NEREUS

Núcleo de Economia Regional e Urbana da Universidade de São Paulo

The University of São Paulo Regional and Urban Economics Lab

POLICY CENTER FOR THE NEW SOUTH

THINK • STIMULATE • BRIDGE

COVID-19 Crisis Monitor: Using High-Frequency Traffic Data in a Trade-Based Regional Economic Activity Index

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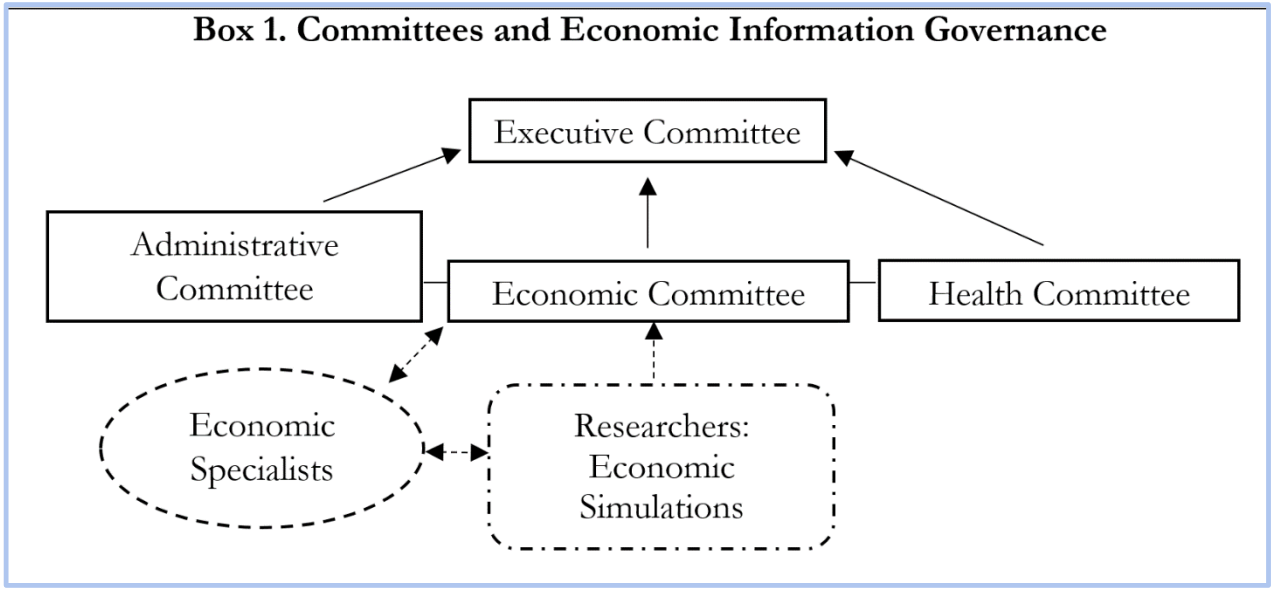
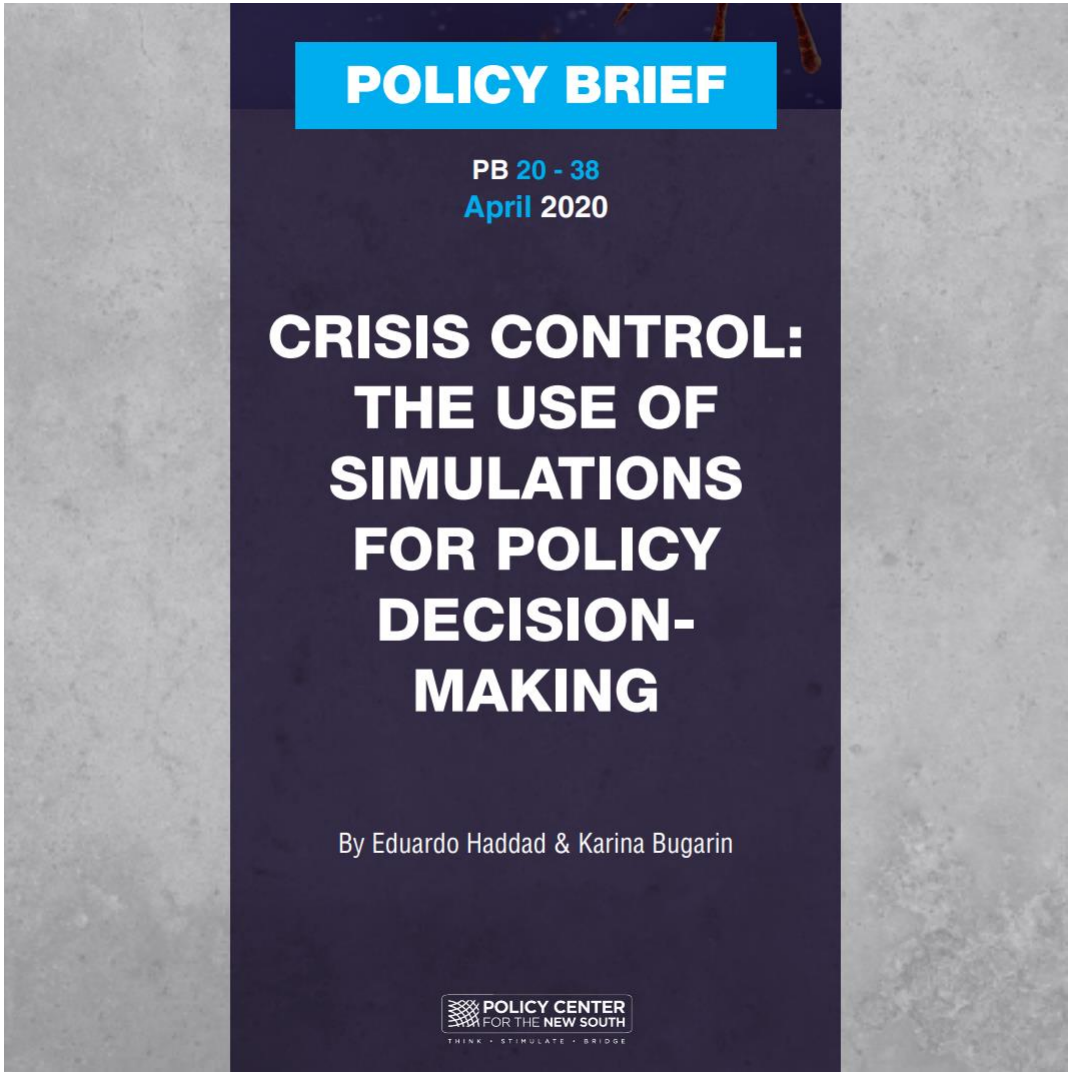
Expert committees to examine initial control measures and define gradual relaxing of social restrictions

