultaneously if feasible, not all are equally feasible for a country due to a variety of reasons or would have the same impact depending on country characteristics. The latter are helpful in identifying the primary policy adopted. Adoption possibilities also vary with the stage of the pandemic. In the initial stages only PBP are available but CBP ones, which require a minimum of testing, became implementable rather quickly in the case of COVID-19, i.e. early in 2020. Of course, vaccines have become available slowly for most countries and hardly any country can make a convincing case that they have eliminated the pandemic as of early June 2021 on this basis. For instance, a country that was one of the most advanced in administering vaccinations at the beginning of May 2021, e.g., Seychelles archipelago, is in the midst of a new wave after having fully vaccinate over 60% of their population. It had to institute a new two- week severe lockdown (https://www.bloomberg.com/news/articles/2021-05-04/world-s-most-vaccinated-nation-reintroduces-curbs-as-cases-surge). Fifty-nine % of their vaccines were from Sinopharm. The latter have lower effectiveness than Moderna or Pfizer, according to Chinese experts. The same vaccine rate may have a different impact on positivity rates and death rates per capita, depending on the effectiveness of a particular vaccine employed.

From an economic point of view, the direct costs of implementing each of these strategies, in terms of products required for their implementation, are easily ranked from lowest to highest, i.e., PBP < CBP < VBP. The benefits are more complicated to estimate for a wide variety of reasons. In any event, for the case of Taiwan the PBP generated more benefits than CBP according to the study cited above. Yet, the basic conclusion of the study was that Taiwan's early success was due to the adoption of both strategies. Some preliminary numerical estimates of the benefits and costs of PBP are available in the context of a large- scale experiment in Bangladesh exploring nudges to make masks and social distancing more likely to be accepted by the population in rural areas. This information is available in material associated with a webinar by Professor M. Mobarak of Yale University, who directs the project. During a webinar organized by NCAER on April 26 2021 (https://www.youtube.com/watch?v=MJCEMvZOnrc), Professor Mobarak indicated that final estimates using actual data from the project, as opposed to literature estimates for some of the costs and benefits, should be available after June 2021.

Health outcomes from countries' initial response to the COVID -19 virus were determined by many initial conditions, in addition to the actual policies employed explicitly or implicitly. These conditions included previous experiences with serious contagious diseases, especially respiratory ones, social and medical infrastructure, political systems' ability to confront the issue (including leadership styles), and even geographical or other characteristics that enhanced or diminish the effectiveness of lockdowns. Table 2 presents the cumulative per capita deaths per million persons in the population as of April 30 2021 for each spatial unit. This is the main welfare outcome of the pandemic from a health perspective. The next column provides a classification of the spatial units into three income levels (High, Medium and Low), relying on the World Bank's Gross National Income per capita classification for 2019. The third column provides the population density of the spatial unit. Since COVID-19 is a respiratory disease, the impact of any policy, especially the NPI ones, interacts with this initial circumstance in determining outcomes. Low- density countries have greater room for policy incompetence without feeling the health consequences as much as high- density countries, at least in the short-run. Column 4 provides the cumulative testing rate per million persons in the population as of April 30 2021 as reported by

Worldometer. Column 5 provides the rank among spatial units by testing rate to highlight the choice of NPI policy implied during 2020. Column 6 provides the percentage of population over 65 for 2019 in a spatial unit to highlight the difficulty experienced by the unit in preventing the most serious health consequences of COVID-19 for its most vulnerable population. Columns 7 and 8 provide the vaccination rates of a spatial unit on 3/31 and 5/23 2021 to evaluate vaccination progress in 2021 as a policy response among spatial units. Finally, column 9 provides our summary judgement based on these data of the main policy responses adopted by a spatial unit during 2020 and 2021 as a long-term policy strategy (LTPS).

After a year and four months of the pandemic, suppressor countries have less than five hundred cumulative deaths per million persons in the population. Moreover, 4 out of 5 suppressor countries have less than 50 cumulative deaths per million. The one exception (Denmark) has the highest testing rate out of the 20 spatial units. Hence, we classify the former four countries as relying on PBP as its long-term policy strategy during 2020. Since they also rank in the bottom half of the 20 units in terms of vaccination rates at the end of May [12, 15, 16 and 17], they also classify as primarily PBP in terms of LTPS during 2021 at this point. Denmark has the highest testing rate out of the 20 units in the sample and by a wide margin (e.g., by a 2.8 ratio relative to its nearest competitor, the UK). It also ranks 8th in terms of its vaccination rate among the 20 units at the end of May 2021. Thus, we classify Denmark as relying on a CBP as its primary LTPS during 2020 and 2021. Incidentally, note that in terms of the direct benefit of lowering the death toll the PBP countries have an above 10 to 1 ratio in their favor compared to the CBP! This insight generates several worthwhile research questions.

For instance, **What is the role of population density, if any, in a country's ability to suppress or mitigate a respiratory virus during a pandemic**? Consider that, among the suppressors relying on PBP as a LTPS in 2020, New Zealand ranks first and Australia ranks third among the 20 spatial units with respect to low values of this variable. But, South Korea ranks last (20) and China 11 while the pursuer of CBP as a LTPS in 2020 ranks 10. **What economic costs did these four countries suffer in foregone income relative to the ones relying on CBP?** It is not obvious what the answers are but any insights on why successful countries relying on PBP as a LTPS during the first year of a pandemic experienced such low costs in term of this important health outcome are extremely worthwhile for public policy in the health area.

Moving on to the 15 spatial units classified as mitigators, all of them have more than 50 cumulative deaths per million. Moreover, 11 out of the 15 spatial units have more than 500 cumulative deaths per million (9 out of 15 have more than a 1,000). Of the four that have less than 500 cumulative deaths per million, all rank in the bottom third of the testing rate (14, 17, 18 and 20), suggesting reliance primarily on population- based policies during the first year of the pandemic. Moreover, they also rank in the bottom third of the vaccination rate at the end of May 2021 [14, 18, 19 and 20] suggesting reliance on population based policies at this point in 2021.[3] **Are these four countries sticking to their PBP for idiosyncratic reasons?** For example, Cuba is betting on its own vaccine development, Japan on athlete's bubbles and external lockdowns during the Olympics, Jamaica on being an island and having a young

[3] It is worth noting that Cuba explicitly adopted a vaccination-based policy by developing their own vaccine but at the end of May had not yet gained emergency use authorization from their own regulators. The number of doses reflected participants in stage 3 trials and front line workers. Nonetheless, it seems warranted to classify them as VBP in terms of their LTPS for 2021 at this time.

population with only 9% over 65, El Salvador on a very repressive lockdown as well as a young population with only 8% over the age of 65.

The two countries having between 500 and 1000 deaths per million (Canada and Germany) rank 9 and 11, respectively, on testing rates, suggesting CBP for 2020 for Canada and PBP for Germany as LTPS. On the other hand, they rank 6 and 7, respectively, on vaccination rates by the end of May, suggesting VBP as their LTPS for 2021. Of the remaining nine spatial units, three are European countries (France, Spain and Italy) that rank 6, 7 and 8 on testing rates and 11, 9 and 10 on vaccination rates, respectively. Thus, we classify them as CBP LTPS for 2020 and VBP for 2021. Four of the nine spatial units are Anglophone areas (UK, Maryland, USA and Florida) that merit the same classification as the European countries, using the term policy loosely and ignoring its lack of applicability to the early part of 2020. In early 2020, the policy makers in three of the four Anglophone areas (except Maryland) were in denial of the existence of a pandemic, and two of them (USA and Florida) were badmouthing PBP policies. In any event, we will assign them as CBP LTPS in 2020 (testing rate rank 2, 3, 4 and 5, respectively) and VBP in 2021 (end of May rank 3, 1, 5, and 4, respectively). The last two countries among these nine (Brazil and Chile) are South American countries where the virus took longer to arrive.[4] In addition, one of them, Brazil, had a policy maker in denial of the seriousness of the virus. Their LTPS 2020 policies were PBP for Brazil and CBP for Chile (testing rates rank 15 and 10, respectively) and their 2021 policies were VBP for both by the end of May although Chile's was far more effective (vaccination rate rank 13 and 2, respectively). The Brazilian policy leader switched from badmouthing the Pfizer's vaccine effectiveness to making a big purchase on behalf of the country. In addition, Brazil has ordered purchases of vaccines produced by countries where their own regulators have not granted emergency used authorization.

This discussion raises the question -- **How effective are VBP as a LTPS once the pandemic has run rampant over a year as in the case of COVID-19**? If by effective, we mean preventing deaths and severe negative health outcomes due to COVID 19 this will obviously depend on the impact of three factors: Effectiveness of earlier policies in doing so while vaccinations are implemented; effectiveness of vaccines per se; effectiveness in the implementation of vaccination policies. The only factor on which we have a substantial amount of reliable information is the second one. At least four of the vaccines have a powerful impact on eliminating the most severe outcomes, namely death and hospitalizations. These are Pfizer, Moderna, J&J and Astra Zeneca. The first two also prevent infection over 90% of the time while the second two at a rate in the low 70% range or lower. The impact of the first and third factor varies by country, by policy employed, by the behavior of the population and by the competence of its government and health system in getting people tested, contacted (through tracing), quarantined and actually vaccinated.

III. **A Time series Application: The Original 20 Spatial Units.**

In this section, we apply the classification to a time series setting by looking at the data on positivity rates and percentage changes in death rates per capita together with the data on vaccination rates for three periods beyond the ones used to derive the classification. In the next section, we apply the classification to the same three biweekly period for a new set of 20 countries.

[4] Since they are located in the Southern Hemisphere, their seasonal patterns differ from those in the Northern Hemisphere lying at similar distances from the Equator. In Chile's case, for example, this means that by the end of August 2021 it will have experienced two full Winter seasons with the virus while the US and Europe have experience only one full Winter season with the virus.

[Insert Table 3 here]

Table 3 provides information on the evolution of the positivity rate, the percentage change in the biweekly death rate per capita, the vaccination rate in terms of total administered doses for each of three biweekly periods as well as LTPS in 2020 and 2021 identified in Section II. The three most successful suppressors have managed to keep positivity rates constant at values less than or equal to .002 at this level of aggregation and the percentage death rates per capita constant at zero during these three biweekly periods. Moreover, they have done so, at least up to April 30 2021, with very low levels of vaccination of their populations. They have relied on PBP policies for all of 2020 and the first five months of 2021. All three countries have been able to resume normal activities within the countries and experienced lower drops in their economic activity in 2020 due to their lockdown policies than many other countries. An important difference between China and the other two countries has been in the severity of restrictions with respect to closing down travel from outside into their own countries. Australia and New Zealand have imposed more severe restrictions than China in this area, including policies with respect to their own citizens caught outside the country. **Differences between China and these two countries in policies and health and economic outcomes are an interesting research question that may be difficult to answer for a variety of reasons, including data reliability in the case of China.** For instance, the cumulative testing rate per million persons reported for China every two weeks between September 4 2020 and May 28 2021 has been the same, 111,163. The cumulative infection rate has varied a little, starting at 59 per million persons and ending at 63 per million persons. This has not affected the positivity rate at the third decimal due to rounding. In any event, future research should look at this issue. That is, -- **Does the same pattern identified here for China also arises in a database other than Worldometer, e.g., John Hopkins?**

South Korea and Japan have also pursued PBP policies during both 2020 and the first five months of 2021, but they have been less strict than the above three countries. This is especially true for Japan with its lockdowns characterized as soft lockdowns, e.g., allowing far more internal mobility than the above suppressor countries. Not surprisingly, the impacts on Japan's POR and changes in death rates per capita relative to these suppressor countries reflect these differences. **An obvious interesting case study for future research is an in depth examination of these differences and their impact on health and economic outcomes.** For instance, while the cumulative death rate per capita at the end of April 2021 is similar between Australia and South Korea, 35 versus 36, it is more than twice the level of both countries in Japan (80). **Is this due to Japan having a percentage of older population (25) almost double that of South Korea (13) (Australia is 15) or due to South Korea's recognized enlightened policy towards COVID-19 stemming from their unhappy experience with MERS relative to Japan's soft lockdowns?** (https://ourworldindata.org/covid-exemplar-south-korea)?

