Epi-economic Modelling of COVID-19: Policy Implications for Australia

Quentin Grafton (quentin.grafton@anu.edu.au)
Australian National University

Tom Kompas (tom.kompas@unimelb.edu.au)
University of Melbourne

(co-authors and technical advisors in alphabetical order: Emily Banks, James Camac, Nhu Che, Long Chu, Kathryn Glass, Kamilini Lokuge and John Parslow)

Australian National University

cebra
Centre of Excellence for Biosecurity Risk Analysis

THE UNIVERSITY OF MELBOURNE

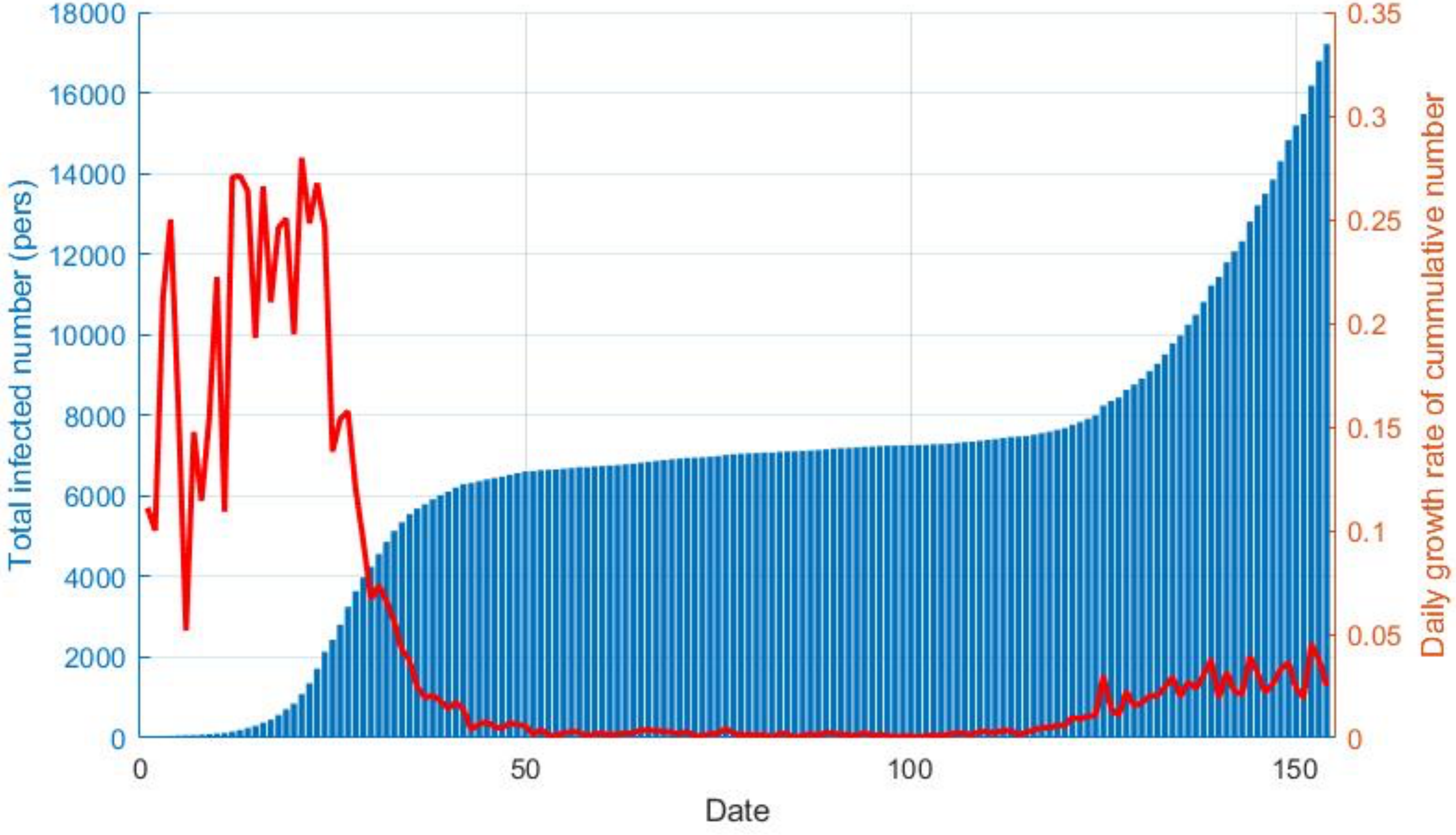
AARES Webinar 5 August 2020

I. Overview

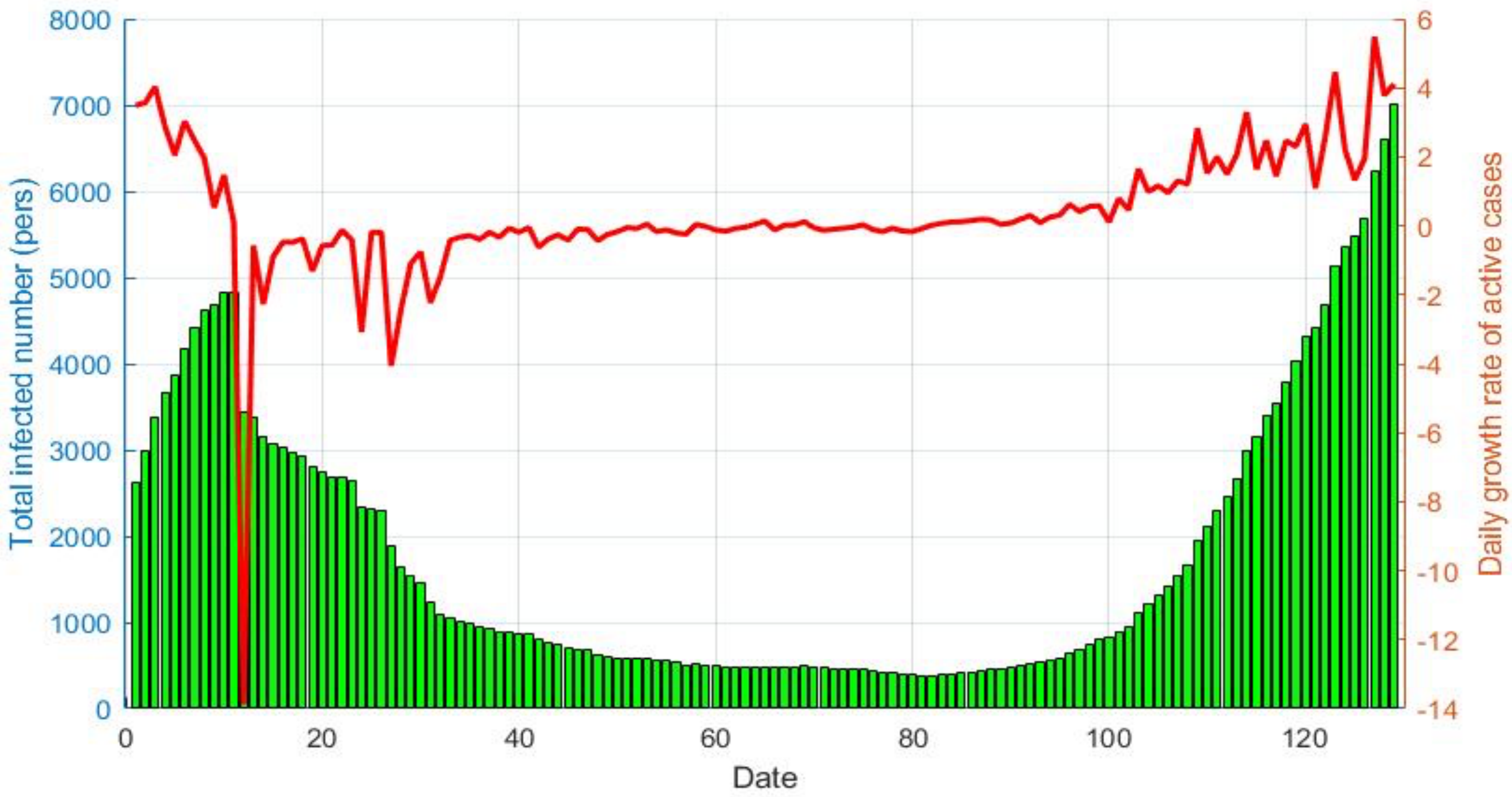
I. Australian COVID-19 experience & Modelling Context