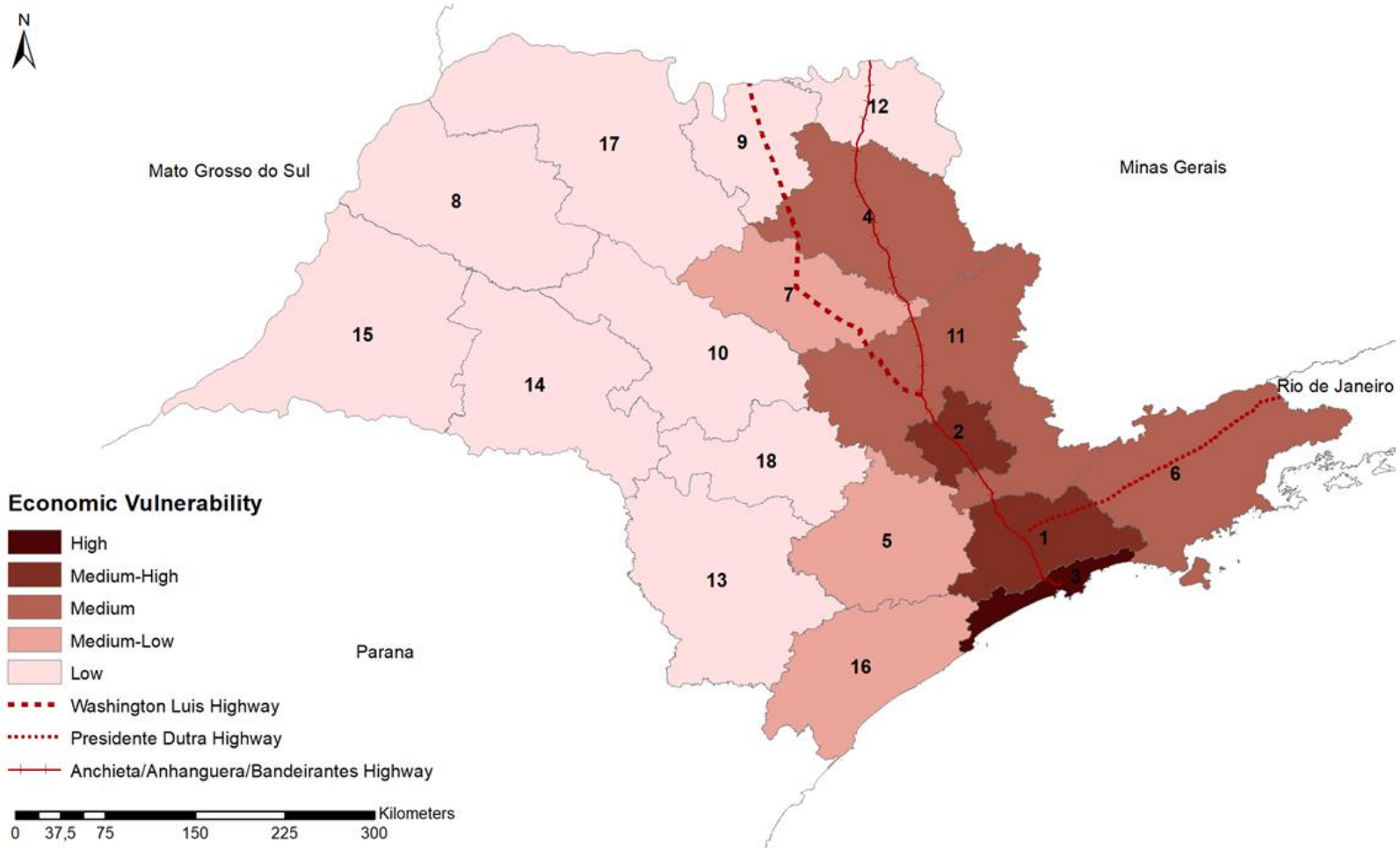
Up against enormous uncertainties, combining epidemiological and socioeconomic simulation-based scenarios to **assess and monitor impacts** is fundamental for informing officials before committing to a strategy