Denmark provides an interesting contrast as a suppressor country because it adopted a case based policy early on in an attempt to suppress the COVID-19 early so it could open quickly. This strategy, or Danish model, was an explicit science based choice, including expectations that vaccines would become available quickly, e.g., see https://www.institutmontaigne.org/en/blog/europe-versus-coronavirus-putting-danish-model-test. The sizable difference in testing rates per capita between Denmark and everyone else continues to exist throughout all stages of the pandemic, thus far. Furthermore, Denmark has been putting vaccines in the arms of citizens more rapidly than any other suppressor country as well as at comparable rates to European mitigators such as Spain, Italy and France. Moreover, it has had a more successful effect in slowing down the increase in death rates per capita during May 2021, [(.012-

.005)/.012]*100 = 58.3%, than any other European country in the table, with France coming closest at 57.2%. Similarly, it has slowed down its positivity rate by a greater percentage, [(.007-.005)/.005]*100 = 28.6%, than any other European country, including the UK which has a much higher vaccination rate.[5]

Denmark's cumulative death rate per capita at the end of April 2021 is less than half that of Germany, the next lowest among the mitigators, and less than a quarter that of Italy, which is the highest among the European mitigators. **An interesting question for future pandemic research suggested by these facts is – Does this favorable trade-off in health outcomes for Denmark also led to a favorable trade-off in economic outcomes compared to the five European countries categorized as mitigators?** Comparisons with Germany could be especially fruitful in that their approaches were similar in some ways but different in others**. More specifically, since the German approach took place in a federally decentralized system and the Danish one in a far more centralized one, --Is decentralization a main reason for the sizable difference in per capita death rates, including the far greater reliance on testing adopted by the Danish?** Of course, narrower questions can also be of great research interest for special sub-disciplines within economics. In the case of education, for example, Denmark was able to return to in person learning by the end of April 2020. **How much did Danish children benefited from in person learning during the pandemic relative to those of other countries?** For example, in the US specific states or counties have had part of their public school systems in online learning mode (Maryland) from March to December 2020 or in an online combined with hybrid mode (Florida's Miami-Dade) since Fall 2020.

Among the mitigator countries, Germany became an exemplar country early in the pandemic and its exemplary analysis was included in a revision that takes us to the spring of 2021 (https://www.exemplars.health/emerging-topics/epidemic-preparedness-and-response/covid-19/germany). A bit of good news is that in terms of death rates per capita Germany maintains its early advantage relative to other European countries and almost equality with respect to Denmark until October 30 2020. Unfortunately, the bad news is that Germany moves closer and closer to other European countries in the mitigators category in terms of positivity rates and farther and farther away from Denmark with respect to the positivity rate. Indeed, while Denmark's positivity rate peaks in early 2021 (January 22) at .016, Germany's overtakes the UK permanently on December 11 2020 at .042 and is still rising toward the levels of the other European countries on May 28 at .062! Since positivity rates are leading indicators of the extent of the pandemic and death rates per capita are lagging indicators, these trends are worrisome. Indeed, they raise a larger question -- **Is there a level of the positivity rate at which we can expect both the death rate per capita and the positivity rate to persistently decline due to increasing vaccinations?** France, Italy, Spain and the UK seem to have gotten there; Canada and Germany have not. **Could it be reliance on population based policies in the early periods of a pandemic, which are often associated with stop and go or selective lockdowns, or is it that Germany and Canada are more effectively decentralized than the UK, France, Italy and Spain, or something else?** In any event, the results from Table 3 for the USA, Maryland and Florida seem to indicate that the answer is not associated with a particular threshold value of the positivity rate below .080. Moreover, the results for Chile suggest that the threshold, if it exists, generates a nonlinear relationship among

[5] In contrast to the UK, it has not delayed the application of the second dose to cover a wider set of members of the population.

these variables. Finally, the results for El Salvador Jamaica, Brazil and Cuba are not reliable to answer questions of the type raised above at this stage given their low levels of vaccination rates.

IV. **A Cross-Section Application: A novel Set of 20 Countries**

We now turn to a more difficult task, which is to consider a similar analysis for a new set of 20 countries. This new set is a result of my perceptions of limitations of the previous set in terms of geographic, demographic and standard of living coverage. First, I wanted countries in Southeast Asia 'close' to China in various ways because they were more likely to have information on the virus early on and similar cultural customs. It led me to the inclusion of the following ones. Taiwan because it has geographical and cultural proximity to China as well as a strong national security interest in keeping up with events there. Vietnam has geographical proximity by sharing a border as well as complex interactions with China due to nationalism and alliances. Singapore has a substantial majority ethnic Chinese population (about 76%) as well as economic/cultural affinity emphasizing material prosperity of its citizens. Thailand has geographical closeness despite not sharing a border together with a different ethnicity. Finally, Malaysia is farther away than the previous ones geographically, has a different ethnicity but a substantial Chinese ethnic minority (about 23%).

Second, I wanted countries in South Asia. Hence, I included India, Pakistan, and Bangladesh due to their population sizes and Sri Lanka for completeness sake. Third, I wanted African countries. This meant South Africa for its importance in terms of its interconnections with the rest of Africa and the world as well as population size and Egypt and Nigeria due to their population sizes. I added Kenya and Botswana for idiosyncratic reasons (history of ethnic strife and of positive economic performance, respectively). Fourth, I wanted more Latin American countries. Hence, I chose Argentina and Peru due to their size and fully lying in the Southern Hemisphere and Colombia and Costa Rica due to their democratic governance. Finally, I added Bahrain and Israel to have middle-eastern countries with the ability to purchase vaccines. With respect to income, the original 20 countries include 15 with high- income status using the World Bank definition for July 2019-July 2020, GNI per capita > $12,535; the new 20 countries include four considered high income by that definition. At the other end of the spectrum, the original 20 countries include two considered low- income status $1,036 < GNI per capita < $ 4, 046 and the new 20 countries include eight that satisfy that definition. While another eight are middle income among the new countries, i.e., $4,046 < GNI per capita < 12, 535, three are middle income among the original ones. Finally, no very poor countries are included, i.e., countries having a GNI per capita<$1, 036. These countries represent 9 % of the world population and have very limited strategic choices to address the pandemic.

[Insert Table 4 here]

I constructed a table similar to table 2 for these 20 countries (Table 4). I applied the same classification based on a POR ≤ .015 to classify a country as a suppressor country and POR > .015 to classify a country as a mitigator country. I begin observing these countries just before April 30 2021 and apply the classification to the value they exhibit on April 30 2021, since the median value of 16 biweekly observations for the three variables of interest is not available. While using a single value to classify a country makes our task more difficult, it also provides a tougher test of the value of the classification during the evolution of a pandemic. Our first task is to use the information in Table 4 to identify the LTPS pursued by these countries. Since there were no vaccines administered to the population prior to December 2020, we can use the cumulative testing rate and corresponding rank to identify three of the four suppressor countries as relying on PBP in both 2020 and 2021. The exception is Singapore. The latter LTPS relied on a CBP in 2020, due to its cumulative testing rate and rank in 2020 (2), and on a VBP in 2021, due to its vaccination rate on May 23 2021 which was higher than that of any European country except the UK.

With respect to the mitigator countries, all but two (Bahrain and Israel) had cumulative testing rates below unity. Indeed, the highest testing rate below unity was Botswana with 0.42. Therefore, Botswana and every lower ranked country on its testing rate was classified as having a PBP in 2020 as part of its LTPS while Bahrain and Israel were classified as having a CBP in 2020 as part of its LTPS. Only the latter two countries had rates of administered vaccines per 100 persons above 25.00 (90.82 and 121.91, respectively) among the mitigator countries. Thus they followed VBP in 2021 and everyone else followed PBP in 2021` as part of their LTPS.

With this preliminary discussion out of the way, we can now consider the evolution of the pandemic in these countries during May 2021 on the same basis as we did for the 20 spatial units in Table 3.

[Insert Table 5 here]

Considering the classification of all 20 countries, one can observe that there is a big gap between the four **suppressor** countries and the 16 **mitigator** countries in their positivity rates at the time of classification on April 30 2021. That is, the ratio of the positivity rate for the first **mitigator** country (Sri Lanka) over the positivity rate for the last **suppressor** country (Thailand) is over five. Thus, the classification seems to do a good job of separating these 20 countries into two sets of countries facing the pandemic in spite of basing it on a single observation in this application. We will consider the evolution of the two subsets separately.

Three of the four suppressor countries have followed a population-based policy in both 2020 and 2021. The exception is Singapore, which has followed a case based policy in 2020 and a vaccination-based policy in 2021. It has a cumulative testing rate that ranks second among these 20 countries and would have ranked third among the original 20 spatial units. It was successful in keeping the positivity rate substantially below unity and enjoyed long periods of normal life within the country despite the pandemic and occasional clusters of infection. Interestingly, it is currently having one infection outburst attributed to vaccinated individuals infected in April 2021 with the new delta variant arising in India, B1.617.2, which is much more transmissible (https://www.washingtonpost.com/world/asia_pacific/covid-singapore-lockdown-virus/2021/05/21/8870ca20-b6f5-11eb-bc4a-62849cf6cca9_story.html). After a virus free year and a vaccination rate slightly higher than all European countries in Table 2 except for the UK, its response has been imposing severe lockdown restrictions again and vaccinating as much of the population as possible to deal with this situation. **How long will it take to control the virus again?** This will determine the magnitude of the economic costs. Thus far, Singapore has avoided the most severe health costs of the new outburst as evidenced by no change in the death rate during the month of May. Singapore's high income makes a response based on increased vaccinations feasible. Its having the highest population density of any of the 40 spatial units in the two tables makes it imperative to succeed quickly if it wants to control the health and economic costs of severe lockdowns.

Of course, the other three suppressor countries are also dealing with recent outbursts that manifest themselves, in contrast to Singapore's, in our elementary statistics at this stage. Their reliance on population- based policies has led to somewhat different manifestations of this issue. Vietnam, viewed as one of the exemplar countries in dealing with the virus last year, shows the beginning of an outburst through a 25% increase in its death rate in the last two weeks of May 2021. Vietnam's success in controlling community transmission of the virus in 2020 with a PBP was due to several factors: prior experience with pandemics, starting with SARS, substantial investment in its public health system, including testing and digitalization, as well as flexibility and agility in addressing local outbursts despite being a highly centralized country (https://ourworldindata.org/covid-exemplar-vietnam). One consequence of that success was one of the highest rates of economic growth in the world during 2020. It has had a recent outburst leading to a 25% increase in its death rate in the last two weeks of May. It has responded by instituting lockdown restrictions nationwide, because the new infections in May constitute half of the total number of infections since the beginning of the pandemic in early 2020 (https://www.npr.org/sections/coronavirus-live-updates/2021/05/29/1001590855/vietnam-detects-new-highly-transmissible-coronavirus-variant).

An even more dramatic change takes place in Taiwan where the death rate increases by 500% in the last two weeks in May and the POR increases six-fold. Once again, a very successful suppressor in 2020 faces a novel outburst in 2021. Its response is a severe lockdown and speeding up vaccinations. Nonetheless, one sees in Table 5 that the latter are at very low levels. I suspect the pace and implementation could pick-up very rapidly, assuming recent accusations about China are false or vigorously addressed by Western democracies, i.e., if claims about China's attempts to prevent Taiwan from access to vaccines are false or thwarted. **In the latter case, will democracies have the courage to do so?** https://www.cnn.com/2021/05/21/asia/taiwan-covid-vaccine-intl-hnk/index.html Finally, Thailand experiences a substantial increase in its death rate in all three biweekly periods (50%, 166.7% and 75 %, respectively) as well as sizable ones in its POR. Its response has been to increase the level of corona virus restrictions nationwide and to grant additional discretion to provincial governors (https://www.reuters.com/world/asia-pacific/thailand-reports-2438-coronavirus-cases-daily-record-11-deaths-2021-04-25/). While the main variants responsible for the outbreak vary across the four suppressor countries, the story is similar in that, in the absence of a rapid increase in vaccinations, the main response its introducing severe lockdowns and restoring the intensity of their population based policies in terms of mask wearing and social distancing together with whatever testing thy can implement. The only country where increased vaccination seems likely to be effective in controlling the virus in the short-term seems to be Singapore. **An interesting research question is a comparison of the economic costs and benefits of Singapore's strategy relative to the other suppressor countries version of PBP during the second half of 2021 as well as during the whole two- year period**. **Similarly, Is Thailand's departure from the suppressor category temporary(less than six months) or permanent, i.e., greater than six months?**

