ECONOMICS DISCUSSION PAPER 20.07
May 2020

ISSN 1179-8823 (Online)

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The Dynamic of COVID-19 New Infections under Different Stringent Policies*

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Abstract

We estimate an unrestricted VAR to summarize the dynamics of the stringency of policy and COVID-19 infections in New Zealand, Australia, Denmark, Sweden, and the U.S. using the newly published Stringency Index by the Blavatnik School of Government at the University of Oxford, Hale et al. (2020). The stringency of the policy responds positively to the number of new infections, and new infection cases respond negatively to the increase in the stringency of the policy. New Zealand and Australia followed slightly different stringent policies, but both managed the pandemic remarkably well. Denmark, Sweden, and the U.S. adopted different policies in terms of stringency and timing. Had Denmark, Sweden, and the U.S. adopted the New Zealand's stringent policy they could have reduced the number of infection cases significantly, but not as much as in New Zealand because the stringency and timing of policy is endogenous and country-specific.

JEL Classification Numbers: I10, C9, C53

Keywords: COVID-19, Stringency Index, VAR, Dynamic Stochastic Projections

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I thank Grant Scobie, Bob Buckle, and Bryce Wilkinson for valuable comments.

1. INTRODUCTION

Countries responded differently to COVID-19. Some countries have been following relatively less stringent policies than others have. While some countries followed very stringent policies such as strict social distancing and lockdowns early on, others waited before they ratcheted up their responses. There is a debate about the efficacy of stringent policies. It is unclear what "better" means; perhaps the advocates of fewer restrictions had the economic cost of lockdown and herd immunity in mind. At this stage, the efficacy of different policies are measurable because data on new infections, deaths, and recoveries are available, albeit with questionable qualities, while the costs are still unclear because the data are not fully published.

Hale et al. (2020) published the COVID-19 Government Response Tracker (OxCGRT), which is described as a simple, additive un-weighted index, as a baseline measure for 150 countries from Jan 1 to Apr 23, 2020. This data set makes it possible to study the policy dynamic. The authors provide a systematic method to track the stringency of government responses to COVID-19 across countries and time. The index combines a number of measures of government responses. The report is from publicly available information on nine indicators of government response.[1] The indicators are of three types, ordinal, which measure policies on a simple scale of severity / intensity; numeric, which measure a specific number, typically the value in USD; and text, which is a "free response" indicator that records other information of interest.

The main components of the stringency index include information about policies of school closure, public event cancellation, workplace closure, school closure, public places closure, domestic and international travel bans, public transport restrictions, etc. The Stringency Index captures variation in containment and closure policies only. For each policy response measure above, a score is created, by taking the ordinal value and adding a weighted constant if the policy is general rather than targeted, if applicable. A rescale is applied by the maximum value to create a score between 0 and 100, with a missing value contributing zero.

[1] They have 19 indicators in total, but the indicators for the economic and health system were not used in calculating the Stringency Index. The question of the effect of these policies on the economy is a question that could not be answered satisfactorily at this stage because of the lack of economic data on the outcomes such as GDP and other variables. GDP data, and many other macroeconomic data, are quarterly and the response of various polices would not probably show in the data until June. Although, we could have mixed-frequency econometric estimation, we do not have enough degrees of freedom just yet.

The data set includes 150 countries. We are primarily interested in studying and comparing the Australian and New Zealand cases. These are two neighbouring countries that are culturally similar; have same language; have similar institutional arrangements; and are geographically located in the same corner of the earth, yet their current governments pursued different stringent policies to deal with COVID-19. While the New Zealand government began imposing restrictions on Feb 2 and ratcheted up the restriction significantly, Australia, on the other hand, began responding earlier on Jan 25, but did not ratchet up the restrictions as New Zealand did. Interestingly, they seem to have achieved similar outcome at the same point in time.

For robustness, we examine three other policy scenarios. First, we examine Denmark and Sweden. These two neighbouring countries also have similar cultural, institutional, economical, and historical backgrounds. The two governments, just like in the case of Australia and New Zealand have same objectives, followed different policies. Sweden first confirmed case was reported on Feb 1, but the government began imposing restrictions on Mar 9, and the policies were not as stringent as in Denmark. Denmark reported the first confirmed case on Feb 27. The government responded on the same day by putting restrictions in place, and increased the policy stringency significantly, as new infection cases were reported. Second, we add the U.S. to the sample because the U.S. is a significantly different case from New Zealand, Australia, Denmark, and Sweden.

Our objective is to formally estimating the dynamic relationship of the COVID-19 infections and the Stringency Index econometrically. We use an unrestricted VAR (2) to summarize the data dynamics. We consider VAR is a natural vehicle to summarize the dynamics of time series variables.[2] We produce dynamic stochastic baseline projections, which measure the expected daily newly confirmed cases up to June 30 conditional on the existing stringency of the policy. Then, we produce another set of projections under a different policy scenario. Finally, we ask, could any of the other countries in the sample, Denmark, Sweden, and the U.S., which still have high numbers of infections on April 23 (the last observation in the sample), have achieved the same outcome of New Zealand had they adopted the New Zealand's stringency policy at the same time it was implemented by New Zealand?

[2] Hartl, Wälde, and Weber (2020) use different methodologies to test the impact of certain policies such as shutdown on the spread of the virus. They search for a structural break in the growth of log confirmed cases with COVID-19. A structural break implies a drop in the average growth rate of the virus disease from a certain day on, so that it takes longer for case numbers to double.