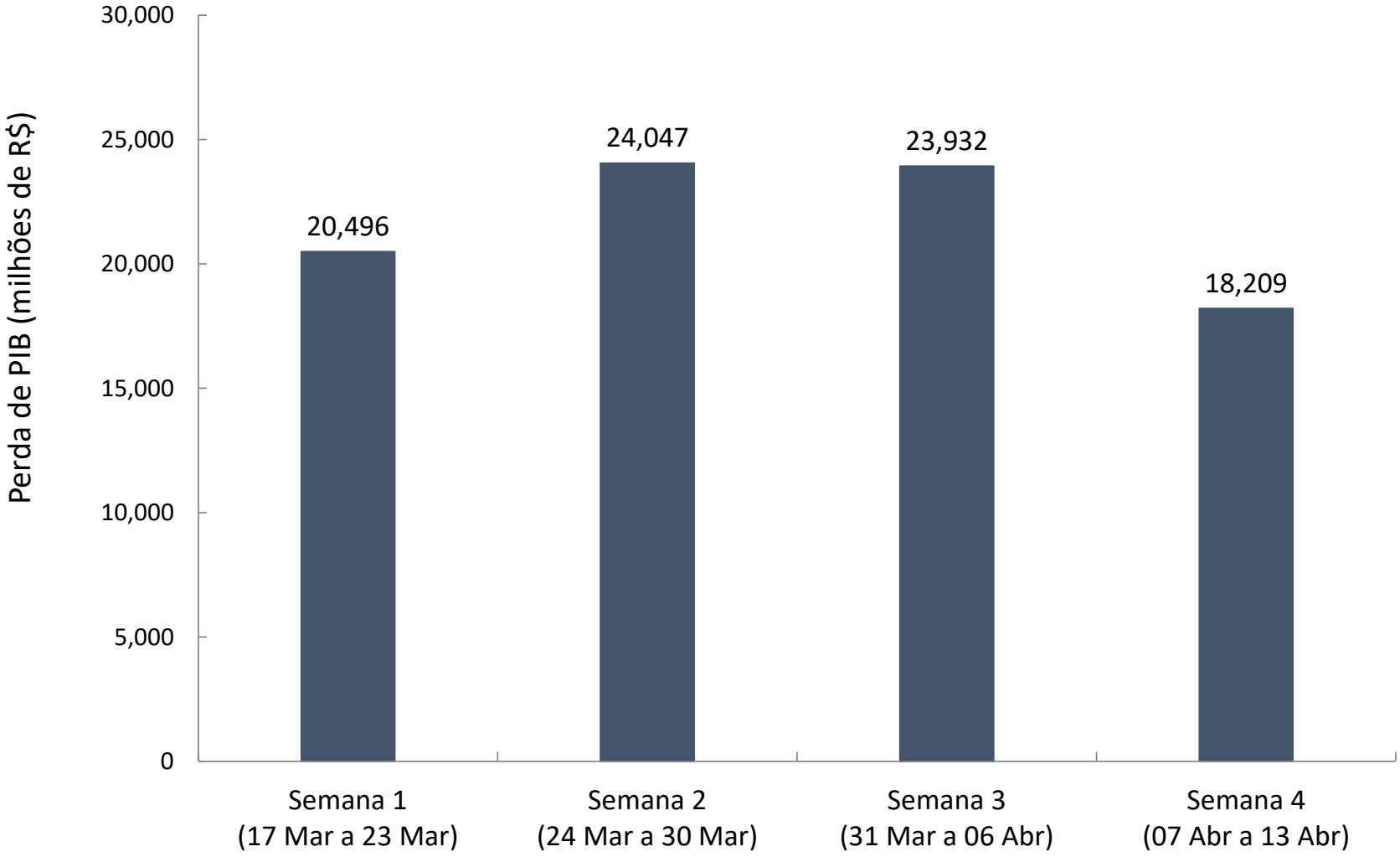
Impact of initial control measures



Heterogeneous sectoral and regional costs



There are also time-related economic costs, which adds another layer of complexity



Determinants of regional economic vulnerability

Regional economic vulnerability to the COVID-19 pandemic was positively correlated with the share of informal workers in the region, the level of compliance with restriction measures, and with adverse impacts in neighboring regions. Moreover, the greater the share of the public sector in a region's GDP, the lower its vulnerability, since public workers tended to be the least affected by the COVID-19 shocks.

Variável dependente: Índice de Vulnerabilidade Econômica (IVE)

Variável	*Modelo de Defasagem Espacial*	*Impacto Médio*		
		Efeito Direto	*Efeito Indireto*	*Efeito Total*
W_Vulnerabilidade Econômica	0,146**			
	(0,062)			
Participação da Adm. Pública no PIB	-2,774***	-2,791***	-0,369**	-3,160***
	(0,304)	(0,301)	(0,169)	(0,346)
Informalidade no Mercado de Trabalho	0,957***	0,963***	0,127**	1,090***
	(0,168)	(0,168)	(0,065)	(0,204)
Índice de Isolamento Social	4,196***	4,223***	0,558**	4,782***
	(0,706)	(0,707)	(0,268)	(0,814)
Constante	-1,226***			
	(0,308)			
Obs.	27			
R2	0,845			

Main take-away

The main losses are concentrated in the regions that most contribute to the state's GDP, which coincide with the most densely populated areas.

The most affected sectors are labor and flow intensive.

More densely populated regions are also the main vector for promoting contamination.

Therefore, a possible flexibility measure would be to loosen the grip in rural areas, *pari pasu* increasing restrictive measures in urban areas, while adopting a series of protocols in labor-intensive sectors with the aim of reducing contamination.

"São Paulo Plan": gradual relaxing of social restrictions as health indicators improve