Among the mitigator countries, the first six are experiencing substantial increases in their death rate over these three biweekly periods. This is the case even for Israel, which has the second highest vaccination rate in the world and for Bahrain, which has the third highest. Moreover, the magnitude of the death rate increase gets higher over time for the first five and it is still over 20% in the last biweekly period for the sixth country. The long and the short of it is that the third wave of COVID-19 affecting the suppressor countries seems to be also affecting these first six mitigator countries. India's struggle with COVID-19 has been in the news as a potential catastrophe in the making. This third wave impact suggests that, while high vaccination rates are desirable and worth pursuing vigorously by countries, attaining herd immunity may be harder to reach than previously thought. Indeed, one of the epidemiologists commenting on the local situation for one of the suppressor countries suggested that 80% as opposed to 70% was a reasonable target in light of this third wave. Thus, it raises an important research question-**What is the most desirable combination of long-term policies to address the COVID-19 pandemic? Is it possible that it includes social distancing and mask wearing on and off during the next two or three years?**

The next five countries in Table 5, in terms of their POR, are all low- income countries with high rates of transmission (between 7% and 13.5% by the end of May), death rates below 10%, and low vaccination rates. Nigeria's 0% change in death rates for three consecutive biweekly periods stands out. **Is it due to faulty data? Most likely, because it has the largest population among the African countries and the lowest testing rate per person.** Bangladesh's high positivity rate (twice that of India) together with its second highest population density among the twenty countries in this table (which is also higher than that of any spatial unit in Table 2) cries out for special attention. This is especially troubling in light of the crisis- situation in India at a much lower level of the POR. It raises interesting but difficult to answer research questions-- **Are the high death rates per capita faced by India a consequence of the populist activities of its Prime Minister and of much poorer implementation of PBP as mitigator policies than Bangladesh, or of something else?**

Finally, the last five countries in Table 5 have positivity rates between 15% and 27%. These rates are higher than the ones for any spatial unit in Table 3 with the exception of Brazil. South Africa is the country with the highest POR rate and death rates per capita in Sub-Saharan Africa. The other four countries are Latin American ones. Peru's death rate per capita is the highest in Latin America. While the biweekly rate decreases in May, a substantial data revision at the beginning of June 2021 reveals the dubious distinction of highest death rate per capita in the world. In Argentina and Colombia, both the POR as well as the percentage change in biweekly per capita death rate increases during May. The same is true in Costa Rica, which increase from a much lower base in terms of death rates per capita. Finally, vaccination rates in all five countries are low when compared to Europe although much higher in the Latin American countries when compared to the African or Asian ones, except for Singapore. If this coming 'third wave' health shock leads to similar consequences as previous ones, the economic trauma could be severe. For example, Kaishu Basu wrote in a recent Brookings report "In 2020, Latin America's economy contracted by 7.7 percent; the Philippines and India took even bigger hits, registering growth rates of -9.5 percent and -9.6 percent, respectively." (https://www.brookings.edu/opinions/the-post-pandemic-whiplash-awaiting-the-worlds-poor/?utm_campaign=brookings-comm&utm_medium=email&utm_content=133186369&utm_source=hs_email).

Once the pandemic has been going on for a significant length of time, let us say at least a year, the use of a single two- week period for classification does not generate any obvious problems in the absence of new major shocks. On the other hand, in the presence of a new major shock such as the third wave one associated with the delta variant, there are new questions – What is the impact of a more transmissible variant in preventing a return to normal at various stages of vaccination? A preliminary answer in the case of the UK is a one- month delay in removing internal restrictions and a questioning of the effectiveness of international restrictions that allowed the variant in. What will be the case in the US where 6% of the cases are already due to this variant? While the answer is uncertain, the need for monitoring seems warranted by two facts: 1) the high variation in POR's in the US (e.g., Florida's is about 1.8 times that of Maryland) and 2) a high average level of POR (7.1%) at the end of May for the whole USA..

Concluding Remarks

Some important broader research questions arise by the possibilities generated through the analysis of Tables 3 and 5. First, in the context of the high-income countries—**Is it feasible for vaccine penetration to take place fast enough that high income countries reach close to pre-pandemic levels of economic activity within a year or a year and a half, i.e., by July 1 of 2022 or January 1 of 2023?** Even for successful suppressor countries such as Australia and New Zealand, the answer is not obvious since they still have severe international travel restrictions and lifting them without the virus under control elsewhere could generate serious outbreaks without a substantial proportion of their populations vaccinated. A similar issue arises for Taiwan and South Korea. Singapore, on the other hand, seems better placed to answer this question in the affirmative by having relied on all three policies as a LTPS. A similar conclusion applies to Denmark.

More generally, some high- income countries that were unsuccessful suppressors but relatively successful mitigators in terms of deaths per capita with PBP policies, e.g., Japan, might find themselves at a disadvantage in suppressing the virus quickly due to their lack of emphasis on vaccinations**. Will the Olympics provide evidence on the merits of that LTPS for Japan?** A case study comparing Japan's strategy with the UK or the USA might generate interesting insights on the health and economic costs and benefits aspects of relying excessively on one policy to deal with the pandemic. It would be especially useful in assessing the costs and duration of getting a pandemic to become endemic under each strategy. Similar comparisons with other less successful mitigators in Europe (Germany, Spain, Italy and France) as well as Canada, Chile, Bahrain and Israel could also be instructive.

With respect to Middle and Low income countries in Asia, Africa and Latin America, there is quite a bit of heterogeneity in their current situations even among the suppressors category. China was quite successful in controlling the virus after the initial wave. Most of its COVID deaths and output drop took place in the first quarter of 2020. Yet use of its vaccines for diplomatic purposes has led to a lower number of administered doses per 100 persons than any European countries in the tables. Moreover, the efficiency of their vaccines has been lower than Moderna and Pfizer-BioNTech, ranging from 51 % to 83% for Corona.Vac and from 79 % -86 for Sinopharm. **Can they reach normalcy within a year or a year and a half by lifting international travel restrictions in the face of new variants such as delta without major policy changes in their LTPS with respect to internal vaccinations or to their vaccine diplomacy**? Vietnam was very successful until recently with their LTPS of population- based policies. Its initial reaction to the current increase in infections suggests it can succeed in maintaining suppressor status while waiting for increased availability of vaccines through COVAX, China or others.

Among the middle and low- income mitigator countries, there is even greater heterogeneity, which is not surprising since the group comprises at least 17 countries excluding Nigeria[6]**.** Nevertheless two groups stand out in terms of the cumulative number of deaths per million experienced, thus far. As of April 30 2021, which is a year and over a month after WHO declared COVI-19 a global pandemic, five of these countries have experienced over 900 cumulative deaths per million. This group of countries are Brazil, South Africa, Perú, Colombia and Argentina). Three of them lie completely in the Southern Hemisphere (Argentina, Peru and South Africa); one of them lies mostly in the Southern Hemisphere (Brazil); and the other one lies partially in the Southern Hemisphere (Colombia). By September 2021, they would have experienced two winter seasons under COVID-19 in contrast to countries in the Northern hemisphere. **Is**

[6] As mentioned earlier the Nigerian data is suspect. Hence, we exclude this country from the rest of the discussion.

that geographical feature relevant in determining the high level of deaths? Should the strategy to end the pandemic in these countries be the same as in the high -income countries depending primarily on vaccinations? Where do they get the vaccines from and at what speed? Should COVAX and other humanitarian guided donors treat them the same as others that have experienced less per capita trauma and on what grounds?

Countries in the second group stand out by having less than 500 cumulative deaths per million during the global pandemic, relying mainly on population –based policies and a variety of lockdown styles in terms of severity and duration. These countries come from three different geographical regions, Africa (3), Asia (5) and Latin America (4) and have a variety of experiences with respect to levels of death rates, positivity rates, percentage changes in biweekly death rates and vaccination rates. Interestingly, an outcome of the recent G-7 meeting is that the 1 billion vaccines donated through COVAX would prioritize Africa. An interesting research question is what is that priority optimizing? Lowering death rates per capita seems unlikely. For, many African countries seem to have low death rates partly because they have lower percentages of their population in the most vulnerable groups. For instance, the ratio of the percentage over 65 in the Asian country with the lowest percentage over 65 to the lowest African country is 4/2= 2 (Pakistan/Kenya). Similarly, the ratio of the Asian country with the highest percentage to the African country with the highest percentage is 11/5 =2.2 (Sri Lanka/Egypt). You would do better by targeting countries with the highest death rates per capita. Is it the duration of the global pandemic? Unlikely. Without entering into details about how the global pandemic ends, either through suppression, which no longer seems feasible, or by becoming endemic, an initial step at the issue is by lowering positivity rates as much as possible. Vaccines, however, do so indirectly. Moreover, there are plenty of positive associations between increased vaccinations and increased positivity rates during the month of May in Africa (e.g., Egypt, Botswana), Asia (e.g., Sri Lanka, Malaysia) and Latin America (e.g., Cuba, Costa Rica). **What should be the allocation criterion?**

In a recent IMF Blog, providing recommendations to the G-7, the amount of money and doses the G-7 and the G-20 should devote to the use of vaccines for ending the pandemic is the focus. The blog report is careful to mention difficulties, e.g., vaccine hesitancy in both donor and recipient countries or different efficiencies of vaccines and government's transparencies or their lack, as caveats or opportunities, especially in the underlying staff notes to which the summary and the report are linked (https://mail.google.com/mail/u/0/#search/IMF+G-7+proposal/FMfcgzGkXSVnMsrHbHcfwgPZPPlHrksr). Nonetheless, the critical issue that the vaccines address deaths directly and transmission only indirectly, and perhaps not at all if sufficiently high, is conspicuously absent from any mention in the report. It is eminently sensible to argue that pandemic policy is economic policy. Nonetheless, it is eminently peculiar for economic advisors to policy makers to stress inputs and ignore outputs in assessing or recommending policy. Vaccine policy, as a mechanism for ending the pandemic in any spatial unit, requires lowering both deaths per capita and transmission or positivity rates as outcomes. Since logically vaccine penetration affects deaths directly and transmission indirectly, the most important substantive conclusion from our research exercise is the wide range of empirical outcomes associated with the second outcome, including some suggesting that the process of vaccine penetration may even have a positive impact on positivity rates if sufficiently high! While the latter potential correlations are very likely to be spurious, learning far more than we know about this process should be a main priority of pandemic research if we are to use vaccine penetration as the main policy instrument for ending the global pandemic successfully. Just as Francis Bacon put it in the context of scientific discourse, "Truth will sooner come out of error than from confusion".

Methodologically, the basic dichotomous classification introduced here has generated value as a useful device in asking relevant questions, forcing subsequent definitions of basic policies and beginning to answer some basic questions. This progress relies on elementary pandemic statistics and their adaptations. Its main value, however, will depend on the stimulation of others to pursue these questions or similar ones that it may raise in their minds with more refined tools in a more systematic and rigorous manner. At the personal level, it has yielded enough progress to warrant continued monitoring the impact of the vaccine penetration process on two alternative measures of the transmission process through the next few months using the two main statistics derived to do so.

Country/State   Table 1: Initial Pandemic Response Classification, 9/04/2020- 4/02/2021.

Country/State	MPOR[1]	MΔDRL2wks[2]	Vacc.Rate[3]	POR4/16/21	ΔDRL2wks (4/16/21)/1000
Suppressors:	**0. < MPOR ≤ .015**				
China	.001	.000	12.8	.001	.000
N. Zealand	.002	.000	2.8	.001	.000
Australia	.003	.000	5.3	.002	.000
Cuba	.010	.010	n.a.	.028	.016
Denmark	.011	.006	25.7	.008	.001
South Korea	.013	.010	2.8	.014	.003
Mitigators:	**.015 < MPOR < 1.0**				
Canada	.036	.007	24.4	.037	.002
UK	.038	.009	60.3	.031	.000
Japan	.045	.008	1.5	.048	.004
Germany	.046	.011	24.8	.060	.004
Maryland	.048	.006	63.5	.047	.003
Spain	.072	.006	25.4	.077	.002
Italy	.072	.008	23.4	.070	.006
France	.072	.007	23.5	.073	.004
El Salvador	.076	.007	6.3	.076	.003
USA	.076	.006	59.3	.076	.002
Florida	.087	.007	58.4	.081	.002
Jamaica	.094	.012	4.6	.140	.019
Chile	.098	.005	66.6	.091	.007
Brazil	.286	.006	15.4	.481	.012

[1]Median biweekly cumulative positivity rate; [2]Median percentage change in the biweekly per capita death rate per 10 million divided by 1000 for expository convenience; [3] As of 4/15/2021: Administered vaccine doses per 100 persons in total population; n.a., at this date, data not available in (https://ourworldindata.org/covid-vaccinations). May 12 2021 is the first time data is available at 0.62

Country/State Table 2: Characteristics, Original Spatial Units.