The data, except for the U.S., confirm that policy stringency responds positively to the number of new infections. The higher the rate of infections the more stringent the policy response is. However, the infection rate responds negatively to policy that is more stringent. We show that New Zealand and Australia managed the pandemic remarkably well even though they followed a slightly different stringent policies. Both countries ran successful yet different stringent policies to reduce the daily newly confirmed cases to zero. Therefore, stringency, maybe necessary, but it is not a sufficient condition to mitigate the problem. We show that Denmark, Sweden, and the U.S. could have reduced the number of daily newly confirmed cases of COVID-19 significantly had they adopted the New Zealand stringent policy early on. However, they could not have reduced infections to zero as in New Zealand and Australia. We interpret this as evidence that the policy response is endogenous country-specific.

Next, we present the model. Section (3) describes the data. Section (4) presents the estimation's results. In section (5), we produce dynamic stochastic projections. Section (6) includes some projections under policy scenarios. Section 7 is a conclusion.

2. THE MODEL

We use a VAR to study the dynamic. The standard Vector Auto-regression (VAR) is a stationary k-dimensional VAR(p) process is given by:

$$y_t = A_1 y_{t-1} + \cdots A_p y_{t-p} + \varepsilon_t, \qquad (1)$$

where, $y_t$is a $k \times 1$ vector of endogenous variables. $A_1 \cdots A_p$ is a $k \times k$ matrix of lag coefficients, and $\varepsilon_t$is $k \times 1$ white noise innovation process with the classic assumptions. $E(\varepsilon_t) = 0$; $E(\varepsilon_t \varepsilon_t') = \Sigma_\varepsilon$; $E(\varepsilon_t, \varepsilon_s') = 0$ for $t \neq s$. We have two variables: the daily newly confirmed cases of COVID-19, and the Stringency Index. The time series are daily data from January 1 to April 23, but there are missing data that vary by country because countries first reported cases at different dates.[3]

[3] Hale *et al.* (2020) report the cumulative daily newly confirmed cases. To get the daily newly confirmed cases we first difference the data.

3. THE DATA

We plot Hale *et al.* (2020) data of the Stringency Index for New Zealand, Australia, Denmark, Sweden, and the U.S. in figure (1). New Zealand started imposing restriction earlier than most countries, on Feb 2. Australia and Denmark imposed restrictions at the same level as New Zealand, on Feb 24 and Feb 27 respectively. Then, New Zealand had zero confirmed cases, Australia had a few confirmed cases, and Denmark had one confirmed case. Sweden, however, did not impose any restrictions until Mar 9, where it had 203 confirmed cases. The U.S. on the other hand began implementing polices on Feb. 2 while its first confirmed case was reported on Jan. 21.

New Zealand increased the stringency of policy in a step fashion, up. However, Australia and Denmark ratcheted up the stringency of the policy at once. Sweden's policy remained relatively lax until now, i.e., the value of the Index is relatively smaller. The U.S. Stringency Index is in between New Zealand and Australia. Figures (2), (3), (4), (5), and (6) plot the Stringency Index and the daily newly confirmed cases of infections. Australia and New Zealand have the typical rise, peak, and declining number of infections to near zero, Denmark and Sweden do not. The U.S. daily newly confirmed cases must have peaked already and began to fall, but far away from zero. While New Zealand had zero cases reported on Apr 23, Australia had seven, Denmark and Sweden had 217 and 628 by Apr 23 respectively. The question is whether stringent policies reduce infections and how many days the number of infections takes to respond to policy.

Next, we estimate the dynamics. However, there is a caveat regarding the measurements of the two main variables. First, the daily newly confirmed cases might be underreported. There are reported issues with asymptomatic people who are infected but not reported. There are issues with inaccuracy of medical tests, which cast doubts about the data (e.g. Ciminelli and Garcia-Mandico (2020)). Second, the Stringency Index, which we plot in figure (1), is a step function, which has significant serial correlation. We will attempt to deal with this issue econometrically, but we cannot remedy the underreporting of the infections.

4. ESTIMATING THE VAR

We focus on estimating an unrestricted VAR for each of the four countries, New Zealand, Australia, Denmark, Sweden, and the U.S. We report the *Generalized Impulse Response functions* in Figure (6), (Pesaran and Shin, 1998).[4]

For New Zealand, the VAR has seven lags chosen using a number of commonly used Information Criteria.[5] The number of the daily newly confirmed infection cases declines significantly 7 days after the increase in the Stringency policies, and remains low and stable. Stringency increases with infections because it is a response to the infection. Figure (7a) plots the impulse response functions for New Zealand.[6]

For Australia, the VAR has three lags according to the Information Criteria. Unlike New Zealand, the Australian number of the daily newly confirmed infection cases declines in response to the increase in stringency policy about 12 days later. Stringency increases with infections. See figure (7b).[7]

For Denmark, we fit a VAR with six lags. The number of daily newly confirmed cases declines in response to the increase in the Stringency Index, but it does not stay low for long. At the end, it had increased again. Like New Zealand and Australia, the stringency of policy responds to the increase in the infections. The response of the daily newly confirmed cases of infections shows a decline 4 days after the increase in the stringency of the policies remained low for 6 days, and then increases again. This response is quite different from the case of New Zealand, where the infection numbers remained low. The number of infections like New

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[4] It resolves, "the ordering" of the variables problem in cases where no further identifying restrictions are imposed as in our case.

[5] We use the LR, sequential test, Final Prediction Error, Akaike, Schwarz, and Hannan-Quinn Information Criteria.

[6] The VAR has the following order, the number of daily newly confirmed cases and the Stringency Index. The F statistics are 11.7 and 37.7 respectively. The null hypothesis that the coefficients are jointly equal zero is rejected.

[7] The VAR has the following order, the number of daily newly confirmed cases and the Stringency Index. The F statistics are 10.5 and 151.4 respectively. The null hypothesis that the coefficients are jointly equal zero is rejected.