II. Results of Modelling the ‘First Surge’

III. Results of Modelling the ‘Victorian Resurgence’



Reported cumulative infections and daily growth rate from March 1 to current



Reported active infectious cases (infections less recovered and deceased) and daily growth rate from March 26 to current

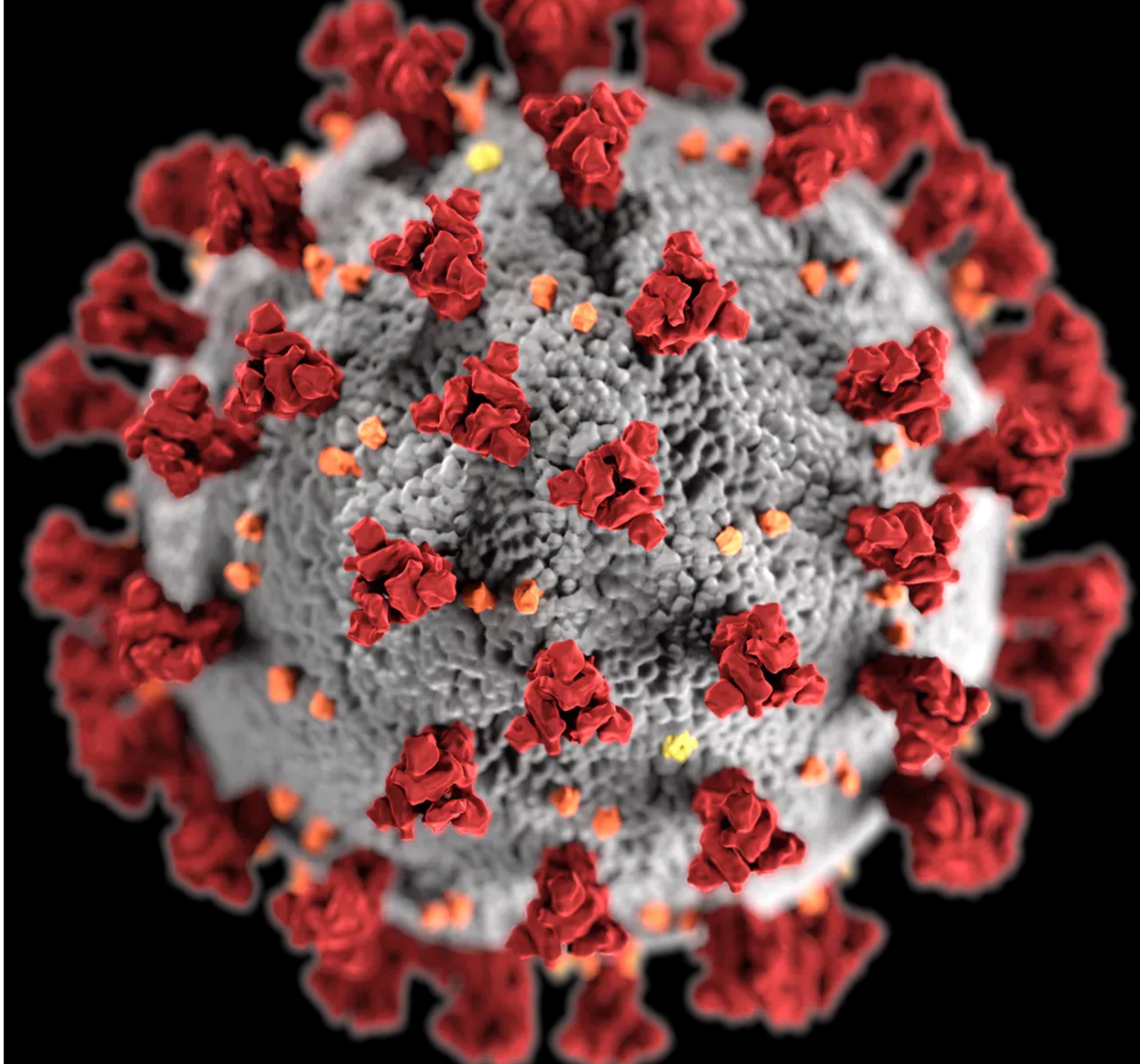
Modelling Context

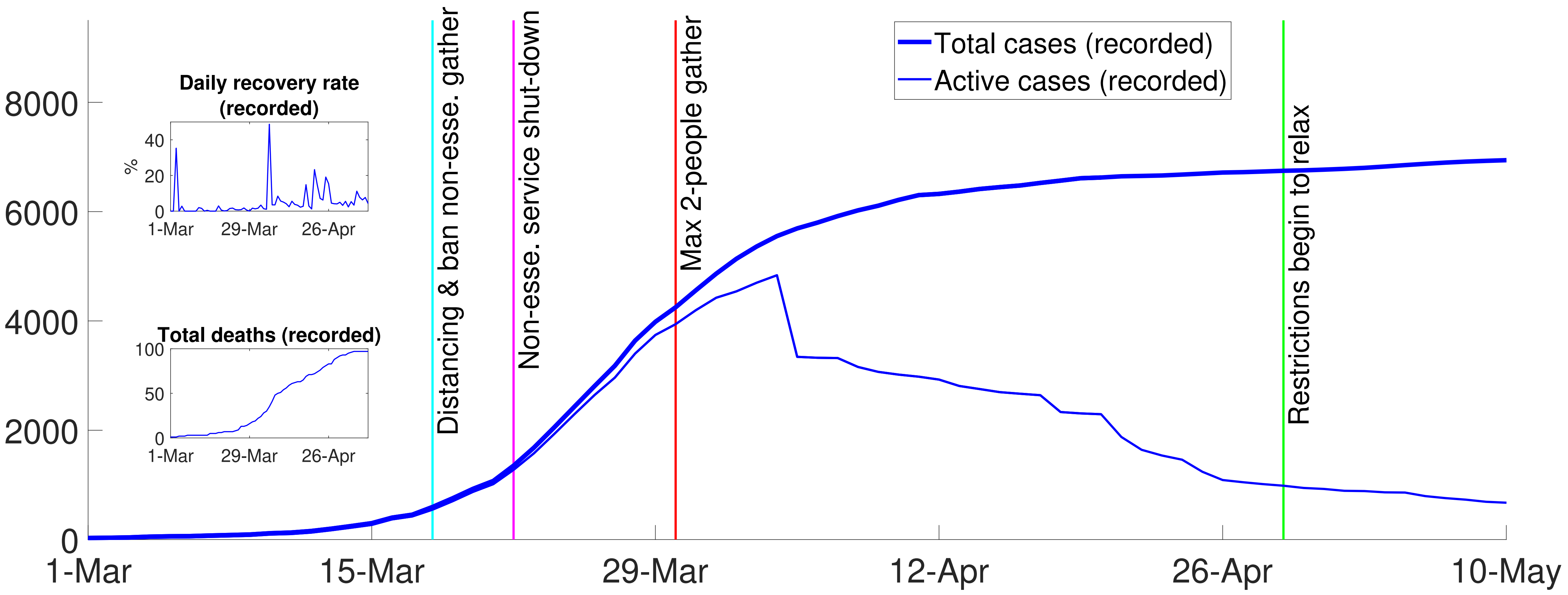
- Compartment Model
  - Susceptible-Infectious-Quarantined-Recovered-Mortality
  - NLS estimates of the impact of control measures on active cases
  - Adjusted value of life measures