Country/State	DR 4/30[1]	PCI[2]	PD[3]	TR4/30[4]	TRrank21[5]	%POP>65[6]	vac. 3/31[7]	vac. 5/23[8]	LTPS20/21[9]
Suppressors: .000 < POR ≤ .015.									
China	003	MI	0.38	0.11	18	10	8.32	33.58	PBP/PBP
N. Zealand	005	HI	0.05	0.40	13	15	1.53	9.84	PBP/PBP
Australia	035	HI	0.01	0.66	11	15	2.63	13.62	PBP/PBP
Denmark	427	HI	0.35	6.40	1	19	19.52	51.57	CBP/CBP
South Korea	036	HI	1.34	0.17	16	13	1.74	10.72	PBP/PBP
Mitigators: .015 < POR ≤ 1.0									
UK	1,870	HI	0.73	2.27	2	17	52.53	88.09	CBP/VBP
Cuba	056	MI	0.26	0.32	14	14	0.00	6.53	PBP/VBP
Canada	636	HI	0.01	0.82	9	16	15.08	53.86	CBP/VBP
Maryland	1,442	HI	0.62	1.60	3	16	46.47	94.26	CBP/VBP
Japan	080	HI	0.86	0.09	20	25	0.79	6.32	PBP/PBP
Germany	991	HI	0.60	0.66	11	19	16.93	52.98	PBP/VBP
Italy	1,996	HI	0.52	0.96	8	21	17.16	49.66	CBP/VBP
USA	1,771	HI	0.09	1.34	4	15	44.93	84.20	CBP/VBP
Spain	1,669	HI	0.24	0.99	7	17	17.19	51.25	CBP/VBP
El Salvador	325	LI	0.83	0.14	17	08	1.54	24.65	PBP/PBP
France	1,594	HI	0.32	1.16	6	18	17.10	47.66	CBP/VBP
Florida	1,684	HI	0.39	1.28	5	21	44.53	84.46	CBP/VBP
Chile	1,363	HI	0.06	0.67	10	10	54.82	90.35	CBP/VBP
Jamaica	259	LI	0.64	0.11	18	09	1.42	5.17	PBP/PBP
Brazil	1,877	MI	0.07	0.20	15	08	9.01	26.60	PBP/VBP

[1]Cumulative per capita deaths per million persons, Worldometer. [2] World Bank classification, 2019 see text as High Income (HI); Upper Middle Income (MI); and Lower Middle Income (LI). https://data.worldbank.org/indicator/NY.GNP.PCAP.CD. [3]Population density measured in thousands of persons per square mile from Wikipedia. [4]Tests per person in population rounding off at second decimal.[5] Rank in testing rate within Table 2 without rounding off. [6]Percentage of population over 65 from World Bank 2019 (US Census for MD and FLA). [7, 8]Administered vaccine doses per 100 persons in population for 3/31 and 5/23 2021, respectively. [9]Long term policy strategy.

Country/State *Table 3: 'Final' Pandemic Response Classification, April –May 2021.*

Country/State	POR=IR/TR			%ΔDR (L2wks)/1000			Vaccination rate[1]			LTPS20/21[2]
	04/30	05/14	05/28	04/30	05/14	05/28	04/30	05/14	05/28	
Suppressors: 0. < POR ≤ .015										
China	.001	.001	.001	.000	.000	.000	17.61	25.49	41.89	PBP/PBP
N. Zealand	.001	.001	.001	.000	.000	.000	4.82	8.06	11.66	PBP/PBP
Australia	.002	.002	.002	.000	.000	.000	8.28	14.90	15.81	PBP/PBP
Denmark	.007	.006	.005	.012	.007	.005	34.12	43.91	56.36	CBP/CBP
South Korea	.014	.014	.014	.029	.028	.027	6.35	8.87	14.71	PBP/PBP
Mitigators: .015 < POR < 1.0										
UK	.028	.026	.025	.002	.001	.001	70.91	80.72	93.32	CBP/VBP
Cuba	.029	.031	.110	.272	.232	.188	n.a.	0.62	7.10	PBP/VBP
Canada	.039	.035	.040	.027	.027	.023	34.79	45.83	60.44	PBP/VBP
Maryland	.046	.045	.044	.022	.020	.016	79.48	90.36	101.09	CBP/VBP
Japan	.050	.052	.052	.052	.112	.134	2.76	4.42	8.34	PBP/PBP
Germany	.061	.062	.062	.037	.036	.029	34.34	46.13	58.79	PBP/VBP
Italy	.069	.067	.064	.035	.027	.018	32.12	42.92	55.56	CBP/VBP
USA	.074	.073	.071	.017	.016	.016	70.97	79.71	87.34	CBP/VBP
Spain	.076	.076	.074	.014	.016	.008	33.92	45.07	55.90	CBP/VBP
El Salvador	.076	.075	.074	.022	.028	.027	12.86	19.43	28.25	PBP/PBP
France	.077	.073	.067	.042	.029	.018	30.77	40.64	51.71	CBP/VBP
Florida	.081	.081	.079	.025	.024	.023	67.63	79.40	86.70	CBP/VBP
Chile	.091	.092	.093	.053	.048	.066	76.47	84.99	95.32	CBP/VBP
Jamaica	.140	.134	.129	.079	.588	.120	n.a.	5.17	5.56	PBP/PBP
Brazil	.335	.329	.333	.096	.072	.060	19.75	23.67	31.25	PBP/VBP

[1] Administered vaccine doses per 100 persons in total population; n.a. data not available at a particular date in (https://ourworldindata.org/covid-vaccinations) for a spatial unit.[2]Based on the judgements explained in Section II while discussing Table2.

Country/State *Table 4: Basic Characteristics: New Countries*

Country/State	DR4/30[1]	PCI[2]	PD[3]	TR4/30[4]	TRrank21[5]	%POP>65[6]	vac.3/31[7]	vac. 5/23[8]	LTPS20/21[9]
Suppressors: 0. < POR ≤ .015									
Vietnam	0.4	LI	0.75	0.03	17	8	0.05	1.74	PBP/PBP
Taiwan	0.5	HI	1.69	0.02	19	15	0.06	1.26	PBP/PBP
Singapore	005	HI	20.45	1.62	2	12	22.54	58.24	CBP/VBP
Thailand	003	MI	0.34	0.12	13	12	0.29	4.03	PBP/PBP
Mitigators: .015 < POR < 1.0									
Sri Lanka	031	LI	0.86	0.12	12	11	4.26	8.06	PBP/PBP
Bahrain	365	HI	5.14	2.33	1	3	45.04	90.82	CBP/VBP
Malaysia	046	MI	0.26	0.29	7	7	2.16	7.55	PBP/PBP
Botswana	298	MI	0.01	0.42	4	4	0.55	3.04	PBP/PBP
Israel	692	HI	1.10	1.54	3	12	116.03	121.91	CBP/VBP
India	152	LI	1.07	0.20	9	6	4.72	13.83	PBP/PBP
Pakistan	079	LI	0.36	0.05	14	4	0.36	2.24	PBP/PBP
Egypt	128	LI	0.16	0.03	18	5	0.16	1.34	PBP/PBP
Nigeria	010	LI	0.56	0.03	20	3	0.35	0.92	PBP/PBP
Kenya	049	LI	0.30	0.01	16	2	0.30	1.77	PBP/PBP
Bangladesh	069	LI	3.07	0.03	15	5	3.26	5.92	PBP/PBP
S. Africa	907	MI	0.10	0.18	11	5	0.44	1.08	PBP/PBP
Peru	1,821	MI	0.07	0.33	5	8	3.11	9.16	PBP/PBP
Colombia	1,427	MI	0.11	0.29	6	9	4.41	15.74	PBP/PBP
Costa Rica	067	MI	0.26	0.19	10	10	7.55	24.58	PBP/PBP
Argentina	1,395	MI	0.04	0.24	8	11	8.61	23.80	PBP/PBP

[1]Cumulative per capita deaths per million persons from Worldometer. [2]Countries as classified by the World Bank in 2019 as High Income (HI); Upper Middle Income (MI); and Lower Middle Income (LI). https://data.worldbank.org/indicator/NY.GNP.PCAP.CD. [3]Population density measured in thousands of persons per square mile from Wikipedia. [4]Tests per person in population from Worldometer.[5] rank in testing rate within Table 4. [6]Percentage of population over 65 from World Bank 2019. [7,8]Administered vaccine doses per 100 persons in population for 3/31 and 5/23 2021, respectively. [9]Long term policy strategy.

Country/State   Table 5: Pandemic Response Classification: New Countries, April-May

	POR=IR/TR			%ΔDR (L2wks)/1000[1]			Vaccination rate[2]			LTPS20/21[3]
	04/30	05/14	05/28	04/30	05/14	05/28	04/30	05/14	05/28	
Suppressors: 0. < POR ≤ .015										
Vietnam	.001	.001	.001	.000	.000	.250	0.52	1.00	1.06	PBP/PBP
Taiwan	.002	.002	.012	.000	.000	5.000	0.24	0.78	1.59	PBP/PBP
Singapore	.006	.006	.005	.000	.000	.000	37.84	54.70	69.19	CBP/VBP
Thailand	.008	.012	.018	.500	1.667	.750	2.12	3.04	5.02	PBP/PBP
Mitigators: .015 < POR < 1.0										
Sri Lanka	.042	.045	.053	.067	.313	.500	4.45	6.46	8.56	PBP/PBP
Bahrain	.043	.046	.050	.034	.106	.281	72.89	85.10	98.24	CBP/VBP
Malaysia	.043	.044	.047	.045	.217	.393	4.39	5.85	9.06	PBP/PBP
Botswana	.047	.045	.047	.031	.054	.105	2.01	3.04	6.01	PBP/PBP
Israel	.059	.058	.057	.002	.003	.004	121.28	121.63	122.20	CBP/VBP
India	.066	.077	.082	.101	.243	.228	11.10	13.02	14.72	PBP/PBP
Pakistan	.069	.071	.070	.039	.089	.070	0.95	1.74	2.78	PBP/PBP
Egypt	.083	.089	.091	.024	.063	.051	0.64	1.34	2.53	PBP/PBP
Nigeria	.086	.084	.079	.000	.000	.000	0.58	0.86	0.96	PBP/PBP
Kenya	.095	.095	.094	.040	.102	.055	1.59	1.74	1.80	PBP/PBP
Bangladesh	.139	.137	.135	.045	.058	.027	5.24	5.78	6.05	PBP/PBP
S. Africa	.150	.146	.144	.004	.012	.020	0.54	0.87	1.52	PBP/PBP
Peru	.161	.157	.153	.070	.062	.053	4.84	7.87	11.64	PBP/PBP
Colombia	.193	.195	.199	.040	.081	.087	9.48	14.49	18.59	PBP/PBP
Costa Rica	.255	.258	.261	.029	.086	.118	16.08	24.58	32.56	PBP/PBP
Argentina	.267	.267	.270	.039	.084	.099	17.40	21.47	25.84	PBP/PBP

[1] except for April 30, which is a single week percentage change;[2] As of 4/29/2021 for 4/30:Administered vaccine doses per 100 persons in total population;[3] Long term policy strategy based on discussion of Table 4 in this section.

Appendix 1: The Statistics-- What They Measure and 16 biweekly observations over 18 selected countries and two selected spatial units (US states). September 04/2020-April 02/2021

1) IR= Infection rate = total or cumulative # of Covid-19 cases per million persons in the population

IR measures how many persons have contracted the virus relative to its total population at a point in time.

Usefulness, comparing any two countries (or areas) at similar times after identification of the first few cases. For instance, 30 days after the first case. It measures the rate of spread of the virus at a given distance in time from its arrival.

2) TR = Testing rate= cumulative # of COVID -19 tests performed per million persons in the population

TR measures the number of COVID-19 tests performed at any point in time relative to the number of persons in the population.

Usefulness, not much by itself. Essential in conjunction with the infection rate to generate.

3) POR = Positivity Rate = IR/TR= total # of COVID-19 cases relative to the number of tests given.

POR measures how fast COVID-19 is spreading in a country at a point in time, especially accurate when multiple tests to same person excluded from TR. It is still useful as an estimate even if multiple tests to same person not excluded, because we know it biases positivity rate downwards. It is a useful dynamic (when measured every two weeks, for example) leading indicator of the spread of the pandemic in a spatial unit at any point in time.

4) DR= Death Rate = cumulative number of COVID-19 deaths per million persons in the population.

DR measures how many people have died from the virus relative to a country's total population at a point in time.