Zealand and Australia drives the strength of the stringency policy. The impulse response functions for Denmark are in figure (7c).[8]

For Sweden, the VAR has six lags. Sweden's daily newly confirmed infection cases response to the stringency of policy is very different from Denmark and different from New Zealand and Australia too. It oscillates and falls for a couple of days only before it resumes an upward trend. Again, like the other countries, the stringency of the policy response increases with the number of confirmed infections. Figure (7d) plots the generalized impulse response functions.[9]

The VAR for the U.S. has six lags. The U.S. impulse response functions in figure (7e) are markedly different from the other countries.[10] While infections respond negatively to increasing policy stringency as in all other countries, stringency of the policy declines as the number of daily newly confirmed cases increased. Quite the opposite of what we expect and observed elsewhere, which might be reflecting the delay in response to the pandemic. This is another indication for the endogeneity of the policy.

5. BASELINE PROJECTIONS

The Stringency Index, being a step function, causes serial correlations and non-normality in the residuals of the VAR. To ameliorate the problem, we use 1000 Bootstraps to generate the innovations in the VAR. The VAR model is solved and we produced mean dynamic stochastic baseline projections for the daily newly confirmed cases up to June 30. The projection horizon is April 24 or 23 depending on the country's last actual data point, to June 30. Since the last actual data were zero in New Zealand and near zero in Australia, the projections cannot be less than zero. Negative numbers of new infections do not make sense. For this reason, we restrict the projections of the daily newly confirmed cases to be bounded by zero from below.

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[8] The VAR has the following order, the number of daily newly confirmed cases and the Stringency Index. The F statistics are 80.6 and 1710.0 respectively. The null hypothesis that the coefficients are jointly equal zero is rejected.

[9] The VAR has the following order, the number of daily newly confirmed cases and the Stringency Index. The F statistics are 151.4 and 708.87 respectively. The null hypothesis that the coefficients are jointly equal zero is rejected.

[10] The VAR has the following order, the number of daily newly confirmed cases and the Stringency Index. The F statistics are 328.9 and 919.5 respectively. The null hypothesis that the coefficients are jointly equal zero is rejected.

For Denmark, Sweden, and the U.S., however, the baseline projections are not zero. Figures (8), (9) and (10) plot the data. The baseline projections for Denmark are almost flat but slightly falling, significantly increasing with time in Sweden, and declining very slowly in the U.S. Without change in the stringency of the policy, fast occurring herd immunity, or a vaccine, none of these projections expected to hit zero in the near future.

6. A POLICY SCENARIO

We assume a scenario, whereby Denmark, Sweden, and the U.S. adopted New Zealand's stringent policy, and then we make dynamic stochastic projections over the period up to the end of June. Figures (11), (12), and (13) show that Denmark, Sweden, and the U.S. could have cut the daily infection cases significantly had they adopted a stringent policy such as the New Zealand policy.

However, none of the projections of the daily newly confirmed cases could fall to zero as they did in New Zealand because the policy response is endogenous; it is country-specific and responds to the country's number of new infections. It is highly certain that New Zealand would move back to level 3 or 4, more stringent policy, if new infections occur after moving to level 2 or if a second wave of infections occurs in the future. Therefore, although a stringent policy response reduces infections significantly in these three countries, it is not a one size fits all. Australia's outcomes are just as good as New Zealand, but with a much less stringent policy. Apparently, stringency itself is necessary but not a sufficient condition to reducing new infections, timing matters too. Australia responded to the pandemic in the right time. Denmark responded earlier than Sweden, and the U.S. Therefore, stringency and timing are sufficient to control the spread of the disease.

7. CONCLUSIONS

We summarized the dynamics of COVID-19 daily newly confirmed cases and the stringency of the policy in New Zealand, Australia, Denmark, Sweden, and the U.S. using the newly constructed Stringency Index by Oxford University, Hale *et al.* (2020). The time series data are from Jan 1 to Apr. 23. We fit an unrestricted VAR for these variables, and produce baseline projections and projections under the scenario that Denmark, Sweden, and the U.S. had adopted the New Zealand's policy. We use the New Zealand Stringency Index along with the countries' daily newly confirmed cases in the VAR, and produce dynamic stochastic projections up to the end of June 2020.

We learned that, first, the stringency of the policy in any country, except the U.S., responds positively to the number of new infection. Second, daily newly confirmed cases decline as policy becomes more stringent. This is evident in the impulse response functions. Third, the policy response is endogenous and country specific. When we use the Stringency Index of New Zealand in the case of Denmark, Sweden, and the U.S., we found that the projection of the daily newly confirmed cases to decline significantly compared to the baseline. However, the confirmed cases never reach zero as it did in New Zealand and Australia. Fourth, policy stringency is a necessary condition to control and reduce the pandemic. That is obvious in the data; however, it may not be sufficient. The timing of the policy matters. Australia, for example, brought down the infections numbers just as New Zealand did even though Australia's policy is less stringent than New Zealand. However, Australia, unlike Sweden and the U.S. and even Denmark, responded earlier. Therefore, policy stringency and timing, which are endogenous and country-specific, are necessary and sufficient to control the spread of the disease.

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Figure (1)

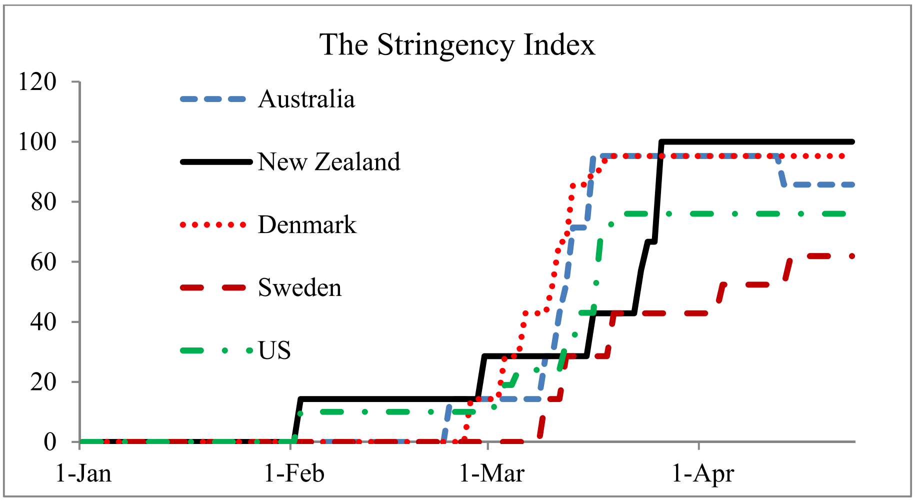


Figure (2)