SÃO PAULO
GOVERNO DO ESTADO

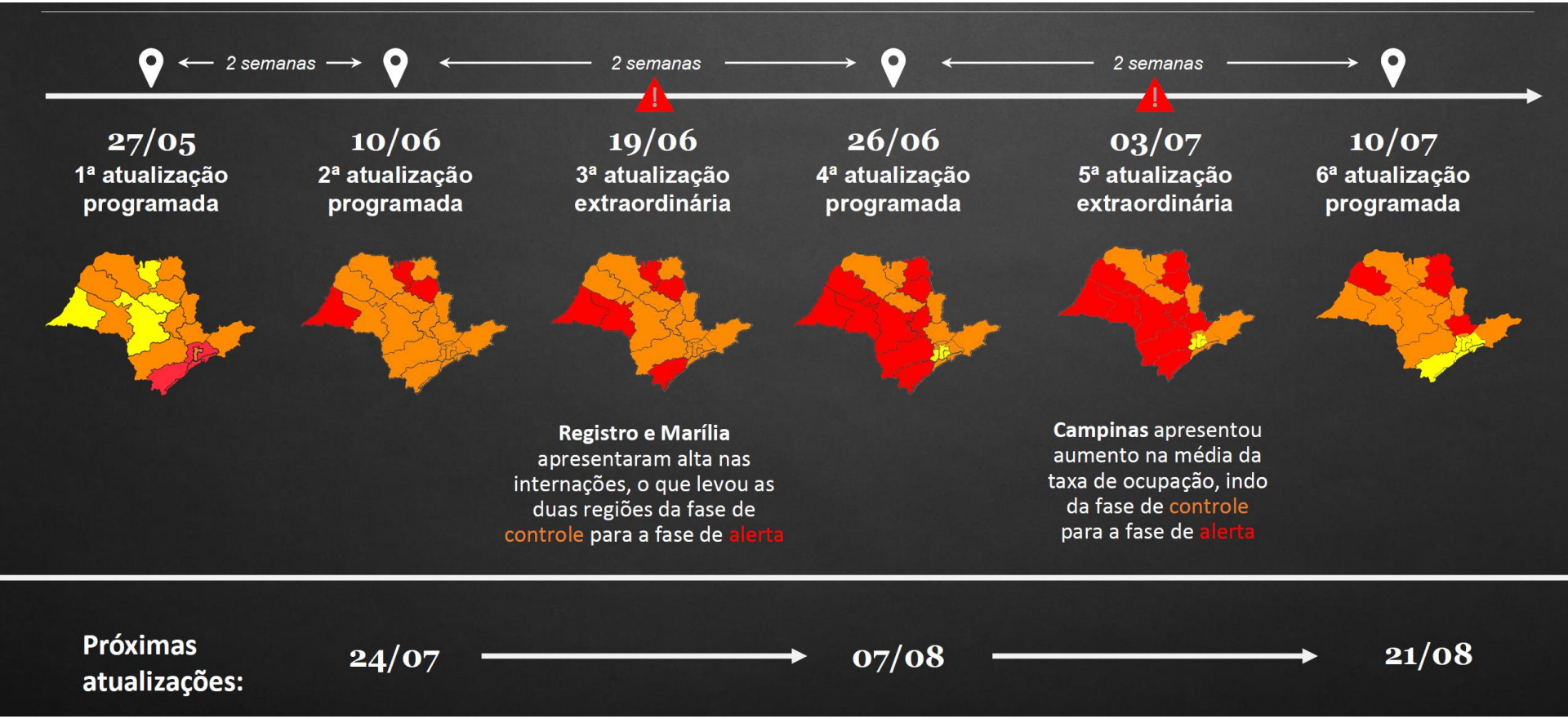
CRITERIA FOR THE PHASES CALCULATION

The criteria for the risk phases are currently defined by objective indicators and a weighting and rating methodology; The final classification is considered as the most restricted among the two sets of indicators

Set of indicators	Indicator	Weight	Phase 1 Maximum alert	Phase 2 Control	Phase 3 Flexibilization	Phase 4 Partial reopening	Phase 5 Controlled normal
Health System Capacity	Average occupancy rate of ICU COVID beds in the last 7 days (%)	4	Above 80%	Between 70% e 80%	Between 60% e 70%	Below 60%	*TBD*
	COVID ICU Beds / 100k habitants	1	Below 3.0	Between 3.0 e 5.0	-	Above 5.0[1]	*TBD*
Evolution of the epidemic	# of new cases in the last 7 days / # of new cases in the previous 7 days	1	Above 2.0	-	Between 1.0 e 2.0[2]	Below 1.0	*TBD*
	# of new hospital internments in the last 7 days / # of new hospital internments in the previous 7 days	3	Above 1.5	Between 1.0 e 1.5	Between 0.5 e 1.0	Below 0.5	*TBD*
	# of deaths by COVID in the last 7 days / # of deaths by COVID in the previous 7 days	1	Above 2.0	Between 1.0 e 2.0	Between 0.5 e 1.0	Below 0.5	*TBD*

1. In case the number of COVID ICU Beds is above 5.0, the indicator becomes automatically green; 2. In case the # of new cases in the last 7 days / # of new cases in the previous 7 days is below 2.0, the indicator becomes automatically yellow

Every two weeks, there was a reassessment of the regional classification based on health indicators



Monitoring health indicators and economic activity

Regional monitoring (DRS)

Health indicators (contemplated in the Plan)

- Health system capacity
- Evolution of the pandemic

Regional economic activity (caveats)

- State Treasury follows daily value-added tax (VAT) collection and VAT-generating transactions
  - Partial coverage of the State economy
  - Formal versus informal
  - Restricted number of sectors (<30% of GRP)

Monitoring regional economic activity

Need to complement tax monitoring with a broader indicator of regional economic activity in "real time"

- Same frequency and regionalization of health indicators
- Combine input-output analysis and traffic data

We developed a daily *Index of Regional Sectoral Economic Activity* (t-3) – **EAI**

- Traffic intensity indicators as a measure of change in trade volumes (341 toll stations and 4,870 smart cameras)
- Daily, OD pair, type of vehicle (trucks and cars)

Traffic mobility → Economic Activity → Future Sanitary Effects

An Index of Regional Sectoral Economic Activity

We consider there are *n* domestic regions, *r* = 1, ..., n, and the rest of the world, *row*, which exhaust the space of the economy

Economic interactions take place inside and outside each region (intraregional, interregional and international trade)

In our multi-sectoral economy, there are *j* sectors, *s* = 1, ..., j, provided by *n+1* different sources

We then assume we can measure, for each sector *s* in region *r*, the value added contents embedded in trade flows associated with each regional origin-destination pair, such that we can complete the information in Table 1

Table 1. Regional Value Added in Trade Flows, by Sector

	Destination					
Origin	R_1	R_2	…	R_{n-1}	R_n	ROW
R_1	$va_{1,1}^{r,s}$	$va_{1,2}^{r,s}$	…	$va_{1,n-1}^{r,s}$	$va_{1,n}^{r,s}$	$va_{1,row}^{r,s}$
R_2	$va_{2,1}^{r,s}$	$va_{2,2}^{r,s}$	…	$va_{2,n-1}^{r,s}$	$va_{2,n}^{r,s}$	$va_{2,row}^{r,s}$
⋮	⋮	⋮		⋮	⋮	⋮
R_{n-1}	$va_{n-1,1}^{r,s}$	$va_{n-1,2}^{r,s}$	…	$va_{n-1,n-1}^{r,s}$	$va_{n-1,n}^{r,s}$	$va_{n-1,row}^{r,s}$
R_n	$va_{n,1}^{r,s}$	$va_{n,2}^{r,s}$	…	$va_{n,n-1}^{r,s}$	$va_{n,n}^{r,s}$	$va_{n,row}^{r,s}$
ROW	$va_{row,1}^{r,s}$	$va_{row,2}^{r,s}$	…	$va_{row,n-1}^{r,s}$	$va_{n,n}^{r,s}$	$va_{row,row}^{r,s}$

An Index of Regional Sectoral Economic Activity (cont.)

According to Table 1, a region's sectoral output is potentially associated with transactions involving economic agents located not only in the region, but also elsewhere

Define the sets of origins, *O*, and destinations, *D*, both comprising all domestic regions, *r*, add the rest of the world, *row.* Thus, we can compute total value added of sector *s* in region *r*,va^{rs}, as:

$$va^{rs} = \sum_{o \in O, d \in D} va_{o,d}^{r,s}$$

We also calculate region's *r* total value added, va^{r}, as:

$$va^{r} = \sum_{s} va^{rs}$$

An Index of Regional Sectoral Economic Activity (cont.)