Usefulness, comparing most damaging unsuccessful outcome between countries or, more generally, spatial units at any point in time.

Finally, it is a very useful lagging indicator of the state of the pandemic.

5) $\%\Delta DR = [(DR_t - DR_{t-1})/DR]100$ = percentage change in the cumulative death rate per capita over the last two- week period.

% ΔDR measures the state of the pandemic in the last two- week period by looking at the growth rate in its main lagging indicator.

Usefulness, it provides a dynamic measure (every two weeks) of the evolution of the state of the pandemic in a spatial unit at a point in time as a result of prior spread, behavior and policy actions wrt to implementation of both Non-Pharmaceutical Interventions (NPI's) and/or Pharmaceutical interventions (PI's).

Country*/State	September 04- October 16, 2020, December 25 Rev.												
	POR=IR/TR				DR				%ΔDR (L2wks)				% POP>65^
	9/04	9/18	10/02	10/16	9/04	9/18	10/02	10/16	9/04	9/18	10/02	10/16	'19
USA	.075	.072	.069	.067	577	610	642	672	n.a.	5.7	5.2	4.7	15
UK	.019	.019	.019	.023	611	614	621	637	n.a.	0.5	1.1	2.6	17
Canada	.070	.022	.022	.023	242	243	246	256	n.a.	0.4	1.2	4.1	16
Australia	.004	.004	.004	.003	029	033	035	035	n.a.	13.8	6.1	0.0	15
N. Zealand	.002	.002	.002	.002	005	005	005	005	n.a.	0.0	0.0	0.0	15
Spain	.053	.061	.061	.064	625	650	684	718	n.a.	0.4	5.2	5.0	17
Italy	.031	.021	.028	.029	587	590	594	602	n.a.	0.5	6.8	1.3	21
France	.040	.042	.052	.064	470	476	490	507	n.a.	1.3	2.9	3.5	18
Germany	.020	.019	.017	.019	112	113	114	117	n.a.	0.9	0.9	2.6	19
Denmark	.007	.007	.007	.008	108	110	112	117	n.a.	1.9	1.8	4.5	19
Japan	.045	.043	.040	.038	010	012	012	013	n.a.	0.2	0.0	8.3	25
S. Korea	.010	.010	.010	.010	006	007	008	009	n.a.	16.6	14.3	12.5	13
China**	.001	.001	.001	.001	003	003	003	003	n.a.	0.0	0.0	0.0	10
Cuba	.010	.010	.009	.008	009	010	011	011	n.a.	11.1	10.0	0.0	14
Jamaica	.048	.062	.083	.093	010	017	037	054	n.a.	70. 0	118.	45.9	9
Brazil	.281	.305	.271	.289	586	634	680	716	n.a.	8.2	7.3	5.3	8
Chile	.166	.149	.138	.128	597	637	669	701	n.a	6.7	5.0	4.8	10
E. Salvador	.080	.076	.073	.071	115	124	131	140	n.a.	7.8	5.6	6.9	8
Maryland	9/26→	.049	.048	.045	→	648	653	666	→	n.a.	7.7	2.0	16^
Florida	9/26→	.133	.133	.131!	→	648	673	733	→	n.a.	3.9	8.9	21^

*All country/state data taken from Worldometer; ^ World Bank data for 2019; Census Estimates 2020.

**The actual POR rates are .00053 for all dates; rounded up to.001 for ease of presentation. ! figure corrected on 10/29/2020 (from .171)

Country*/State October 30 – December 11, December 25 Rev.

	POR=IR/TR				DR				%ΔDR (L2wks)				%pop.> 65^
	10/30	11/13	11/27	12/11	10/30	11/13	11/27	12/11	10/30	11/13	11/27	12/11	‘19
USA	.060	.067	.071	.075	706	749	813	903	5.1	6.1	8.5	11.1	15
UK	.029	.034	.037	.038	676	749	838	927	8.9	10.8	11.9	10.6	17
Canada	.023	.028	.032	.036	266	284	312	346	3.9	6.8	9.9	10.9	16
Australia	.003	.003	.003	.003	035	035	035	035	0.0	0.0	0.0	0.0	15
N. Zealand	.002	.002	.002	.002	005	005	005	005	0.0	0.0	0.0	0.0	15
Spain	.074	.077	.075	.072	762	865	949	1,012	6.1	13.5	9.7	6.6	17
Italy	.040	.059	.071	.075	631	721	875	1,036	4.8	14.3	21.4	18.4	21
France	.082	.102	.108	.083	551	658	780	871	8.7	19.4	18.5	20.8	18
Germany	.023	.030	.036	.042	124	146	188	253	6.0	17.7	28.8	34.6	19
Denmark	.009	.010	.011	.012	123	130	140	158	5.1	5.7	7.7	12.9	19
Japan	.037	.038	.041	.043	014	015	016	020	7.7	7.1	6.7	25.0	25
S. Korea	.010	.010	.011	.012	009	009	010	011	0.0	0.0	11.1	10.0	13
China**	.001	.001	.001	.001	003	003	003	003	0.0	0.0	0.0	0.0	10
Cuba	.008	.008	.008	.008	011	012	012	012	0.0	9.1	0.0	0.0	14
Jamaica	.095	.094	.094	.093	068	076	084	091	25.9	11.8	10.5	8.3	09
Brazil	.251	.215	.283#	.264	746	771	804	843	4.2	3.4	4.3	4.9	08
Chile	.120	.112	.105	.100	736	767	794	822	5.0	4.2	3.5	3.5	10
El Salvador	.071	.071	.071	.071	149	158	170	170	6.4	6.0	7.6	7.1	08
Maryland	.043	.043	.044	.047	683	705	752	829	2.6	3.2	6.7	10.2	16^
Florida	.080	.080	.080	.081	776	809	850	912	5.9	4.3	5.1	7.3	21^

*All country/state data taken from Worldometer; ^Word Bank estimates, 2019; Census estimates, 2020. **The actual POR rates are .00053 for all dates; rounded up to.001 for ease of presentation; #, the testing rate for Brazil in this two- week period decreases, which is peculiar and unexplained.

Country*/State December 25 /2020 – February 05/2021

	POR=IR/TR				DR				% ΔDR (L2wks)				%POP>65^
	12/25	01/08	01/22	02/05	12/25	01/08	01/22	02/05	12/25	01/08	01/22	02/05	‘19
USA	.079	.083	.086	.086	1015	1127	1264	1406	12.4	11.0	12.2	11.2	15
UK	.042	.050	.053	.051	1023	1153	1389	1619	10.4	12.7	20.5	16.6	17
Canada	.040	.044	.044	.036	388	437	490	541	12.1	12.6	12.1	10.4	16
Australia	.003	.002	.002	.002	035	035	035	035	0.0	0.0	0.0	0.0	15
N. Zealand	.002	.002	.002	.001	005	005	035	005	0.0	0.0	0.0	0.0	15
Spain	.072	.073	.085	.087	1065	1105	1177	1300	5.2	3.8	6.5	10.5	17
Italy	.078	.081	.080	.077	1173	1279	1394	1494	13.2	9.0	9.0	7.2	21
France	.074	.074	.073	.072	953	1023	1102	1193	9.4	7.3	7.7	8.3	18
Germany	.048	.053	.056	.056	354	468	609	725	39.9	32.2	23.2	19.0	19
Denmark	.015	.016	.016	.014	192	256	329	329	21.5	33.3	28.5	14.3	19
Japan	.045	.050	.056	.056	024	030	038	048	20.0	25.0	26.7	26.3	25
S. Korea	.014	.015	.014	.014	015	021	026	028	36.4	40.0	23.8	7.7	13
China**	.001	.001	.001	.001	003	003	003	003	0.0	0.0	0.0	0.0	10
Cuba	.008	.009	.011	.015	012	013	016	020	0.0	8.3	23.1	25.0	14
Jamaica	.093	.094	.094	.096	098	103	112	120	7.7	5.1	8.7	7.1	09
Brazil	.260	.278#	.304#	.329#	891	940	1004	1072	5.7	5.5	6.8	6.8	08
Chile	.095	.094	.092	.090	849	881	922	975	3.3	3.8	4.7	5.7	10
E. Salvador	.073	.075	.078	.079	197	214	235	254	8.2	8.6	9.8	8.1	08
Maryland	.048	.050	.051	.051	931	1021	1114	1199	12.3	9.7	9.1	7.6	16
Florida	.083	.087	.089	.090	978	1047	1152	1269	7.2	7.1	10.0	10.2	21

*All country/state data taken from Worldometer; ^Countries, Word Bank estimates, 2019; US states, Census estimates, 2020; #, again the testing rate for Brazil decreases without explanation. **The POR rates are .00053 until 01/08 and .00056 after; rounded up to.001 for ease of presentation.

Country*/State February 19 /2021 – April 02

Country*/State	POR=IR/TR				DR				% ΔDR (L2wks)				%POP>65^
	02/19	03/05	03/19	04/02	02/19	03/05	03/19	04/02	02/19	03/05	03/19	04/02	'19
USA	.084	.081	.079	.077	1520	1605	1662	1704	8.1	5.6	3.6	2.5	15
UK	.049	.045	.039	.034	1753	1821	1848	1860	8.3	3.9	1.5	0.6	17
Canada	.036	.036	.035	.036	566	583	595	605	4.6	2.9	2.1	1.7	16
Australia	.002	.002	.002	.002	035	035	035	035	0.0	0.0	0.0	0.0	15
N. Zealand	.001	.001	.001	.001	005	005	005	005	0.0	0.0	0.0	0.0	15
Spain	.084	.080	.078	.077	1426	1507	1559	1615	9.7	5.7	3.5	3.6	17
Italy	.074	.072	.072	.072	1571	1639	1719	1819	5.2	4.3	4.9	5.8	21
France	.072	.071	.071	.072	1276	1344	1402	1468	7.0	5.3	4.3	4.7	18
Germany	.055	.055	.055	.057	805	858	892	920	11.0	6.6	4.0	3.1	19
Denmark	.013	.012	.010	.009	399	409	413	417	6.1	2.5	1.0	1.0	19
Japan	.054	.052	.049	.048	057	064	069	073	18.8	12.3	7.8	5.8	25
S. Korea	.014	.014	.013	.013	030	032	033	034	7.1	6.7	3.1	3.0	13
China**	.001	.001	.001	.001	003	003	003	003	0.0	0.0	0.0	0.0	10
Cuba	.019	.022	.024	.026	025	030	034	038	25.0	20.0	13.3	11.8	14
Jamaica	.107	.111	.132	.140	129	147	172	202	7.5	14.0	17.0	17.4	09
Brazil	.351#	.377#	.412#	.449#	1141	1223	1347	1523	6.4	7.2	10.0	13.1	08
Chile	.089	.088	.088	.089	1030	1084	1143	1213	5.6	5.2	5.4	6.1	10
E. Salvador	.079	.078	.077	.077	273	290	301	308	7.4	6.2	3.4	2.3	08
Maryland	.049	.048	.047	.047	1267	1310	1342	1373	5.7	3.4	2.4	2.3	16
Florida	.089	.088	.082	.081	1372	1462	1518	1561	8.1	6.6	3.8	2.8	21

*All country/state data taken from Worldometer; ^Countries, Word Bank estimates, 2019; US states, Census estimates, 2020; #, again the testing rate for Brazil decreases without explanation. **The POR rates are .00053 until 01/08 and .00056 after; rounded up to.001 for ease of presentation;

Appendix 2: Why Cuba belongs in the **mitigators** category if one uses the percentage change in the biweekly death rate per capita as an indicator of the spread of the virus.

Looking at column 2 as an alternative indicator of the spread of the virus, it certainly makes sense to place Cuba below Australia and Denmark and at best at the same level as South Korea within a category classification based on the median as a measure of its ability to control the spread of the virus . That is, the median percentage change in the death rate over the last two weeks (divided by 1000), MΔDRL2wks, is an inverse indicator of pandemic suppression. Once again looking at the range of values of the percentage change in the death rate per million (divided by 1,000) is illuminating. For Cuba, this median fluctuates between .111 on September 18 2021 and .000 on December 25 and between .250 on February 5 2021 and .118 on April 02 2021. For Australia, this percentage change in the death rate (divided by 1,000) reaches a low of .000 on October 2 2020 and it stays constant at this value until the period ends April 02 2021. Denmark's % ΔDR (L2wks)/1000 peaks at .333 on January 8 2021 from where it decreases to .010 on March 19 2021 and remains at that value thereafter. In South Korea's case, this change in the DR fluctuates between .000 and .400 (its peak between September 2020 and January 8 2021) in the early period, decreasing to .003 by April 02 2021.