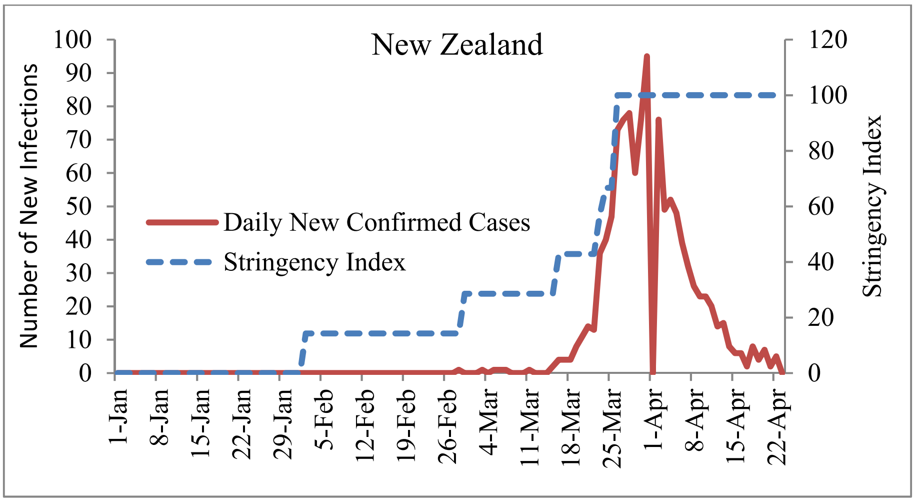


Figure (3)

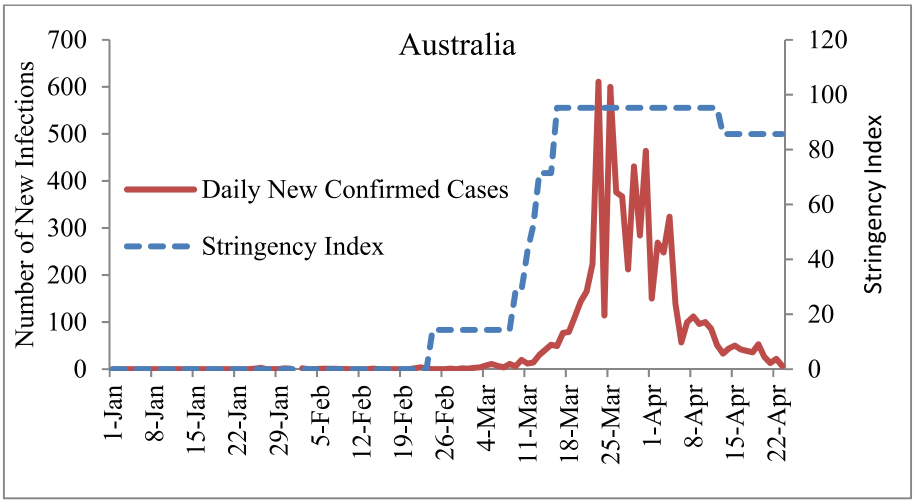


Figure (4)

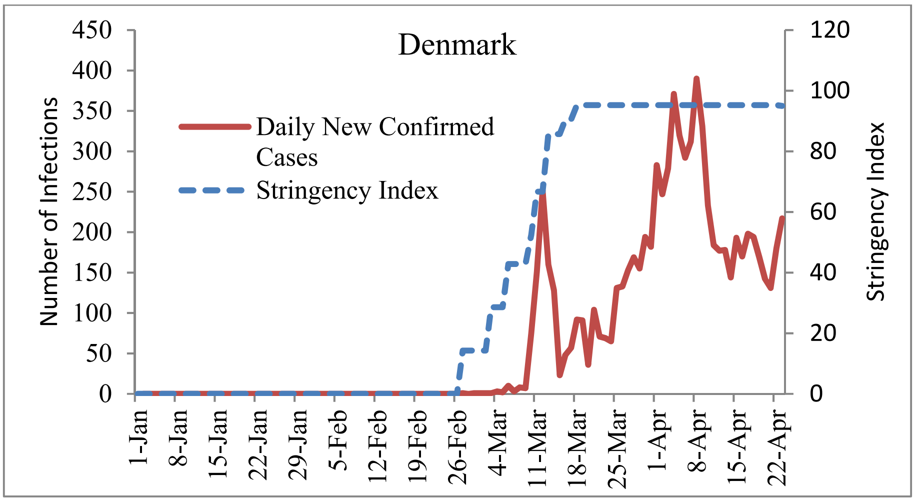


Figure (5)