In order to **monitor** sectoral regional economic activity, we would need to follow va^{rs} over time. This information, when available, is usually published with a delay and at a low frequency (annual).

To circumvent such informational constraint, we could track changes in trade flows for each regional origin-destination pair, and combine them with the information in Table 1 to calculate a trade-weighted index of regional economic activity.

An Index of Regional Sectoral Economic Activity (cont.)

Thus, if we can observe, in each period *t*, changes in values of flows from each origin *o*, to each destination *d*, $\Delta F_{t,o,d}$, a regional index of economic activity could be calculated as

$$EAI_t^{r,s} = \sum_{o \in O, d \in D} w_{o,d}^{r,s} \, \Delta F_{t,o,d}$$

where $EAI_t^{r,s}$ is the economic activity index for sector *s*, in region *r*, in time *t*, and the weights $w_{o,d}^{r,s}$ are calculated as

$$w_{o,d}^{r,s} = \frac{va_{o,d}^{r,s}}{\sum_{o \in O, d \in D} va_{o,d}^{r,s}} \text{ such that } \sum_{o \in O, d \in D} w_{o,d}^{r,s} = 1$$

Implementation

The implementation of the index depends on two pieces of information: **first**, we need to define an empirical strategy to estimate values in Table 1, so that we can define the weights, $w_{o,d}^{r,s}$; **second**, we have to collect timely information to estimate $\Delta F_{t,o,d}$.

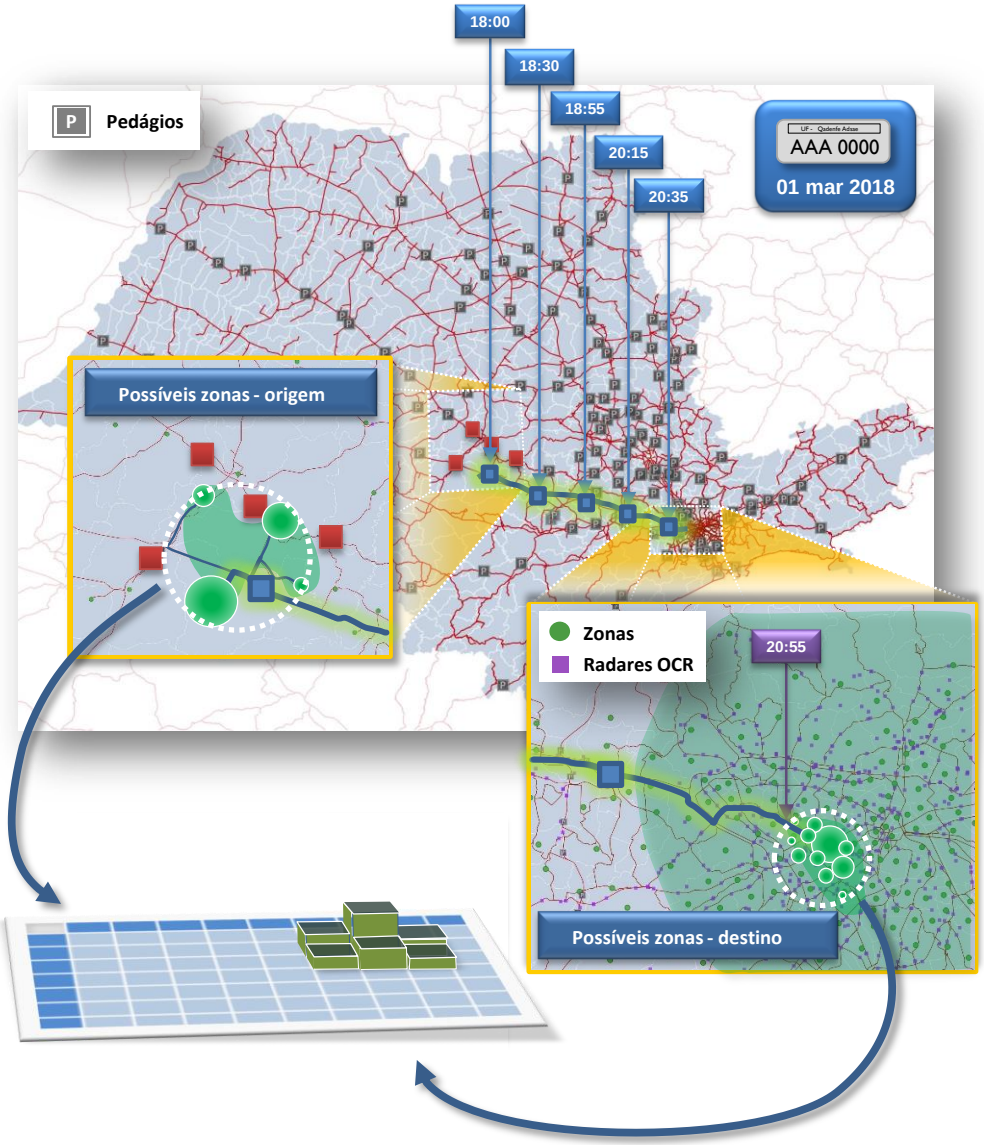
1. Measurement of domestic value added in trade flows

- Hypothetical extraction method

2. Traffic intensity indicators (341 toll stations and 4,870 smart cameras)

- Daily, OD pair, type of vehicle (trucks and cars)

Analysis of road traffic flows



Use high-frequency traffic data from different sources in the state of São Paulo, including automated vehicle identification on toll stations and smart-camera records.

Track specific vehicles and infer their origin and destination in each trip that they make.

Calculate the total traffic flows of passenger and freight vehicles (light commercial vehicles and trucks) between all pairs of regions (Regional Health Departments) in each day of our analyses.

Analysis of road traffic flows

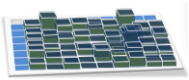
1 – Identification of routes used by vehicles through AVI (Automatic Vehicle Identification) toll data

2 – Specification of routes in urban áreas using smart cameras data located in urban areas (OCR – Optical Character Recognition)

3 – Definition of origin and destinations of each trip using geostatistical / probabilistic models

4 – Processes automation for application in databases with billions of registers

Analysis of road traffic flows (cont.)