  https://www.medrxiv.org/content/10.1101/2020.06.21.20136549v1

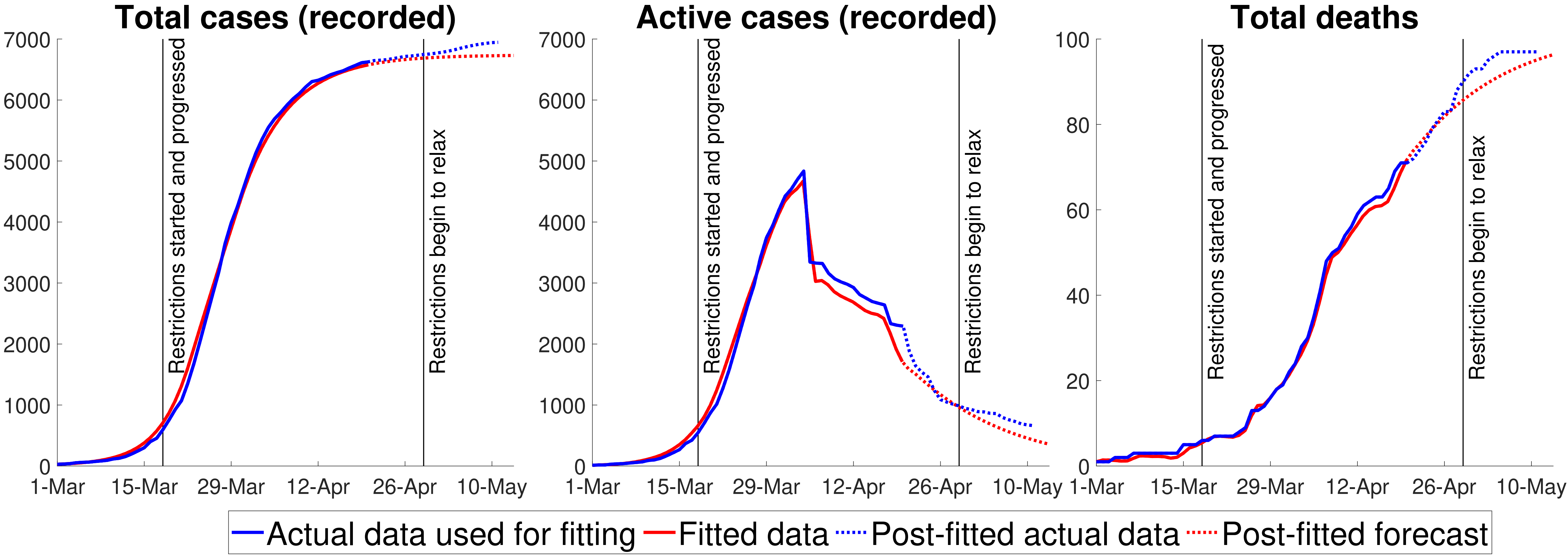
- IBM/SCM/DCM Models
  - Individual-based model: infected individuals through time, starting on the day when they are infected, and ending when they are officially recovered. Each individual is characterised by a set of attributes whose values evolve over time according to a set of rules.
  - Stochastic compartment model: A parallel stochastic compartment model (SCM) was developed to replicate the behaviour of the IBM efficiently with high numbers of active cases. Instead of representing individuals, this model represents numbers of individuals in daily cohorts.
  - Deterministic compartment model: The DCM is identical in structure, parameters and processes to the SCM. On every occasion where the SCM draws a random variable from the binomial or negative binomial, the DCM replaces this with the expected value.
- Economy and Heath Costs
  - Economy-wide costs of first phase lockdown were obtained from Kompas et al. (2020, p. 13, above link) using ABS data at a Victorian level equivalent to approx. $200 million per lockdown day.
  - COVID-19 related fatalities are valued at $4.9 million per value of statistical life (VSL) from Prime Minister and Cabinet (2019), adjusted for those over 70 years, and health costs comprise hospitalisation costs using average measures of bed costs (Independent Hospital Pricing Authority 2020).