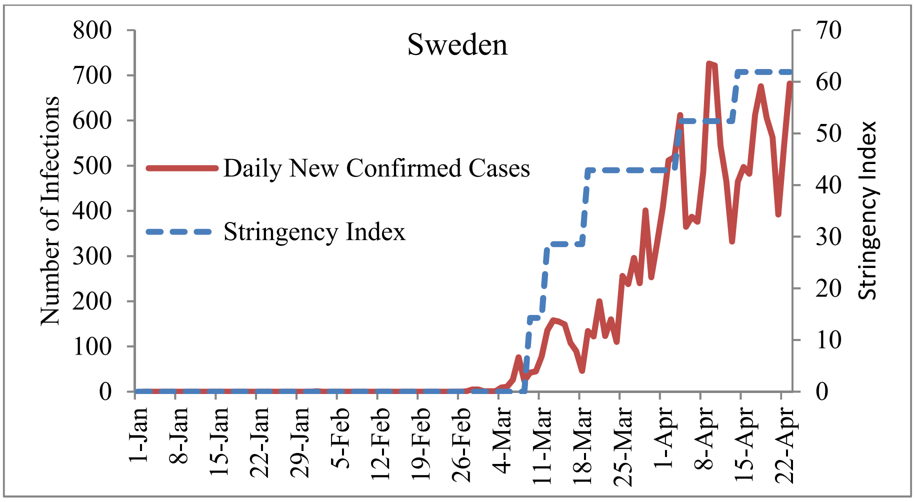


Figure (6)

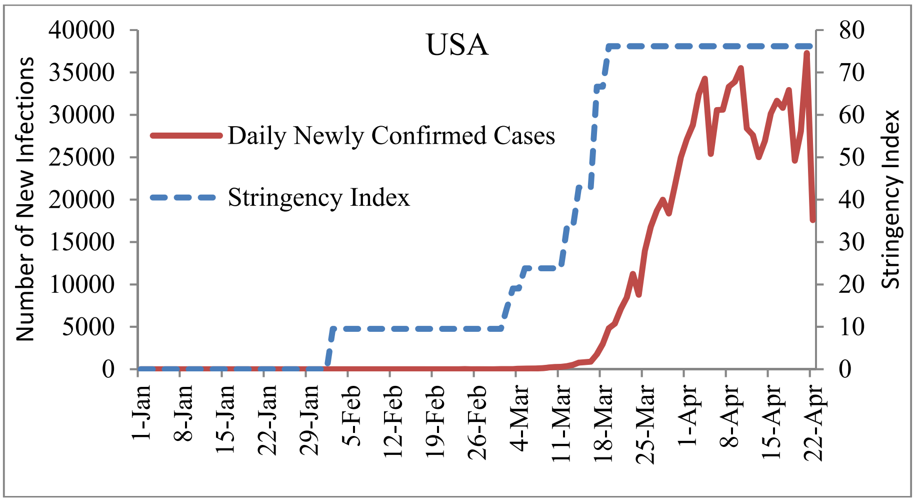
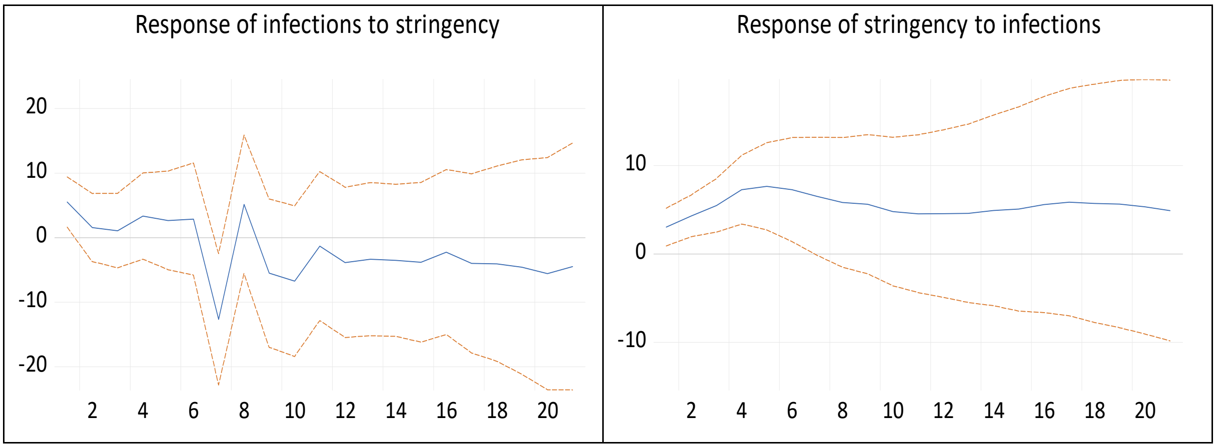
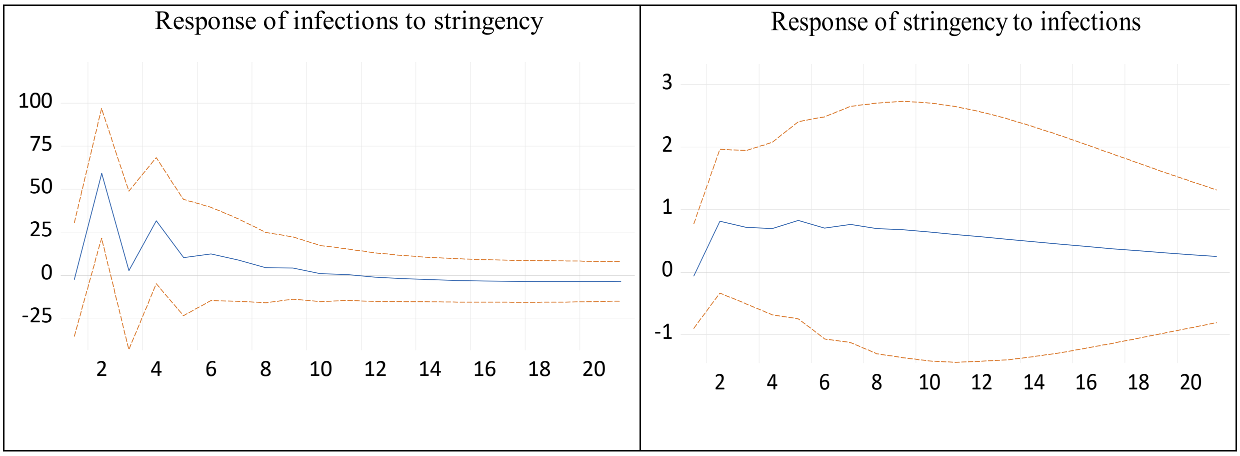