5 – Alocation of OD matrices in simulation networks

6 – Characterization of flows using flows-bundle traffic analysis

7 – Organization and tabulation of data from transportation agencies DER and ARTESP

8 – Development of ***Dashboards*** **in** ***Business Intelligence Systems***

Analysis of road traffic flows (cont.)

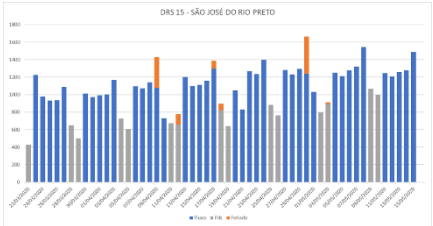
9 – Measurement of inter-regional traffic variation (between pairs of Health Department Regions - DRS)

Antes	antes 21/3
Semana 14	29/4-04/4

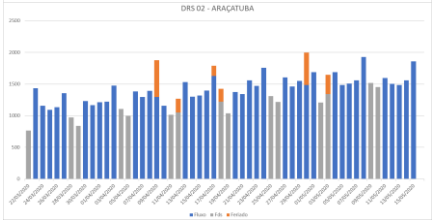
Tipo de veículo: Automóveis 46,15%

Origem		Destino 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Grande_SP	1	50%	45%	41%	43%	41%	45%	44%	43%	47%	43%	48%	44%	43%	43%	41%	50%	39%	37%
Aracatuba	2	45%	55%	33%	44%	52%	52%	47%	53%	53%	49%	57%	49%	52%	49%	51%	49%	43%	43%
Araraquara	3	41%	53%	42%	40%	45%	44%	42%	49%	47%	43%	49%	45%	48%	46%	44%	44%	39%	39%
Baix_Santista	4	44%	45%	41%	50%	41%	44%	43%	43%	46%	42%	47%	53%	43%	42%	41%	47%	43%	40%
Barretos	5	41%	53%	44%	40%	52%	46%	42%	46%	53%	42%	56%	44%	50%	44%	51%	43%	40%	39%
Bauru	6	44%	52%	43%	43%	47%	48%	46%	46%	48%	44%	50%	47%	46%	45%	47%	47%	42%	42%
Campinas	7	45%	47%	43%	42%	42%	46%	45%	44%	45%	51%	47%	47%	43%	44%	42%	48%	37%	37%
Franca	8	43%	55%	46%	43%	46%	46%	44%	45%	49%	43%	55%	45%	46%	45%	45%	44%	41%	41%
Marilia	9	47%	53%	47%	46%	51%	48%	45%	48%	48%	45%	53%	46%	50%	46%	56%	45%	45%	44%
Piracicaba	10	43%	49%	44%	41%	42%	45%	51%	43%	45%	46%	49%	47%	42%	46%	43%	48%	39%	38%
Pres_Prudente	11	48%	57%	49%	47%	54%	51%	48%	55%	53%	49%	56%	50%	56%	46%	56%	48%	47%	46%
Registro	12	45%	49%	45%	53%	44%	47%	47%	45%	46%	46%	48%	54%	45%	46%	44%	47%	45%	44%
Ribeir_Preto	13	43%	53%	48%	42%	50%	46%	43%	46%	50%	42%	55%	45%	44%	44%	47%	44%	40%	39%
S_J_Boa_Vista	14	43%	49%	46%	42%	44%	45%	45%	43%	45%	45%	45%	46%	44%	45%	45%	45%	38%	38%
S_J_Rio_Preto	15	41%	52%	44%	40%	51%	48%	42%	45%	56%	44%	56%	43%	46%	45%	45%	46%	40%	40%
Sorocaba	16	51%	49%	44%	47%	43%	47%	48%	44%	45%	48%	47%	45%	44%	46%	44%	52%	46%	45%
Taubate	17	40%	43%	39%	43%	40%	43%	38%	41%	45%	38%	47%	46%	40%	38%	40%	46%	37%	36%
Saida_Dutra_RJ_ES	18	38%	43%	38%	40%	39%	42%	36%	40%	44%	37%	46%	44%	39%	38%	40%	45%	35%	

Variação do Tráfego entre:
DRS **RMSP** - DRS **S.J R. Preto**



Variação do Tráfego entre:
DRS **RMSP** - DRS **Araçatuba**



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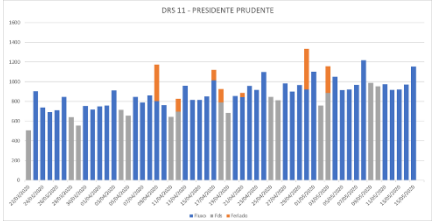
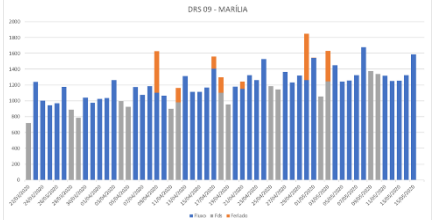
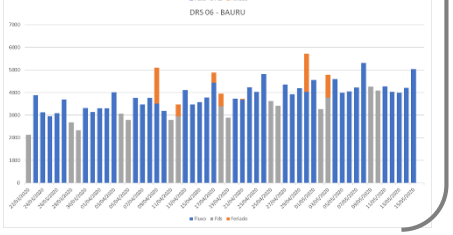
DRS **RMSP** - DRS **P. Prudente**