A comparison of column 2 with the first out of sample statistic for this indicator on April 16 in column 5 yields an even stronger conclusion. While Cuba's value on April 16 (.016) moves farther away from its median (.010) in an upward direction away from all other medians in the suppressors category, Denmark's value (.001) and South Korea's value (.003) move away from their median values in the direction of the median values for the three other members of the suppressors category. Hence, this evidence also suggests removing Cuba from the suppressor category, placing it above Denmark and South Korea and in the mitigators category. If we look at Cuba's classification from the perspective of Canada and the UK, the first two countries in the mitigators category according to the MPOR, the evidence reveals values of MPOR for these countries at least twice the value of .010 for Cuba or South Korea (.036 and .038, respectively). Yet, the values of their M% ΔDRL2wks (which is an inverse indicator of pandemic spread) in column 2 (.007 and .009, respectively) are above Denmark's (.006) but below Cuba's and South Korea's (.010). Once again, it is useful in this comparison to look at the range of values over the period. With respect to Canada and the UK, at the end of the period on April 02 2021, these values are close to their lowest values (.017 and .006, respectively) while Cuba's is at .118. Moreover, the values of the statistic for the first out of sample period in column 4 are at their lowest (.002 and .000, respectively) as well as moving toward the medians in the suppressors' category rather than away from the medians, which is Cuba's case.

Research Note 1: July 18 2021

In mid-June, I distributed the earlier material to a subset of friends, colleagues and relatives. While I was not sure if I wanted to do additional work on this topic, I did not want to foreclose the possibility. Since then, I received a number of responses that encouraged further thought and work. Indeed, they led to a bit of progress in three areas that are worth sharing.

I. The Effective Reproduction rate, R^0.

In the discussion arguing why R^0 was conceptually unobservable (pp. 1-2) I gave two reasons, which is fine if one assumes a simple model with the same variant as in the SIR model (Susceptible Infected Recovered) underlying the epidemiological literature cited earlier, e.g., Ives and Bozzuto 2021 (https://www.nature.com/articles/s42003-020-01609-6). Ariel Benyishay pointed out, however, that some of the difficulties I described with respect to understanding the impact of vaccination rates across different countries on transmission and death rates reminded him of the social diffusion issues in the technology adoption literature. In a recent article, (Beaman et al. AER June 2021), he and his coauthors rely on complex contagion models to explain successful adoption through network theory based targeting. For our purposes, the new delta variant, which is far more transmissible than the original one (80% by some estimates), suggests a third reason why the effective R^0 is conceptually unobservable. It is a weighted average of the one corresponding to the original variant and the one corresponding to the new variant. The weights would be the share of the successfully vaccinated plus the exposed that survived and the remaining unvaccinated and unsuccessfully vaccinated members of the population. In any event, our basic point on the procedure for obtaining estimates of the actual transmission rate is not directly affected.

Perhaps more important, one of the main implications from the technology diffusion literature results in their paper is for vaccination policies in the context of the new delta variant. Namely, these policies would be wise to rely in attracting participation in their vaccination campaigns by more than one central figure in the social networks of the vaccine hesitant. It would increase the probability of success of these policies. Unfortunately, the central figures are likely to differ dramatically across countries and even within countries among the larger and/or more diverse ones.

II. Puzzles Generated by Pandemic Research

Two types of puzzles arise due to pandemic research: Data puzzles and Interpretation puzzles.

The former are simpler and require little or no explanation. They are either mistakes or decisions not to provide information by the relevant authorities. Three I repeat here for the reader's convenience but I discussed them when I found them using worldometer's publically available data. 1) The Chinese cumulative testing rate per million has not changed since September 4 2020. 2) The Brazilian cumulative testing rate decreased at various points during the biweekly periods between September 04 2020 and April 02 2021. I identify them with the number sign (#) next to the positivity rate in the tables where they are used. 3) The Nigerian cumulative death rate per biweekly period has remained at 10 between April 30 and July 9 2021. 4) The fourth and last data puzzle arises in "our world in data" publically available data set provided by John Hopkins University. In the data subset on the total administration of doses per 100 persons, no figures are available for Denmark on the website since May 26 2021. I highlight the issue in Table 6A below with interrogation signs (?) when I first noticed it and discuss it further when interpreting Table 6A.

Interpretation puzzles are more complex, potentially substantive and worthy of explanations if the latter are feasible or available. Indeed, just identifying the puzzle can be useful in terms of raising interesting questions. Since I raised enough of those in the previous material, here I will limit myself to three puzzles identified in the literature, i.e., they were raised in an insightful article at the time by Federico S. Mandelman on December 2020" COVID-19 International Evidence: Some Notable Puzzles" Federal Reserve Bank of Atlanta Policy Hub, No-14- 2020. These puzzles are in Mandelman's words

1) "Peru adopted unprecedented lockdowns early in the pandemic **(March 15 2020)**, which led to a record contraction in economic activity. The country's residents also adopted near universal mask usage. None of these actions, however, prevented Peru from experiencing the world's highest ty per capita mortality death rate from the virus." [I added the item in bold to the quote for expository reasons]. As of the beginning of July 2021, Peru still has the world's highest per capita mortality death rate from the virus (5,790 on July 7 2021 in the worldometer data but that includes a recent revision to correct for undercounting so it is not comparable to the December figures in the cited article). What went wrong? Probably many things, but important ones recently noted in the press, e.g., Jack Horton of BCC (https://www.bbc.com/news/world-latin-america-53150808), are: i) 70 % of employed population work in the informal economy. ii) The health care system is underfunded and was unprepared. iii) Slow vaccine rollout. Often ignored consequences of the first reason are that if you were a migrant in an urban area and could not go to work due to the lockdown you might go back to where you came from in the rural area, carrying the virus with you, and many did. These moves are unlikely to show in Google's mobility reports on retail and transit. Similarly, if you were not reachable to available financial help due to the informality, going to work to survive using public transport or participating in crowded markets despite the lockdown was an essential activity, and many had to do one or the other or both despite substantial lower general mobility measured by Google's index. Finally, modern labor economics makes a distinction between raw labor and labor in efficiency units; the same applies to mask usage. In countries where citizens trust their government to follow the rule of law, citizens simply refuse to wear masks if they disagree or do so as best they can if they agree. In countries where trust in governments is traditionally low, citizens are more likely to pretend to go along but not do so very carefully if they disagree. In addition, detailed instructions on how to wear masks and engage in social distancing might be ignored due to cultural reasons together with lack of familiarity with the practice.
2) "...southeast Asian countries practically did not register cases despite being closely interconnected to the source of the virus and adopting lax virus containment policies."
In the discussion, five countries identified as part of this puzzle are part of the material in our data. China and South Korea are in the category of suppressor countries (in the first set of 20 spatial units). Vietnam, Taiwan and Thailand also are in the category of suppressor countries (in the second set of 20 spatial units). All five of them relied on effective population based policies in 2020 and 2021 emphasizing strict lockdowns, mask wearing and social distancing. Moreover, they all took advantage of favorable unusual circumstances to become successful suppressors in the early stages of the pandemic. For instance, China relied on its effectiveness as a repressive state and its economic prowess to impose an initially very effective lockdown and subsequently

engaging in population-based policies. Similarly, but not as effectively, South Korea imposed an initially very restrictive lockdown followed by population-based policies, relying on its technical successes (e.g., elaborate contract tracing mentioned by the author) and economic accomplishments. Taiwan was similar to South Korea in this regard and had the additional benefit of being an island, which facilitates enforcement with respect to external borders. While Vietnam is much poorer and classifies as a low- income country, it had the advantage of a centralized and effective health system infrastructure, its nationalistic desire to be independent of China and a sufficiently high level of state repressive capacity. Finally, Thailand is a country that the author devotes most of the time to justify the puzzle statement. Population- based policies (mask wearing and social distancing) were responsible for these countries being successful suppressors in 2020. They are unlikely to suffice in 2021 due to the much more effective transmission of the delta variant.

Incidentally, mask wearing was a norm in these countries, including Thailand (as Mandelman points out) long before COVID-19. When Mandelman was writing, however, we were not aware of how important airborne transmission was in the case of this virus.[7] Thus, mask wearing and social distancing, competently done, were indeed essential for the success of population- based policies in 2020. The policies relied on by these countries were effective in controlling the pandemic in their early stages. The delta variant has changed that view profoundly as illustrated by the Australian justification for the new restrictive lockdown around Sydney to stop the spread of the virus. https://www.wsj.com/articles/delta-variants-spread-outpaces-australias-covid-19-contact-tracers-11625045400 . The justification is that airborne transmission of the delta variant is so quick that efficient contract tracing is not sufficient to prevent spread. Hence, the need for the very severe lockdowns around Sydney this time around. In 2020, it was possible for successful suppressors to ignore vaccines. This is unlikely to be sufficient in 2021. Indeed, our data suggests that Thailand is well on its way out of the successful suppressor category already, since it has exceeded the upper bound of the category (.015) for 4 straight biweekly periods (May 28-July 09). The delta variant has changed the neglect of vaccines by suppressors, e.g., Taiwan is sending tourists to Guam just to get the vaccine! (https://www.cnn.com/travel/article/taiwan-guam-vaccination-travel-intl-hnk/index.html).

3) "…sub-Saharan countries were largely spared from the virus despite being considered very high risk countries at the outset of the pandemic." Among the potential explanations considered in the article was the low percentage of persons aged over 65 in sub-Saharan Africa. That is certainly the case for the five African countries in Table 4 (Botswana, 4; Egypt, 5; Nigeria 3; Kenya, 2; and South Africa, 5). The five continental European countries in Table 2 range from 17 (Spain) to 21 (Italy). That is a ratio of 8.5 for the lower bound of the range of vulnerable percentages and a ratio of 4.2 for the higher bound of vulnerable percentages between the two sets of countries! In any event, the delta variant has changed the situation for African countries with respect to their transmission rates, which is especially troubling in light of their vaccination rates. We will return to this point briefly in the context of tables 6A and 6B below, which update Tables 3 and 5,respectively, up to July 9. Not surprisingly, per capita death rates have shot-up

[7] For instance, the CDC guidance for health workers on transmission on February 26 2021 contained the following statement. "Current data do not support long-range aerosol transmission of SARS-CoV-2, such as seen with measles or tuberculosis." We were still concerned about fomites.

even prior to the delta variant. For example even with the ridiculously and dubious low level for Nigeria frozen since April at 10, this yields a total number of per capita deaths of 2,060, which is almost double the 1,135 reported in the December 2020 article. I return to this general topic in discussing Tables 6A and 6B below.

III. Are There Any Conclusions?

In the earlier material, finished by mid-June, I emphasized questions as opposed to answers or conclusions for two reasons. First, there is too much of an emphasis in the economics profession on presuming to have convincing answers by asking incredibly narrow questions or by making some rather unattractive assumptions. I found that path unattractive. Second, the topic and circumstances required relying on cross country data, which some or perhaps many economists have extremely strong biases against for both good and bad reasons. The good reasons are the difficulties in establishing causality with this type of data; the bad reasons are the private interests that lead some or many to jump to the conclusion that this type of data provides no useful information. Since the topic at hand is of some urgency and to some extent requires this type of data, I decided to be very careful when drawing conclusions while doing the best I could with the material at hand. Thus, I was delighted to come up with one strong positive conclusion: Namely, the classification of countries into suppressors and mitigators based on their scores on an elementary statistic (supported by ancillary information including another elementary statistic) is extremely valuable for policy analysis of the COVID-19 pandemic.

Furthermore, the classification provides a very useful basis for further policy analysis as the situation evolves. Conclusions in this novel setting, however, are likely to be either tentative or qualified when positive or of the negative type when firmly asserted which is common to scientific undertakings. We illustrate the point with our analysis of the impact of the new delta variant on the results for the three biweekly periods after May 28 presented in Tables 6A and 6B. They present the information in ways that correspond to Tables 3 and 5, respectively, in the earlier material. This novel setting provides a 'natural experiment' in the evolution of the pandemic. For instance, the variant identified in India in February, accounted for 1% of US cases by May 10, 6% by June 10, and is already over 52% of the cases early in July (https://www.hindustantimes.com/world-news/delta-variant-first-identified-in-india-now-dominant-in-us-101625701597250.html). It has spread to at least over 100 countries. All but 8 of the 38 in our tables are explicitly mentioned by WHO (https://www.aljazeera.com/news/2021/7/7/map-tracking-the-covid-19-delta-variant). Moreover, it is stated that some not included by WHO are likely to be due to lack of reporting, e.g., in our case one of them is Taiwan since China prevents it from being included by WHO but we know from other sources that the delta variant was identified there.