Figure (7) – Generalized Impulse Response Function
Response to Generalized One S.D. Innovation $\pm 2\sigma$

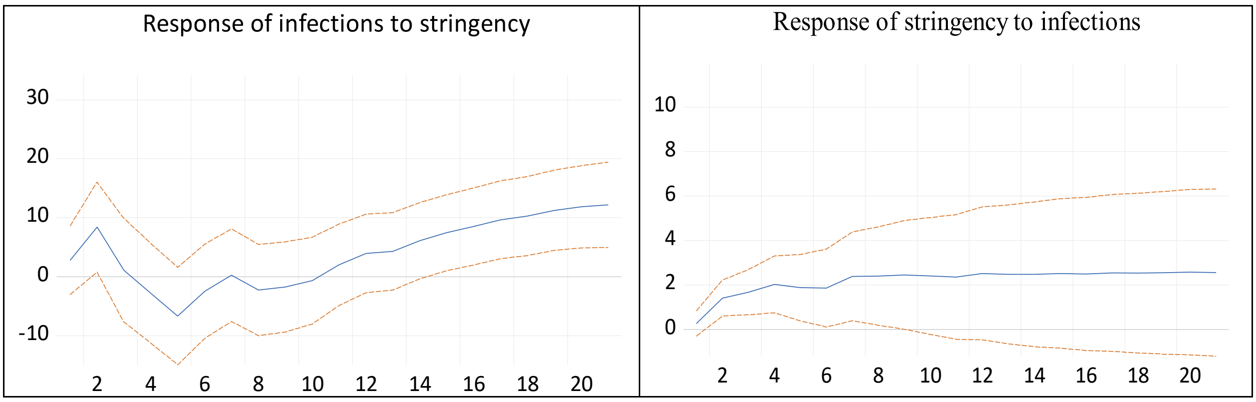
(a) New Zealand



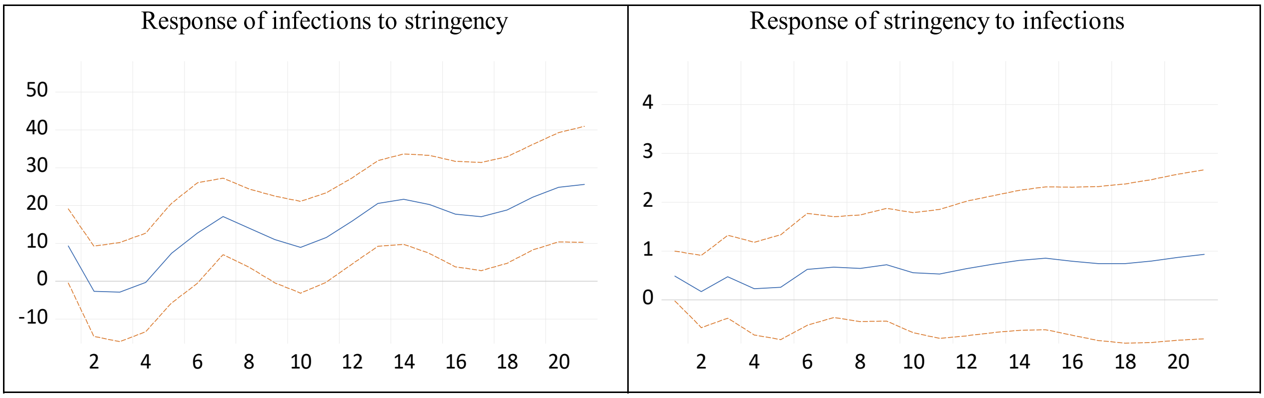
(b) Australia



(c) Denmark



(d) Sweden



(e) U.S.

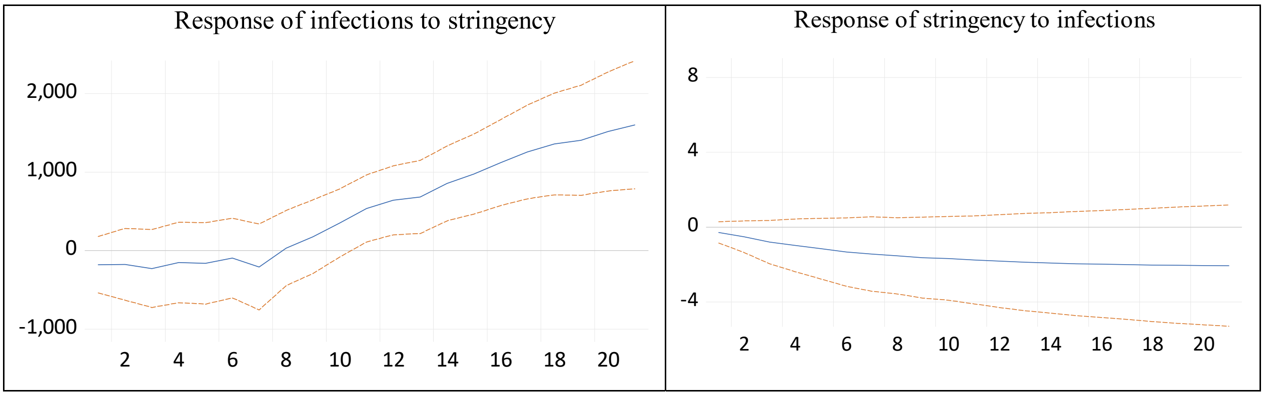


Figure (8)