Variação do Tráfego entre:
DRS **RMSP** - DRS **Marília**

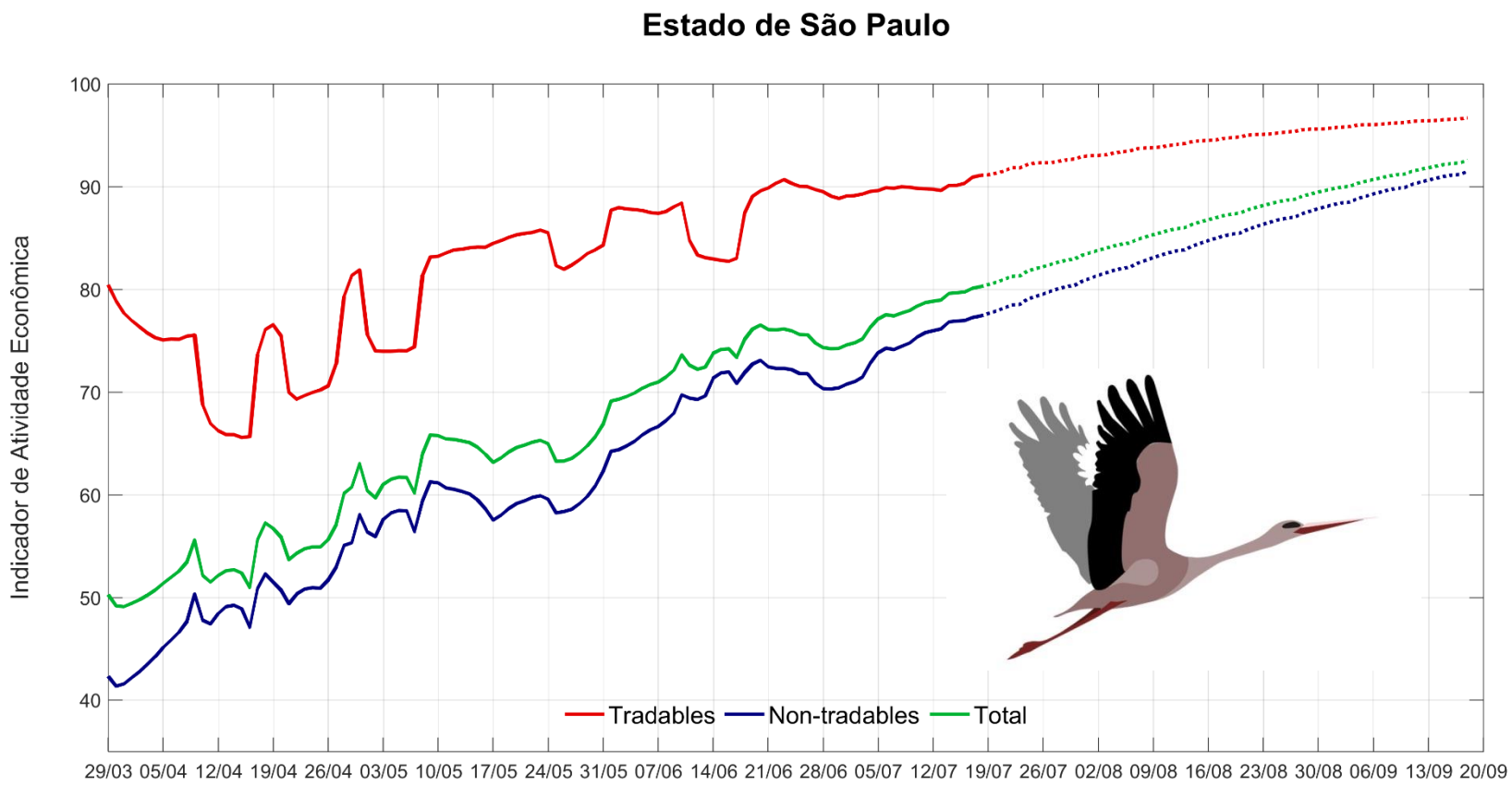


Variação do Tráfego entre:
DRS **RMSP** - DRS **Bauru**



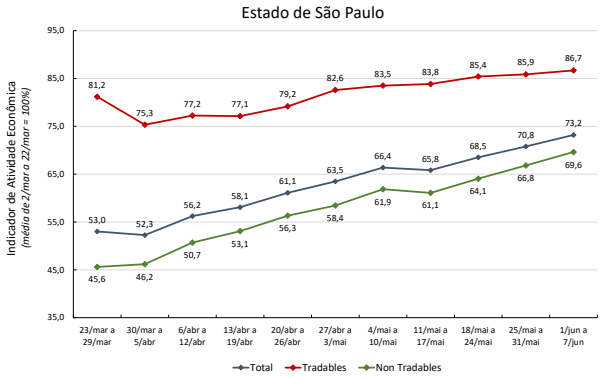
Economic Activity Indicator: State of São Paulo

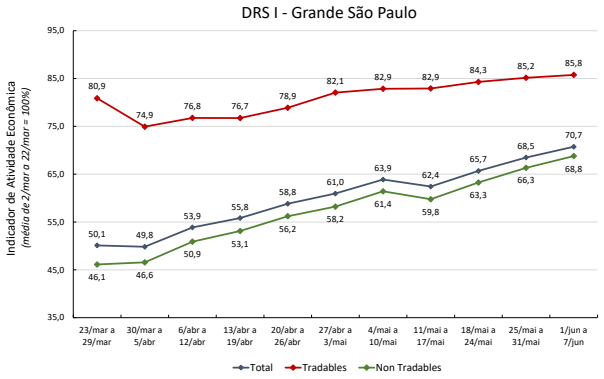
Period: March 29 to July 18, 2020 (+ 60-day projection)

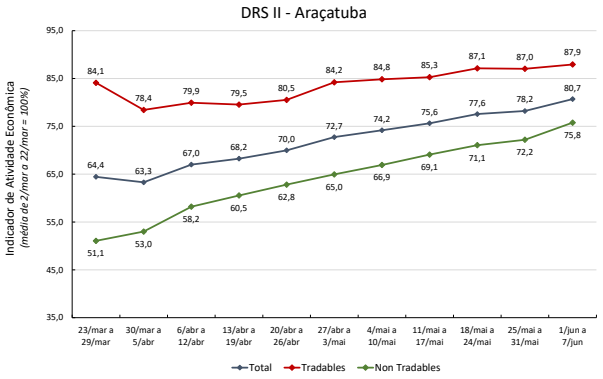


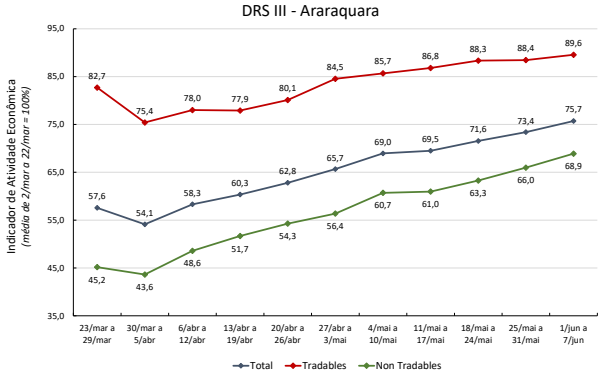
Economic Activity Indicator: State of São Paulo