The data in Table 6A provides three biweekly periods of additional information on the spatial units in Table 3. We start with the suppressor countries. The first three suppressor countries continue to perform as before in terms of our elementary statistics, i.e., cumulative positivity rates and percentage changes in biweekly per capita death rates despite the new delta variant. Indeed, Australia even experiences an improvement in its positivity rate in the last biweekly period despite the presence of the new more transmissible variant. This is due to the aggregate nature of these measures, the localized impact of outbreaks in general and of the new variant in Australia as well as Australia's aggressive lockdown policies responding to it, mentioned in our earlier more granular and anecdotal information of the variant's arrival in Australia. The variant's main impact for these three countries in terms of our cross-country data shows up in its impact on their vaccination policies with respect to their own populations. While ignored earlier relative to many other countries (e.g., European countries), their rate of increase, measured by the ratio of administered doses per 100 persons in the population, has been remarkable from April 30 2021 to July 9 2021 (China, 5.3; New Zealand 5.5; Australia, 4.1). The comparable ratio for any of the five continental European countries in the table is below 3.0. **Success as a suppressor with PBP early in a pandemic and VBP later in a pandemic are complements and not substitutes when it comes to LTPS. This positive conclusion based on three country experiences is likely to withstand the test of time over a wide range of values.**

Further evidence for this proposition arises from the experience of other early successful suppressor countries impacted by the delta variant that followed PBP. For instance, South Korea experiences an increase of 0.1% in its positivity rate between May and June of 2021 that continues through July 9. It may not seem that much but this is a cumulative positivity rate. If one looks at the percentage change in the biweekly per capita death rate, it had been steadily decreasing since a high of 40% on January 08 of 2021 every biweekly period observed until it reached 0 on June 25. It increased again on July 9 to 2.6 %, which was its value on June 11! Since the new outbreak is in Seoul, aggressive lockdown restrictions similar to Australia's have been re-imposed to control the outbreak. The ratio of vaccination rates between July 09 and April 30 for South Korea is 6.1. If we look at other early successful suppressor countries with PBP in 2020 and 2021, we find Taiwan, Vietnam and Thailand. In Taiwan, the cumulative positivity rate increases to 1.2% from 0.2 % between May 14 and May 28, steadily decreasing back to 0.6 % on July 9. Ironically, this may have been fortuitous as Taiwan was battling a cluster of infections of the alpha variant upon detection of the first case of the delta variant (https://www.reuters.com/world/asia-pacific/taiwan-reports-first-domestic-case-delta-covid-variant-2021-06-26/). The vaccine penetration ratio rises to 50.1 between April 30 2021 and July 9 2021. Vietnam's initial increase in its positivity rate of 100% stabilizes prior to a subsequent smaller increase of 50% at the end of the period and the same seems to be true of per capita death rates. Here the outbreak seems localized to areas with foreign factory workers. Thus, longer quarantines upon arrival and increased vaccinations seem to be the main weapons chosen by the government to address the outbreaks (https://asia.nikkei.com/Editor-s-Picks/Interview/Vietnam-s-new-COVID-variant-part-of-existing-Indian-strain-WHO). The vaccine penetration ratio between April 30 and July 9 is 7.8. Both countries experiences provide positive support for the proposition in bold above.

Thailand, on the other hand, provides evidence in support of the qualification that this complementarity of strategies can breakdown if the PBP and/or the VBP are sufficiently weak. Thailand's cumulative positivity rate increases by 50% through the two biweekly periods in May and by between 26% and 31% during each of the biweekly periods between May 28 and July 9. The percentage changes in the biweekly per capita death rate between April 30 and July 9 range between 30 % and 166%. While the vaccine penetration ratio between April 30 and July 9 is 7.9, it is not sufficient to keep Thailand anywhere near the boundary of the suppressor category of 1.5%. It is over twice that rate at 3.8% on July 9. Thailand has clearly moved into the mitigators category. It is likely to remain there unless it bring its positivity rate down systematically for a number of biweekly periods. The latter is difficult if not impossible at this stage for two reasons. First, the delta variant already makes up 52% of the cases in Bangkok, which has required a re-imposition of a strict lockdown recently (https://asia.nikkei.com/Spotlight/Coronavirus/Thailand-locks-down-Greater-Bangkok-as-delta-rips-through-ASEAN). Second, the vaccination rate on July 9 2021 stood at 16.6 doses administered per 100 persons. It took the UK 12 weeks to decrease its positivity rate from 5.3% on January 22 2021 to 3.4%

on April 2 2021 under the much less transmissible alpha variant when their vaccination rate per doses administered stood at 9.3 per 100 persons. Since the UK is a mitigator country, however, it also has the advantage in reaching herd immunity of a greater share of the population having acquired immunity from that exposure by January 2021 than Thailand has by July 9 2021! Of course, this mitigator advantage came at the cost of the UK paying the price of having 1,875 per million per capita deaths from COVID relative to Thailand's 35 on July 9 and ignoring any relative long haul effects for the COVID infected survivors in the two countries at that point.

Finally, the other two suppressor countries, Denmark and Singapore, relied on CBP in 2020 and early 2021 with a switch to VBP in 2021. The latter is especially notable in Singapore. The ratios of vaccine penetration between April 30 and July 9 were 2.8 and 50.1, respectively, with the number of doses administered per 100 persons having reached 97.42 and 101.42, respectively, at the end of the period. An interesting difference between these two countries is that the level of deaths per million persons differ dramatically—437 for Denmark and 6 for Singapore. Lockdowns were more extreme but of shorter duration in Singapore, which suggests these countries as an interesting pair to compare in terms of detailed benefit- cost analysis of pandemic policy strategies.[8]

We have 29 mitigator countries and 2 mitigator U. S. states among the remaining spatial units. Regardless of policy choice, including neglect, these spatial units are unsuccessful suppressors in 2020. While vaccines become very attractive, albeit necessary policy options to adopt in 2021 to address the pandemic for these countries, they face obstacles that are more severe than in suppressor countries' except for the previously mentioned and qualified greater immunity of the surviving share of the population in mitigator countries. The main impact of the vaccines is in preventing severe disease requiring hospitalization and death for those infected. The impact of the vaccines on transmission is uncertain. Epidemiologists suspect it lowers transmission by lowering the viral load in the patient. They know that the delta variant is far more transmissible than either the original or the alpha variant and that it increases the viral load in patients, but are not certain of which effect predominates. Moreover, not all vaccines are equally effective in preventing severe disease or transmission. Below we try to derive insights from the data for the same three biweekly periods on our two elementary statistics and the vaccination rate on these issues for the mitigator countries. For this purpose, however, additional work is necessary due to the intrinsic heterogeneity of these spatial units and their interactions with COVID-19.

We grouped the 31 spatial units classified as mitigators into two categories: those for which the percentage change in per capita death rates increased or did not change between June 11 and July 9 and those were it decreased during the same period. In Table 6 C1, we present the results for the first

[8] I have no idea why Denmark's current vaccination series is discontinuous between the biweekly period ending on June 11 and the one ending on July 9. What I know is that before June 17, the table entry indicates that is the value calculated for May 26; and on June 17 and thereafter, the table entry indicates the value is the one calculated for the current date. Before I noticed the interruption I had been able to obtain values for dates beyond June 16 prior to my checking on July 8 to calculate the relevant one for July 9. I would be careful in using those numbers. Because the value for May 23 on Table 2 is higher than the value for May 28 on Table 3, which implies that the two series are different. Of course, it is also possible that I made a mistake when copying these numbers. A similar issue arises with respect to Cuba. In Table 3, I have figures for May 14 and May 28 but not for April 30. If you look at the table now you find no figures for April 30, or earlier, and 17.99 for every day between May1 and May 31, indicating that the value is for May 31. It changes periodically thereafter. Earlier figures may have been participants in third stage clinical trials or medical and military personnel required to vaccinate them.

category together with other potentially useful information for interpreting the evolution of the virus in these spatial units during the three biweekly periods. The first three countries in the table exhibit both substantial increases in their percentage per capita death rates during the period as well as substantial increases in their positivity rates. Moreover, they face substantial danger from the delta variant due to their low vaccination rates. In their case, increased vaccinations become a necessary complement to their PBP.

Cuba and Chile have higher vaccination rates. In Cuba's case, however, the rate is well below that of most high income countries as of July 9 and widespread vaccination started recently compared to advanced countries because Cuba insisted on using their own vaccines, which are in critical third stage trials not yet evaluated by WHO and refused to participate in COVAX. Thus, widespread vaccination started recently. The unique protests against the government on July 11 arise for many reasons but a frequently mentioned one by protesters is the government's failure to protect their own citizens from COVID-19, which is ironic in light of the government's claim to be a medical superpower. In Chile's case, their vaccination campaign outstrips that of many high-income countries, including the five continental European countries in Table 6A. Nonetheless, their vaccination program includes vaccines from Pfizer, Astra-Zeneca and Sinovac's CoronaVac. Questions about the effectiveness of the latter in general and specifically with respect to the delta variant exist. Indeed a Chilean public health official suggested a third dose of a different vaccine to supplement the previous ones recently (https://www.reuters.com/business/healthcare-pharmaceuticals/chile-raises-covid-19-spending-urges-citizen-caution-with-delta-variant-2021-06-28/). In these two cases, VBP policies provide limited protection due to faulty or untimely implementation or reliance on less effective vaccines and their increasing positivity rates provide a warning signal, suggesting continued reliance on their earlier policies and on their improvement[9]

The last three countries show substantial impact from the delta variant through the magnitude of the increases in their death rates per capita despite the slight decreases in their positivity rates during the period. The UK has one of the highest vaccination rates in the world as well as a low and persistently decreasing cumulative POR since January 22 2021. Its Prime Minister, however, just announced that all mandatory recommendations by the government to slow the spread of the virus terminate on July 19 as previously announced despite the delta variant. The argument is that it is better to do so in the summer than in the fall. Because the behavioral response to termination leading to an 'exit wave' would be the same and there would be more illness in the fall due to citizens engaging in this behavior indoors. The US has left these decisions on how to prevent spread to the individual states, which has led to outbreaks in states with low rates of vaccination. The latter usually also oppose mask mandates and social distancing. One consequence is that the 'exit wave' in terms of hospitalizations and deaths depends on the individual states and it has been taking place primarily among the unvaccinated in all the states while leading to serious local outbreaks in the states with low vaccination rates.[10] El Salvador not having the luxury of a high vaccination rate has opted for continuing many restrictions and potentially

[9] Jamaica and Nigeria's figures show no impact from the delta variant directly, perhaps because the variant has not yet penetrated the countries extensively or because of the level of aggregation over time and space in the data, or faulty data in Nigeria's case.

[10] This difference also contributes to the differences in levels of death rates per capita, positivity rates and vaccination rates between the two US states shown in Table 6C2. Moreover, it is worth noting that the percentage decreases in death rates and positivity rates over the 3 biweekly periods are larger in Maryland than in Florida, i.e., their ratios for Maryland relative to Florida are 5.6 and 1.4, respectively.

introducing new ones, e.g., forbidding spectators to be present at World Cup qualifiers in September 2021.

Behaviors by governments and/or their consequences in these three countries are an implicit recognition of the complementarity between VBP and PBP in controlling the pandemic from a public health perspective. The two advanced countries among these three have implicitly chosen positive economic gains at the cost of negative public health losses. The low- income country seems primed to choose the loss of revenue to prevent a public health loss.

Finally, in Table 6C2 we present similar data for mitigators experiencing decreases in the percentage change of their per capita death rates over these 3 biweekly periods. The table's last 5 mitigator countries are also experiencing increases in their positivity rates over these 3 biweekly periods, which is a bad sign in light of two additional features that they share. First, all five of these countries have cumulative positivity rates above 5% as of July 9, including two in South America that are above 20%. Second, their vaccination penetration rates are below 40 per 100 administered doses for 4 of them and the higher one (Brazil with 51.8 per 100) includes a substantial proportion of China's vaccines which are presumably less effective. Thus, these countries provide fertile grounds for the spread of the delta variant that are worrisome in all cases but especially so in Colombia and Brazil given their high levels of per capita deaths, positivity rates and relatively low vaccination rates.