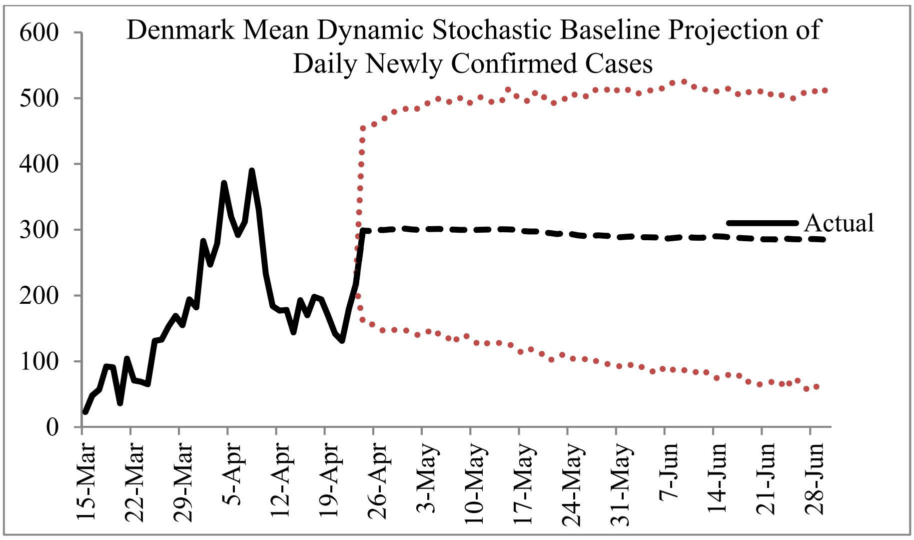


Figure (9)

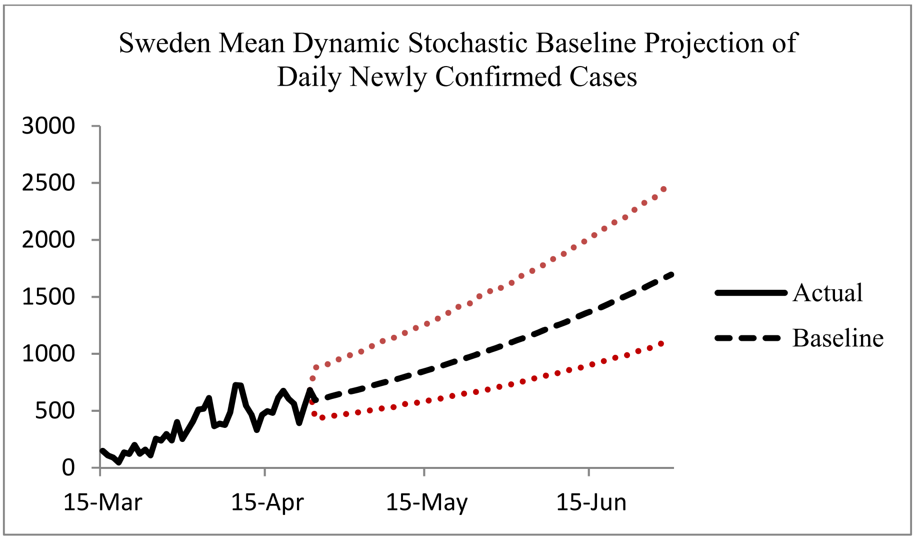


Figure (10)

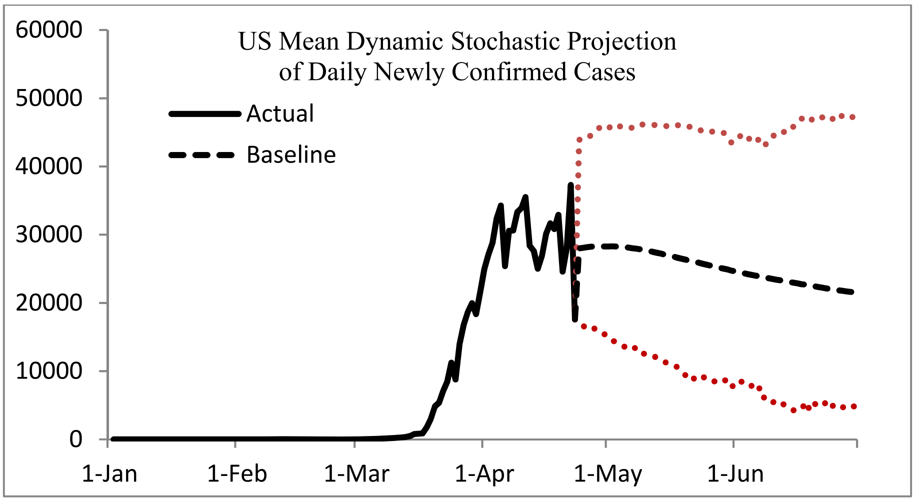


Figure (11)

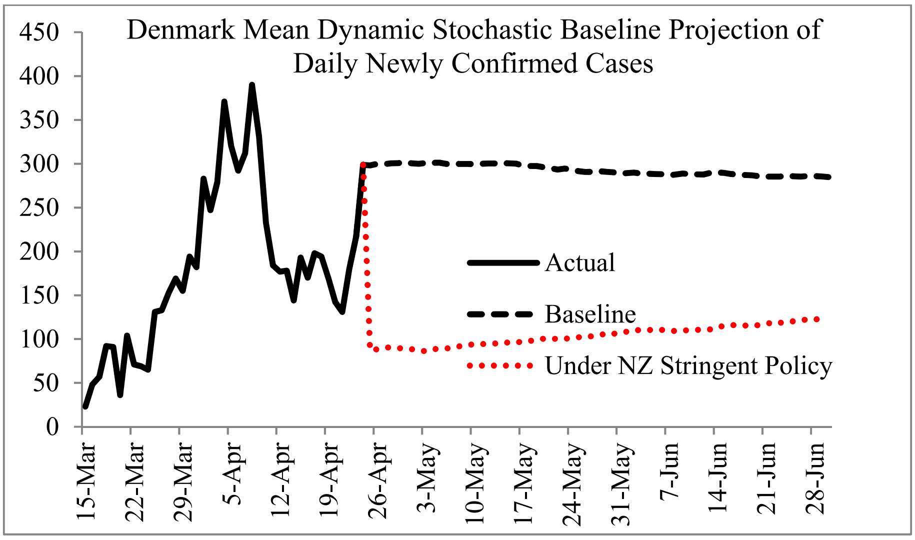


Figure (12)