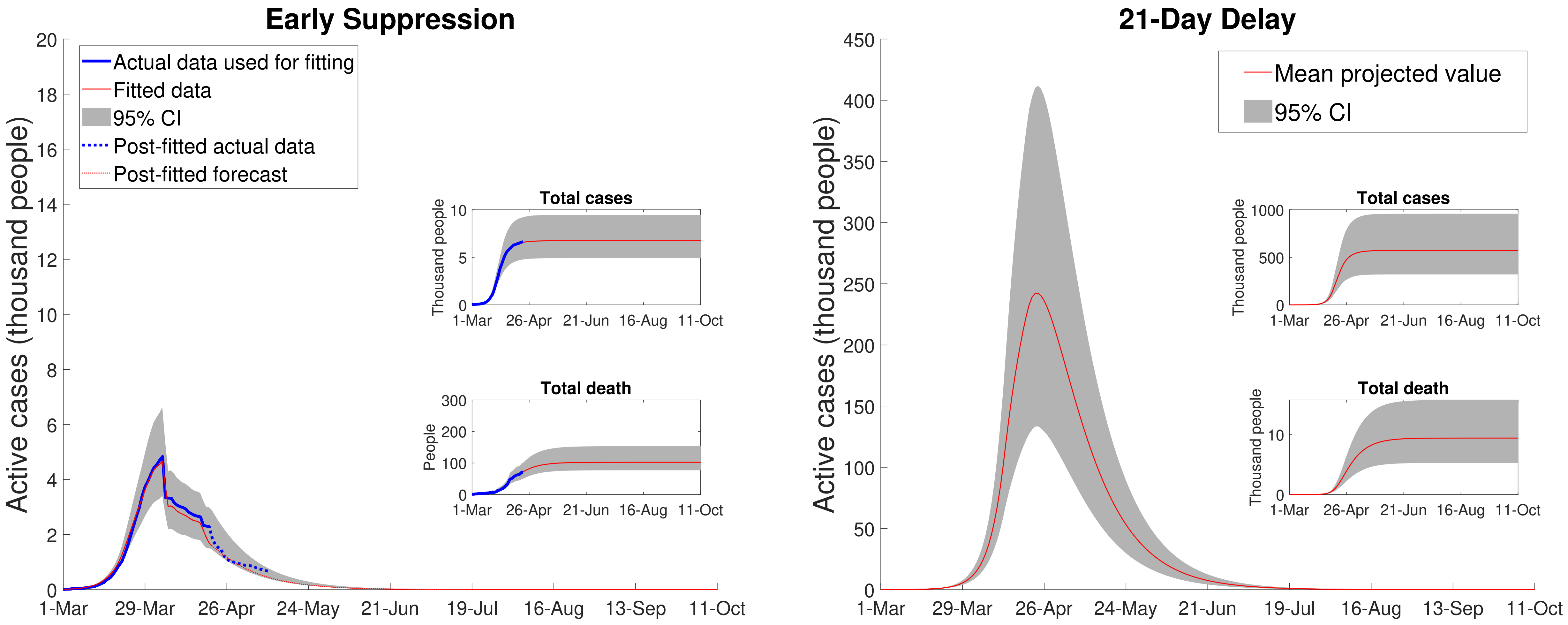
II. Compartment Modelling of 'First Surge'



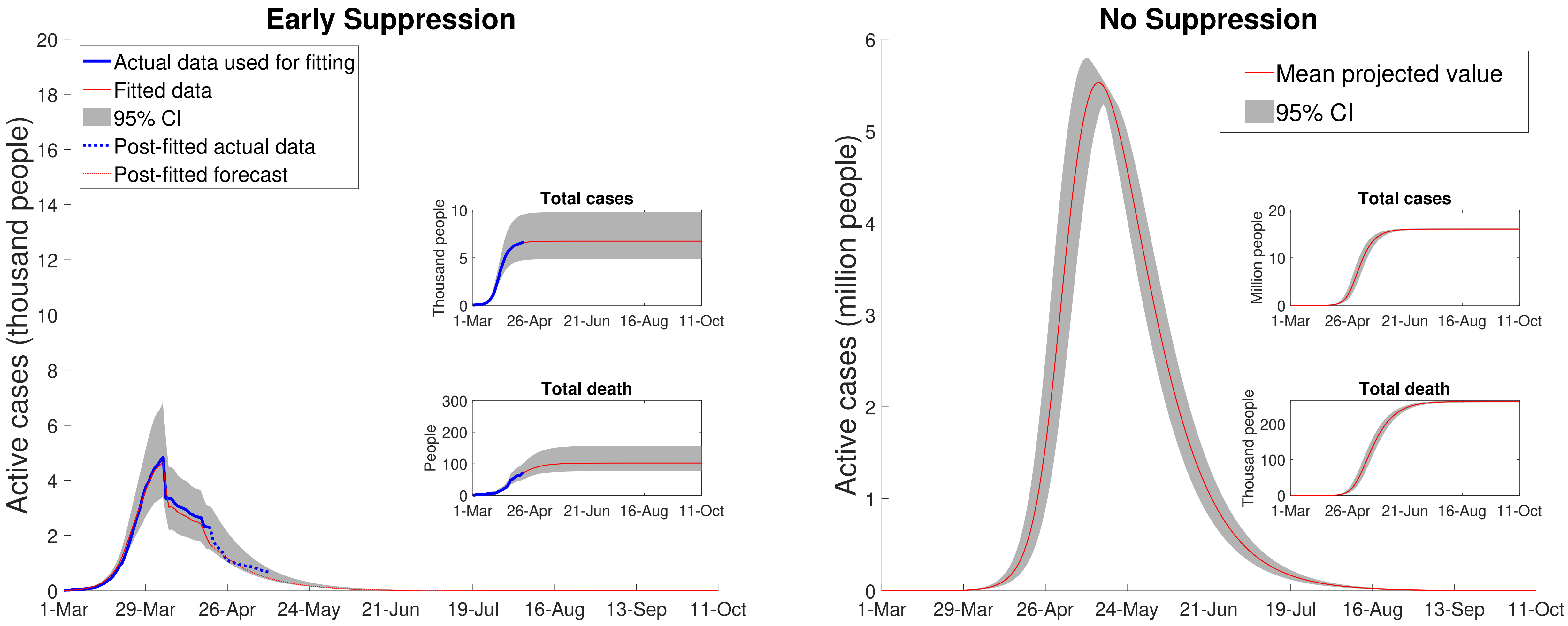


Total and active recorded cases and various control measures, from March 1 to May 10


Total cases (recorded)
Active cases (recorded)
Total deaths
Restrictions started and progressed
Restrictions begin to relax
1-Mar
15-Mar
29-Mar
12-Apr
26-Apr
10-May
Actual data used for fitting
Fitted data
Post-fitted actual data
Post-fitted forecast



Compartment model and actual results for active cases with early and 21-day delayed suppression



Compartment model and actual results for active cases with early and no suppression

Table 4: Cost of Control Measures *($ million per day AUD)*.

Sector/Region	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	Sum
Mining	11.9	3.2	30.5	2.3	67.9	0.7	4.3	0.0	120.9
Manufacturing	29.2	23.4	19.0	4.9	10.3	1.8	1.1	0.4	89.9
Electricity, gas, water, waste	6.9	4.5	5.3	1.8	2.6	0.9	0.3	0.3	22.5
Construction	31.7	26.2	19.3	5.7	14.4	1.5	3.3	1.8	103.9
Wholesale trade	12.0	9.6	7.6	2.3	3.5	0.5	0.2	0.3	36.0
Retail trade	8.4	7.0	5.2	1.8	2.7	0.6	0.3	0.5	26.5
Accom & food services	6.5	3.9	3.0	0.9	1.6	0.3	0.1	0.7	16.9
Transport, postal, warehouse	10.5	9.8	8.4	2.5	6.8	0.9	0.7	0.5	40.2
Infor media & telecom	10.3	6.6	3.4	1.5	1.9	0.4	0.2	0.4	24.7
Financial & insurance	45.0	28.0	13.3	4.9	6.7	1.1	0.4	0.9	100.4
Rental, hiring, real estate	13.1	7.1	7.1	1.6	2.7	0.6	1.0	0.8	34.0
Professional, scientific & tech	34.4	24.8	13.2	4.0	8.9	0.7	0.8	2.4	89.2
Administrative services	17.6	11.4	9.6	2.8	5.4	0.4	0.5	0.6	48.3
Education & training	26.4	21.1	14.6	5.0	7.0	1.6	0.8	4.4	81.0
Health care, social assistance	22.5	17.6	14.6	5.7	8.5	1.4	0.9	1.6	72.7
Arts & recreation services	2.7	1.8	1.1	0.3	0.5	0.1	0.1	0.4	7.0
Other services	4.5	3.7	2.8	0.8	1.6	0.2	0.1	0.2	14.0
Sum	293.6	209.6	177.8	48.8	153.2	13.8	15.1	16.3	**928.2**

Note: Calculations based on source survey material on business activity from (ABS, 2020*b*);(ABS, 2020*c*); IMF (2020); and Claughton et al. (2020).