The first 14 of these mitigator countries seem to be experiencing the best of all worlds in the short-run, decreases in per capita death rates and non-positive changes in positivity rates (the two US states were already discussed). Nonetheless, magnitudes matter for both statistics. 10 of these 14 countries have decreases in per capita death rates over 60% during the 3 biweekly periods, which is good. Only two of these 10, however, have decreases in positivity rates greater than 10% during this interval (Israel and Germany) which is not so good. Israel has the largest decrease in magnitude of the 14 and is a unique success story through its vaccination implementation strategy, together with its pursuit of additional strategies such as severe lockdowns. It led to 121.28 doses administered by April 30 2021, which increased only to 125.73 by July 9. This success resulted in per capita death rate increases of less than 4 % in every biweekly period between April 30 and July 9 while the cumulative POR decreased from 5.9 % to 5.5%. Their level of per capita deaths are below all high and middle income countries in this group except Japan. Similarly, their positivity rates are lower than all countries in this group except Japan and Bahrain. Yet, they are considering the imposition of a severe lockdown to prevent a new wave of COVID-19 due to the delta variant on September 7-9 arising from the Rosh –Hashanah celebrations (https://www.timesofisrael.com/official-reportedly-warns-lockdown-could-be-ordered-for-rosh-hashanah/), which illustrates again the complementarity between the pandemic policies broadly identified here.

Of course, detailed comparisons would be valuable for a variety of reasons. The latter include a definition of these policies in terms of specific dimensions more easily quantified as well as in terms of evolutionary patterns identified more precisely than in a broad cross-country setting. For instance, the evolutionary patterns between Israel-Bahrain and Bahrain differ in some respects despite basic similarities in other aspects. Both are high- income countries with high rates of vaccinations (they rank one and two, respectively, on vaccinations administered per 100 persons as of July 9 among the 14 countries) and have relatively low per capita death rates per million persons in the population (between 500 and 1,000). Nonetheless, the patterns followed to get there are different, e.g., since April 30 Israel has been decreasing its positivity rate while Bahrain has been increasing it and Israel achieved its high rate of vaccinations during this period much earlier than Bahrain (121.28 vs. 72.89 on April 30). The same applies to an Israel-Japan comparison in light of the difference between their vaccine penetration rates (much lower in Japan at 41.62 on July 9) and their difference in per capita death rates per million (much lower in Japan at 118). Perhaps more important, Japan's choice to hold the Olympics, starting on July 23, despite the delta variant. In both comparisons, a detailed cost-benefit analysis of the trade-offs between economic and public health outcomes could be very instructive for public policy. **More generally, our discussion illustrates that pandemic policy strategy is economic policy strategy. Thus, it would be useful to characterize these strategies in those terms when evaluating outcomes for suppressor countries and mitigator countries as well as for spatial units within each category.**

While intensive international cooperation on the issue of how to end the pandemic would be ideal, it is likely to be limited given the facts on the ground. For instance, the IMF recently outlined a proposal along those lines in its blog (https://blogs.imf.org/2021/05/21/a-proposal-to-end-the-covid-19-pandemic/). One part of the plan requires donations in 2021 of 1 billion doses through COVAX (500 million vaccines). Unfortunately, other important players have expressed alternative views. For instance, the institution that applied for Russia's participation in COVAX added the following qualification in the press release announcing this participation in March 2021 "… fund applauds being able to cooperate with the international COVAX platform, although it will prioritize direct supplies from Sputnik V." China has not contributed money or vaccines to COVAX but it is willing to sell to COVAX at a price from its vaccine supplies. US decision makers are aware of the latter issue and not exactly overjoyed by this knowledge. (https://www.washingtonpost.com/opinions/2021/07/15/china-charging-un-for-vaccine-when-us-is-donating/). Clearly a minimum that could be contributed by international organizations would be solid information on the status of the pandemic from a public health perspective in various countries as accurately as possible as well as on the economic and technical needs to further the process as it evolves. The more ambitious plan in the proposal, however, is likely to fall by the wayside due to inability to meet its objectives in the face of so many uncertainties and recalcitrant major participants. **Our analysis of suppressors and mitigators suggests the need for incentive mechanisms for all agents, including citizens and policy makers, to participate actively and efficiently in ending the pandemic quickly. Unfortunately, it is unlikely to happen under current circumstances due to the usual collective action problems.**

Country/State *Table 6A: Pandemic Response Original Spatial Units, June- July 2021*

Country/State	POR=IR/TR			%ΔDR (L2wks)/1000			Vaccination rate[1]			LTPS20/21
	06/11	06/25	07/09	06/11	06/25	07/09	06/11	06/25	07/09	
Suppressors: .000 < POR ≤ .015.										
China*	.001	.001	.001	.000	.000	.000	59.99	76.14	93.26	PBP/PBP
N. Zealand	.001	.001	.001	.000	.000	.000	16.08	21.14	26.35	PBP/PBP
Australia	.002	.002	.001	.000	.000	.000	22.12	26.90	33.60	PBP/PBP
Denmark	.005	.004	.004	.005	.002	.005	70.21	????	97.42	CBP/CBP
South Korea	.015	.015	.015	.026	.000	.026	27.82	35.96	38.81	PBP/PBP
Mitigators: POR > .015.										
UK	.024	.023	.023	.001	.001	.002	103.49	111.31	117.17	CBP/VBP
Cuba	.034	.036	.040	.146	.138	.178	27.62	45.15	59.67	PBP/VBP
Canada	.039	.039	.039	.018	.012	.007	74.82	88.99	107.81	PBP/VBP
Maryland	.044	.043	.042	.071	.005	.003	105.49	111.45	115.21	CBP/VBP
Japan	.050	.049	.048	.089	.045	.026	16.93	28.30	41.62	PBP/PBP
Germany	.060	.059	.059	.017	.009	.006	70.47	83.03	95.16	PBP/VBP
Italy	.062	.060	.058	.008	.004	.003	68.33	78.97	90.50	CBP/VBP
USA	.070	.069	.068	.001	.007	.006	91.65	95.64	99.17	CBP/VBP
Spain	.073	.074	.073	.008	.003	.003	69.05	81.90	96.75	CBP/VBP
El Salvador	.074	.074	.073	.023	.028	.030	34.40	39.88	46.02	PBP/PBP
France	.065	.063	.061	.011	.005	.004	62.95	72.51	84.59	CBP/VBP
Florida	.079	.077	.076	.012	.012	.010	90.75	96.37	99.60	CBP/VBP
Chile	.088	.092	.091	.053	.044	.053	105.79	113.68	123.17	CBP/VBP
Jamaica	.122	.116	.112	.057	.060	.057	6.01	6.56	8.44	PBP/PBP
Brazil	.343	.345	.350	.055	.056	.041	36.11	43.09	51.80	PBP/VBP

[1] Administered vaccine doses per 100 persons in total population; data available in (https://ourworldindata.org/covid-vaccinations.); *.00058 as of June 25 2021, rounded off to .001.??? see footnote 8 in text for an explanation of the missing Danish figures.

Country/State   Table 6B: Pandemic Response Classification: New Countries, June-July

Country/State	POR=IR/TR			%ΔDR (L2wks)/1000			Vaccination rate[1]			LTPS20/21
	06/11	06/25	07/09	06/11	06/25	07/09	06/11	06/25	07/09	
Suppressors: 0. < POR ≤ .015										
Vietnam	.002	.002	.003	.200	.333	.250	1.45	2.70	4.07	PBP/PBP
Taiwan	.010	.007	.006	4.333	.625	.154	3.36	7.33	12.18	PBP/PBP
Singapore	.005	.005	.004	.200	.000	.000	75.07	85.96	101.42	CBP/VBP
Thailand	.023	.029	.038	.300	.300	.346	8.12	12.03	16.65	PBP/PBP
Mitigators: .015 < POR < 1.0										
Sri Lanka	.060	.066	.067	.492	.394	.206	11.82	15.72	21.15	PBP/PBP
Bahrain	.053	.053	.052	.293	.121	.026	110.28	116.94	127.31	CBP/VBP
Malaysia	.049	.051	.053	.474	.278	.224	12.68	20.25	31.01	PBP/PBP
Botswana	.049	.051	.056	.078	.222	.096	6.38	8.54	11.07	PBP/PBP
Israel	.057	.056	.055	.003	.000	.001	122.68	123.29	125.73	CBP/VBP
India	.078	.074	.072	.138	.068	.032	17.66	21.26	25.95	PBP/PBP
Pakistan	.068	.067	.065	.043	.021	.020	4.33	6.10	8.25	PBP/PBP
Egypt	.094	.097	.098	.042	.034	.019	3.26	4.04	4.43	PBP/PBP
Nigeria*	.077	.074	.072	.000	.000	.000	1.08	1.51	1.86	PBP/PBP
Kenya	.094	.094	.094	.088	.032	.063	1.97	2.23	2.81	PBP/PBP
Bangladesh	.135	.136	.144	.040	.064	.145	6.11	6.13	6.14	PBP/PBP
S. Africa	.143	.147	.156	.026	.030	.069	2.85	4.30	6.44	PBP/PBP
Peru	.150	.146	.143	1.729	.018	.012	15.00	20.51	25.30	PBP/PBP
Colombia	.205	.205	.215	.084	.091	.083	23.99	31.52	38.20	PBP/PBP
Costa Rica	.258	.254	.244	.094	.065	.033	37.42	45.76	49.50	PBP/PBP
Argentina	.271	.267	.265	.102	.089	.070	34.84	41.26	51.59	PBP/PBP

[1]Administered vaccine doses per 100 persons in total population; data available in (https://ourworldindata.org/covid-vaccinations). *the death rates per capita figures for Nigeria are suspect , stuck at 10 per million since April 30 2021.

Country/State	*Table 6C1: Non-Negative Per Capita DR Δ, Mitigator Countries, June- July 2021*					
	% ΔDR	% ΔPOR	DR07/09	POR07/09	Vaccination rate/07/09[1]	LTPS20/21
Botswana	23	+12	501	.056	11.07	PBP/PBP
Bangladesh	262	+67	95	.144	6.14	PBP/PBP
S. Africa	165	+9	1,057	.156	11.09	PBP/PBP
Cuba	22	+18	126	.040	59.67	PBP/VBP
Chile	0	+34	1,738	.091	123.17	CBP/VBP
Jamaica	0	+18	373	.112	8.44	PBP/PBP
Nigeria*	0	- 6	10	.072	1.86	PBP/PBP
UK	100	- 4	1,880	.023	117.17	CBP/VBP
USA	500	- 3	1,869	.068	99.17	CBP/VBP
El Salvador	30	- 1	372	.073	46.02	PBP/PBP

[1] Administered vaccine doses per 100 persons in total population; data available in (https://ourworldindata.org/covid-vaccinations.); *per capita deaths reported at 10 since April 30.

Country/State	*Table 6C2: Negative Per Capita DR Δ, Mitigator Countries, June- July 2021*					
	% ΔDR	% ΔPOR	DR07/09	POR07/09	Vaccination rate/07/09[1]	LTPS20/21
Maryland	-96	- 5	1,614	.042	115.21	CBP/VBP
Japan	-71	-4	118	.048	41.62	PBP/PBP
Bahrain	-91	-2	778	.052	127.31	CBP/VBP
Israel	-67	-35	690	.055	125.73	CBP/VBP
Germany	-65	-17	1,091	.059	95.16	PBP/VBP
Italy	-63	-6	2,116	.058	90.50	CBP/VBP
France	-64	-6	1,701	.061	84.59	CBP/VBP
Pakistan	-53	-4	100	.065	8.25	PBP/PBP
India	-77	-8	291	.072	25.95	PBP/PBP
Florida	-17	-4	1,771	.076	99.60	CBP/VBP
Peru	-1	-5	5,794	.143	25.30	PBP/PBP
Costa Rica	-65	-5	-920	.244	49.50	PBP/PBP
Argentina	-31	-2	2,146	.265	51.59	PBP/PBP
Canada	-61	0	693	.039	107.81	PBP/VBP
Spain	-63	0	1,792	.073	96.75	CBP/VBP
Kenya	-37	0	68	.094	2.81	PBP/PBP
Sri Lanka	-58	+12	158	.067	21.15	PBP/PBP
Malaysia	-53	+8	180	.053	31.01	PBP/PBP
Egypt	-55	+4	157	.098	4.43	PBP/PBP
Colombia	-1	+5	2,161	.215	38.20	PBP/PBP
Brazil	-25	+2	2,477	.350	51.80	PBP/VBP

[1] Administered vaccine doses per 100 persons in total population; data available in (https://ourworldindata.org/covid-vaccinations