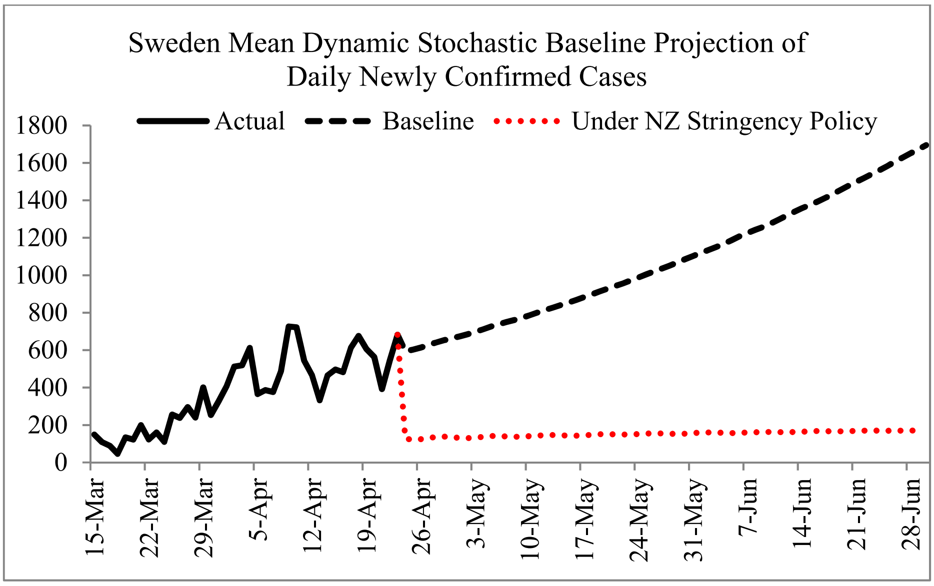
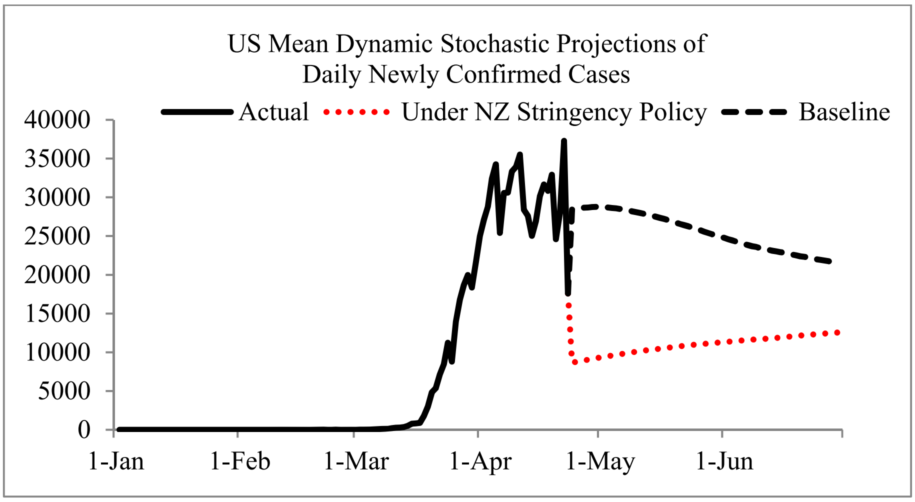


Figure (13)



Data Appendix

Aruba, Afghanistan, Angola, Albania, Andorra, United Arab Emirates, Argentina, Australia, Austria, Azerbaijan, Burundi, Belgium, Burkina Faso, Bangladesh, Bulgaria, Bahrain, Bosnia and Herzegovina, Belize, Bermuda, Bolivia, Brazil, Barbados, Brunei, Botswana, Canada, Switzerland, Chile, China, Cameroon, DRC, Colombia, Costa Rica, Cuba, Cyprus, Czech Republic, Germany, Djibouti, Dominica, Denmark, Dominican Republic, Algerian, Ecuador, Egypt, Spain, Estonia, Ethiopia, Finland, France, Gabon, United Kingdom, Ghana, Gambia, Greece, Greenland, Guatemala, Guam, Guyana, Hong Kong, Honduras, Croatia, Hungary, Indonesia, India, Ireland, Iran, Iraq, Iceland, Israel, Italy, Jamaica, Jordan, Japan, Kazakhstan, Kenya, Kyrgyz Republic, South Korea, Kuwait, Laos, Lebanon, Libya, Sri Lanka, Lesotho, Luxemburg, Macao, Moldova, Madagascar, Mexico, Mali, Myanmar, Mongolia, Mozambique, Mauritania, Mauritius, Malawi, Malaysia, Namibia, Niger, Nigeria, Nicaragua, Netherlands, Norway, New Zealand, Oman, Pakistan, Panama, Peru, Philippians, PNG, Poland, Puerto Rico, Portugal, Paraguay, Palestine, Qatar, Kosovo, Romania, Russia, Rwanda, Saudi Arabia, Sudan, Singapore, Sierra Leone, El Salvador, San Marino, Serbia, South Sudan, Slovak Republic, Slovenia, Sweden, Eswatini, Seychelles, Syria, Chad, Thailand, Trinidad and Tobago, Tunisia, Turkey, Taiwan, Tanzania, Uganda, Ukraine, Uruguay, USA, Uzbekistan, Venezuela, Vietnam, South Africa, Zambia, and Zimbabwe.