Table 6: Direct Economic Costs with Early Suppression in $ billions and GDP loss, and Health and Welfare Losses

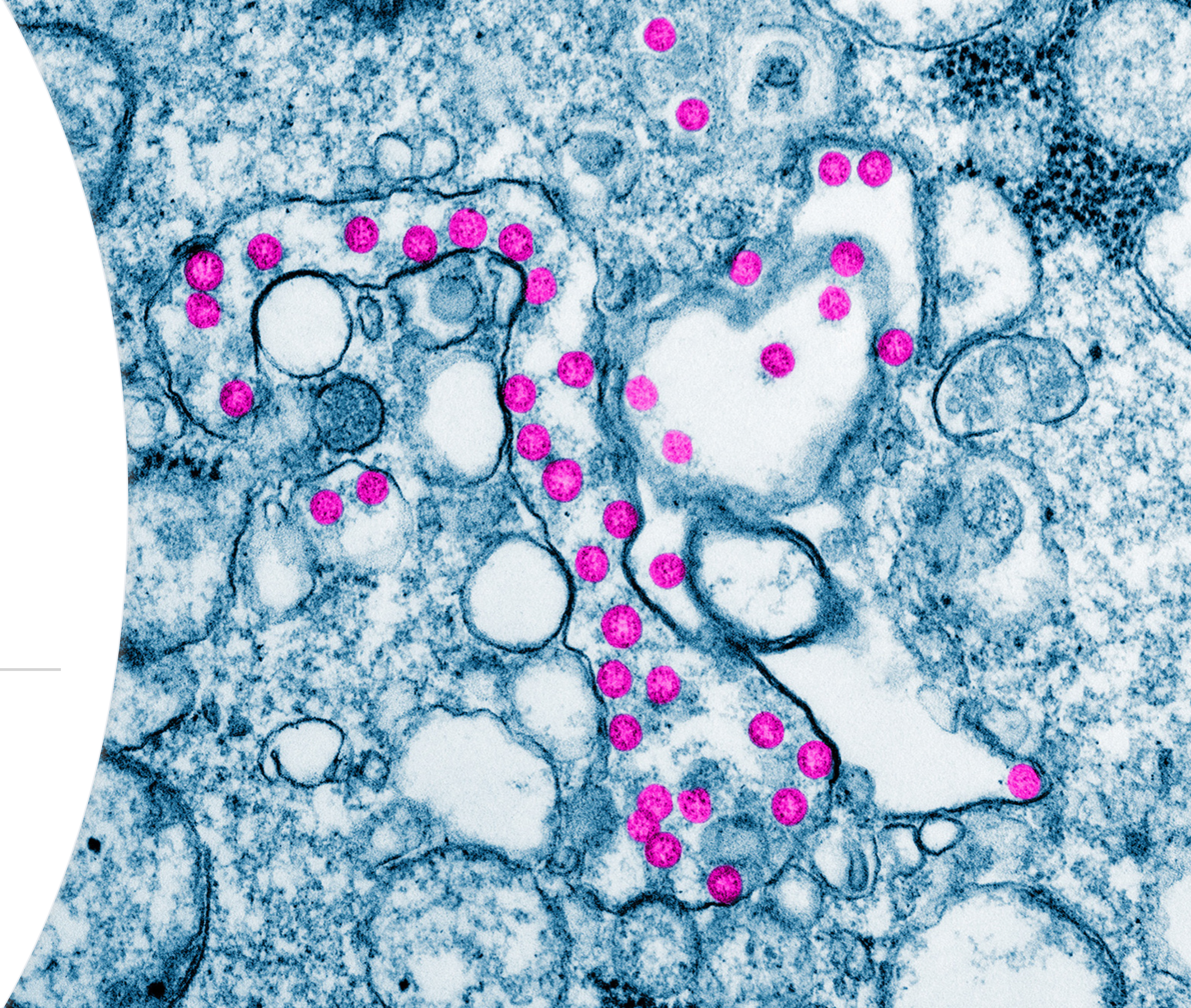
	Recovery (months)	Costs (*$ billion AUD*)			Economy Costs (% annual GDP)
		Lock-down	Recovery	Total	Annual Loss GDP (%)
	Early Suppression Measures for 8 Weeks from March 30th				
Transition 1	1	51.98	14.39	66.37	3.33
Transition 2	2	51.98	30.39	82.37	4.13
Transition 3	3	51.98	48.27	100.26	5.03
Transition 4	4	51.98	68.59	120.57	6.04
	Welfare Losses, Hospitalization Costs and Fatality Equivalents of No Suppression				
		Welfare	Hospital	Total	Annual Loss GDP (%)
VSLY		572.8	23.3	596.1	29.8
VSLY*		240.0	23.3	263.3	13.1
A-VSL		956.2		956.2	47.9
A-VSL*		401.6		401.6	20.1
Fatality equivalent at % GDP**		30,491 (3.3%)	37,816 (4.13%)	46,057 (5.03%)	55,305 (6.04%)
Fatality equivalent at %GDP*		12,808 (3.3%)	15,882 (4.13%)	19,343 (5.03%)	23,228 (6.04%)

*VSLY, A-VSL and fatality equivalent measures using the fatality ratio in Verity et al. (2020). **Fatality equivalent is the VSLY-measured number of fatalities under the no suppression scenario that equals the direct economy cost associated with an early 8-weeks lock-down (early suppression) for each % GDP loss (3.33, 4.13, 5.03, and 6.04). N.B. The estimated early suppression model fatalities are 100.

Key Results: ‘The First Surge’

- Early suppression leading to elimination or no community transmission of COVID-19 is best for both public health **AND** economy outcomes. Our first compartment model indicated a ‘lockdown’ until early June in Australia was most preferred.
- VSLY welfare losses of fatalities equivalent to GDP losses mean that for early suppression to **NOT be the preferred strategy requires that Australians prefer more than 12,500–30,000 deaths to the economy costs of early suppression**, depending on the fatality rate
- **Results equivalent to the ‘Swedish model’ would imply roughly 14,000 deaths** in Australia.
- We find **robust evidence for ‘go early, go hard’ strategy**, at least in a high-income country like Australia.

III. IBM/SCM/DCM Modelling of ‘Victorian Resurgence’



Symbol	Description
T_S	Days to onset of symptoms
T_I	Days to onset of infectivity
T_F	Days to cessation of infectivity
T_H	Days to develop severe symptoms
T_D	Days to first deaths
T_R	Days to first recovery
T_M	Maximum period cases are active.
P_A	Probability cases are asymptomatic
P_H	Probability of hospitalization for symptomatic cases
P_M	Probability of death among hospitalized cases
P_D	Daily probability fatally ill die after TD.
P_R	Daily probability of recovery after TR
G0	Daily transmission rate before social distancing
G_{LD}	Daily transmission rate at peak of March-April lockdown
RSD	Relaxation of social distancing = $(G-G_{LD})/(G0-G_{LD})$
F_A	Ratio of asymptomatic to symptomatic transmission
P_{DC}	Daily probability of detection in community
P_{DSQ}	Daily probability of detection in self-isolation
P_T	Daily probability of tracing downstream contacts
P_L	Daily probability of transmission from self-isolated cases
P_U	Fraction of community hidden / uncooperative
P_Q	Daily probability of quarantine breakdown
POP	Total population size
TCAP	Maximum tracing capacity in daily new cases

Results are preliminary

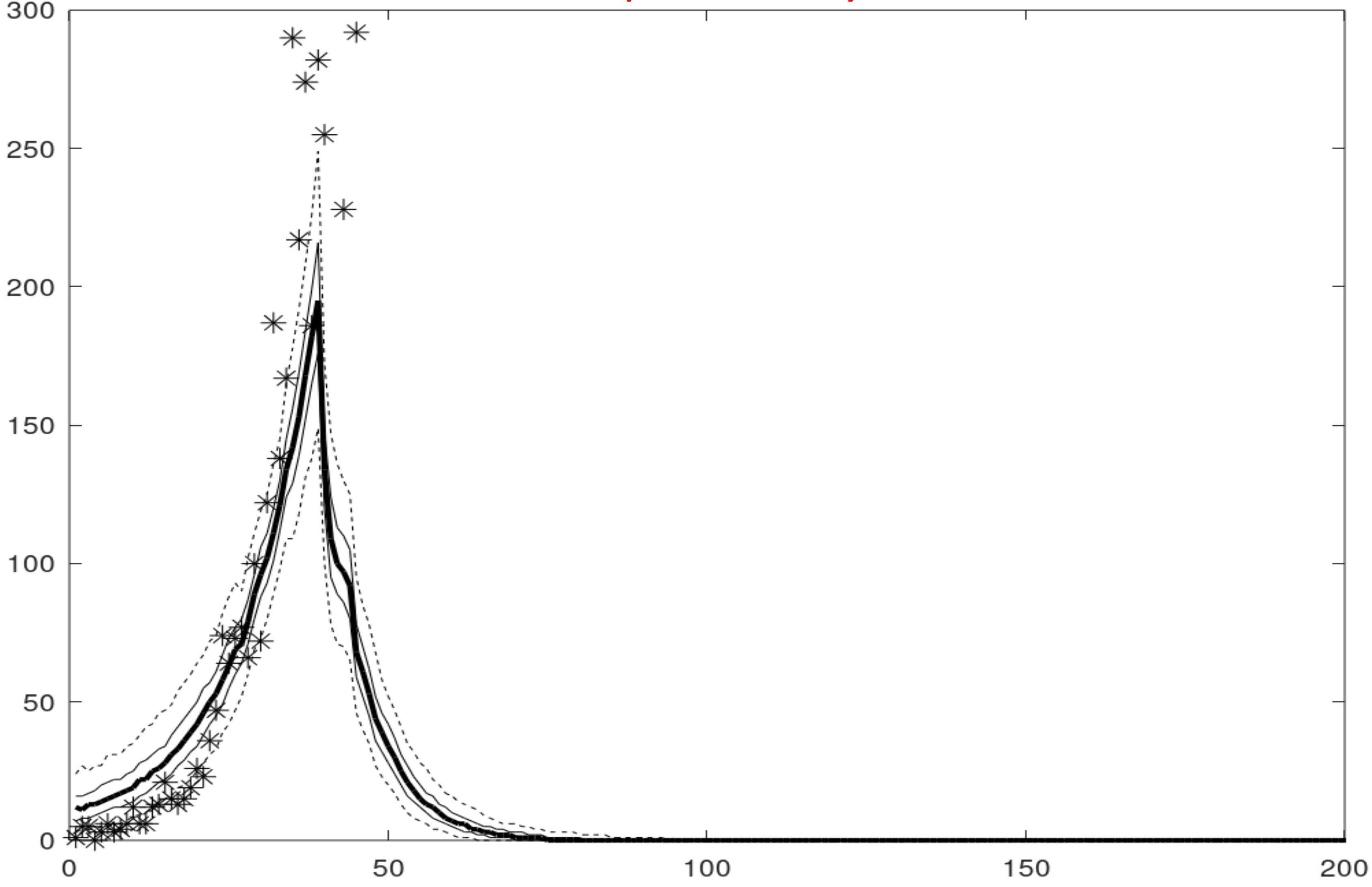


Fig. 1A. **Elimination Strategy**, lockdown trigger = 100 daily cases, lockdown **SD = 1.0** applied at day 35, NO quarantine leakage ($P_Q = 0.0$). Ensemble percentiles: median (thick line), quartiles (thin lines), 5-95 percentiles (dashed lines), Observations (*).

Results are preliminary

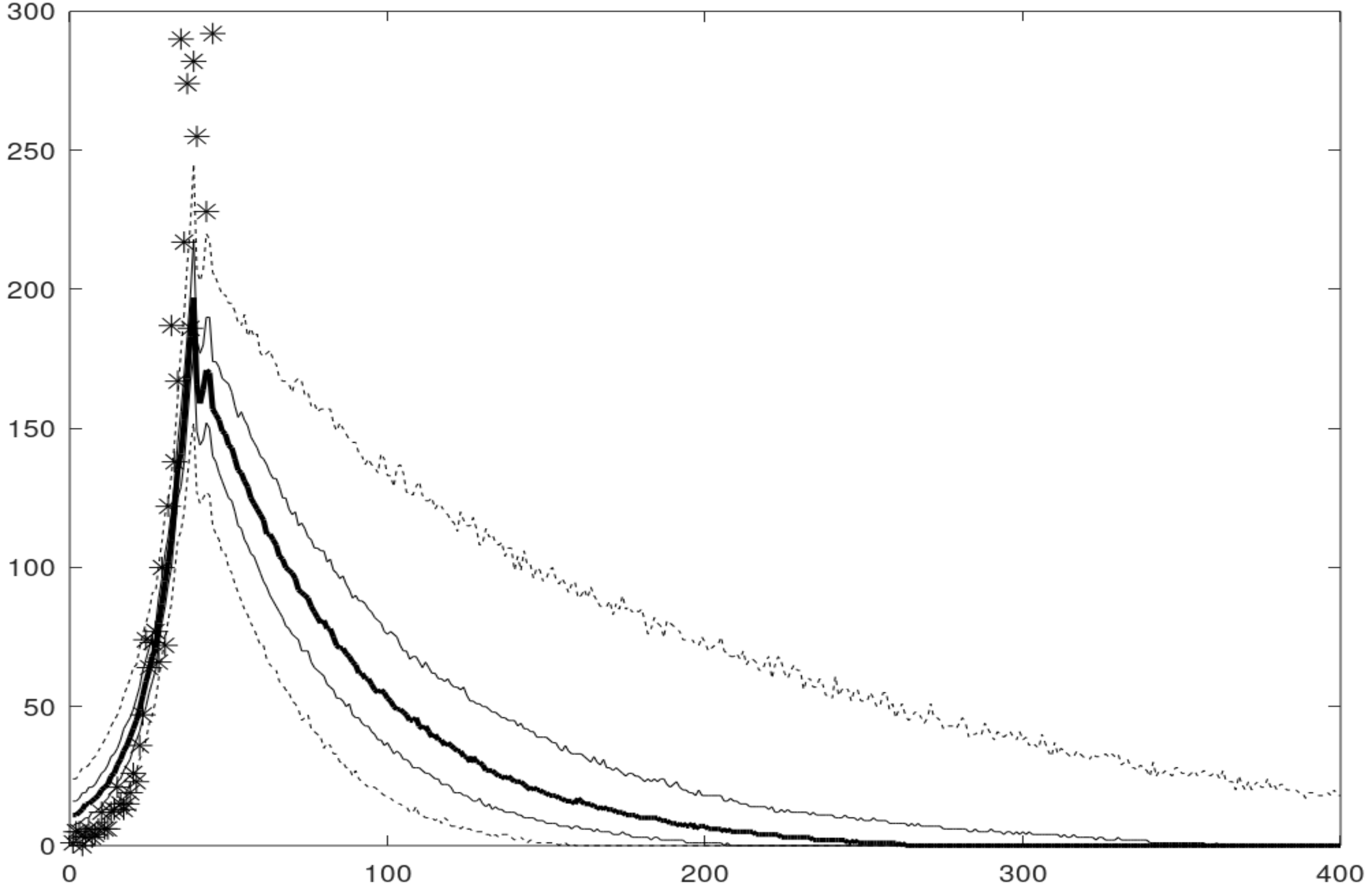


Fig. 1B. **Elimination Strategy**, lockdown trigger = 100 daily cases, lockdown **SD = 0.7** applied at day 35, NO quarantine leakage ($P_Q = 0.0$). Ensemble percentiles: median (thick line), quartiles (thin lines), 5-95 percentiles (dashed lines), Observations (*).

Results are preliminary

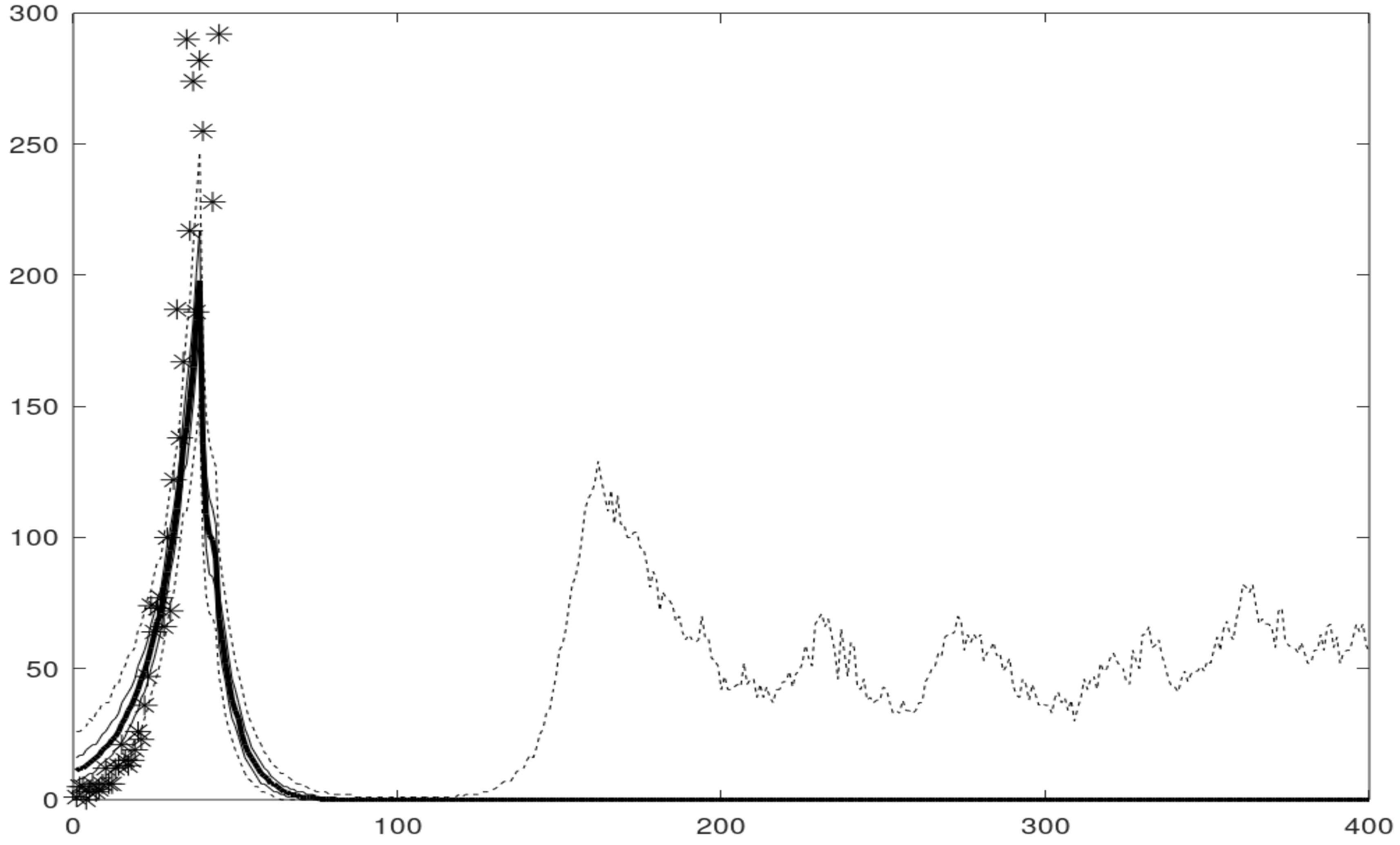


Fig. 2A. **Suppression Strategy**, lockdown trigger = 100 daily cases, lockdown SD = 1.0 applied at day 35, **minimum lockdown period = 40 days**, relaxation trigger = 20 daily cases, quarantine leakage ($P_Q = 0.002$). Ensemble percentiles: median (thick line), quartiles (thin lines), 5-95 percentiles (dashed lines), Observations (*).

Results are preliminary

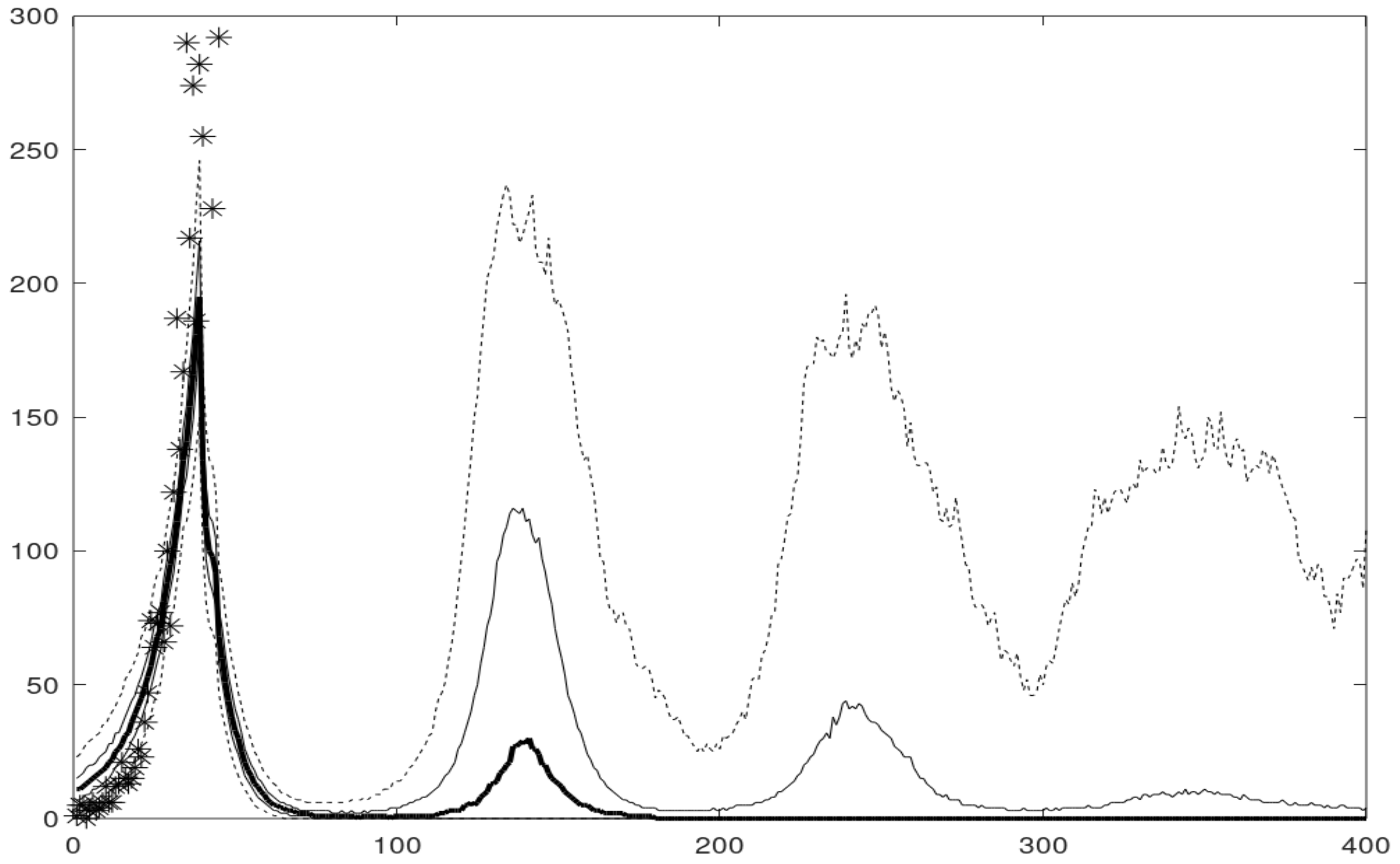


Fig. 2B. **Suppression Strategy**, lockdown trigger = 100 daily cases, lockdown SD = 1.0 applied at day 35, relaxation trigger = 20 daily cases, **no minimum lockdown period**, quarantine leakage (P_Q = 0.002). Ensemble percentiles: median (thick line), quartiles (thin lines), 5-95 percentiles (dashed lines), Observations (*).

Results are preliminary

Table 1. Median (2.5%-97.5 CI) values of additional Elimination Days and Social Distancing Days (sum of social distancing level each day for 365 days) and number of COVID-19 deaths and associated (based on median values) Economy Costs of Social Distancing, Value of Statistical Lives Lost and Hospitalisation Costs for Social Distancing Levels from 0.5 to 1.0 for 365 days after implementation of Social Distancing.

Social Distancing Level	0.5	0.6	0.7	0.8	0.9	1.0
Elimination Days (#)	366 (283-366)	366 (366-366)	239 (127-366)	111 (75-183)	71 (51-107)	50 (37-50)
Social Distancing Days (#)	183 (157-183)	220 (220-220)	189 (111-256)	114 (85-172)	92 (74-125)	82 (71-104)
Economy Costs of Social Distancing (billion $)	38.43	46.2	39.69	23.94	19.32	17.22
COVID-19 Deaths (#)	76,496 (51,677-102,869)	24,595 (427-69,667)	228 (121-1,043)	122 (83-182)	91 (65-126)	81 (58-109)
Value of Statistical Lives Lost ($ billion)	374.83	120.52	1.12	0.60	0.45	0.40

Note: Economy costs of social distancing = $210 million per social distance day. Value of statistical life = $4.9 million, age adjusted.

Results are preliminary

Table 2. Median (2.5%-97.5 CI) values of additional Social Distancing Days (sum of social distancing level each day for 365 days) and number of COVID-19 deaths and associated (based on median values) Economy Costs of Social Distancing, Value of Statistical Lives Lost and Hospitalisation Costs for Social Distancing Level = 1.0 for 365 days after implementation of Social Distancing.

	Suppression Scenario A	Suppression Scenario B
Social Distancing Days (#)	71 (71-208)	113 (51-221)
Economy Costs of Social Distancing (billion $)	14.91	23.73
COVID-19 Deaths (#)	105 (61-241)	177 (65-379)
Value of Statistical Lives Lost ($ billion)	0.51	0.87

Note: Economy costs of social distancing = $210 million per social distance day. Value of statistical life = $4.9 million, age adjusted.

Key Results: ‘The Victorian Resurgence’

- A ‘Go Hard’ (versus ‘Go Soft’) strategy with highest levels of social distancing generates lowest public health **(hardest (SD = 1.0) lockdown generates a tiny fraction of COVID-19 deaths as the softest lockdown (SD = 0.5))** and economy costs **(hardest (SD = 1.0) lockdown generates less than half the cost of softest lockdown (SD = 0.5))**.
- A strategy that achieves elimination (no community transmission) results in much lower public health and economy costs than a strategy that only suppresses infection.
- Early relaxation of social distancing (no minimum suppression period) increases public health **(70% higher costs, depending on scenario)** and economy costs **(more than 50% higher costs, depending on scenario)**.

Results from ‘First Surge and ‘Victorian Resurgence’ combined provide robust support for a ‘**Go Early, Go Long and Go Hard**’ strategy to control COVID-19 infections in Australia.

Thanks for listening!

Quentin Grafton

quentin.grafton@anu.edu.au

https://crawford.anu.edu.au/people/academic/quentin-grafton

Tom Kompas

tom.kompas@unimelb.edu.au

www.tomkompas.org

Australian National University

cebra Centre of Excellence for Biosecurity Risk Analysis

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Follow Up Reading

- Kompas T, Grafton RQ, Che TN, Chu L, Camac J. *Health and Economic Costs of Early, Delayed and No Suppression of COVID-19: The Case of Australia.* https://www.medrxiv.org/content/10.1101/2020.06.21.20136549v1
- Grafton RQ, Parslow J, Kompas T, Glass K, Banks E, and Lokuge K, *Epidemiological and Economic Effects of Social Distancing for COVID-19 in Australia: Quantifying the payoffs of 'Go Long and Go Hard'*. Mimeograph.