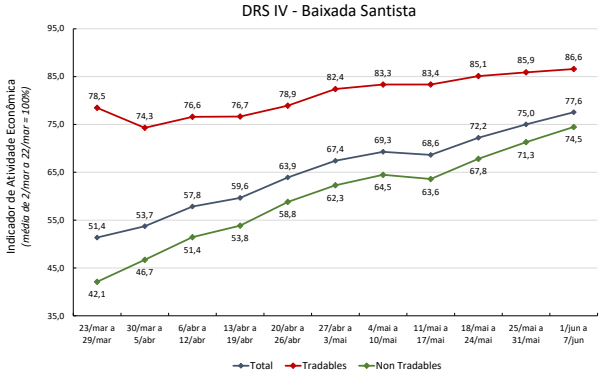
Period: March 23 to June 07, 2020

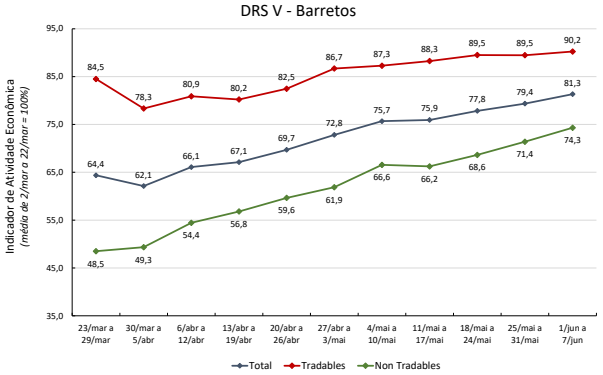






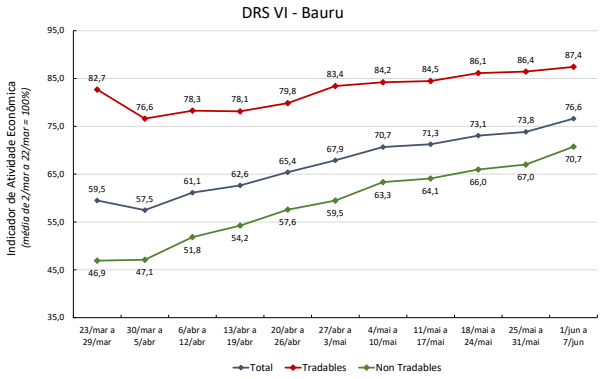


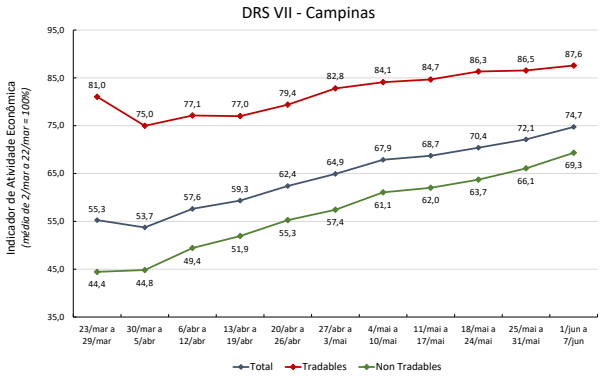


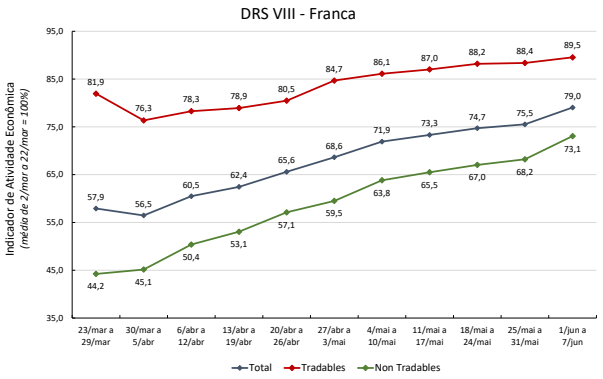


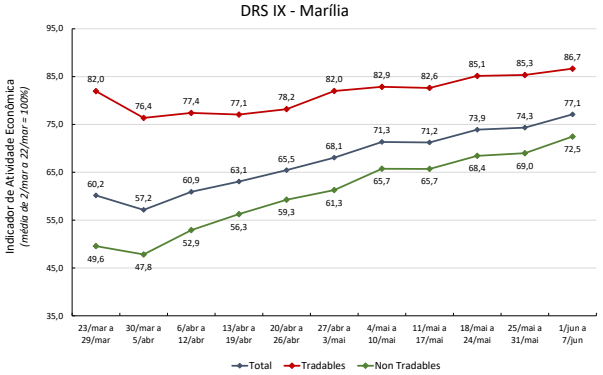
Economic Activity Indicator: State of São Paulo

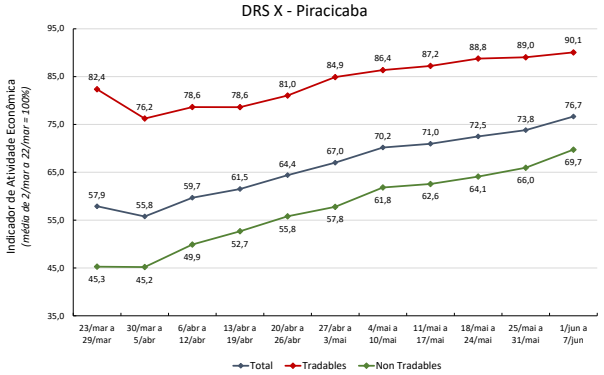
Period: March 23 to June 07, 2020

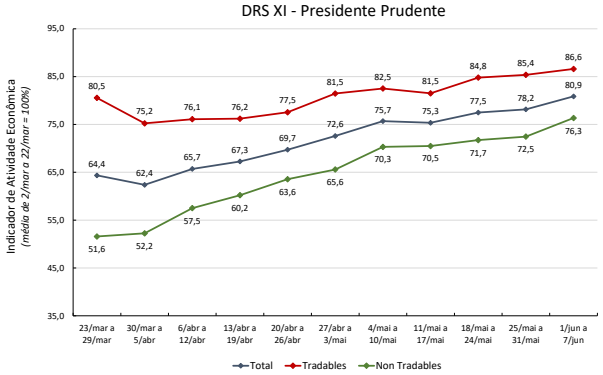






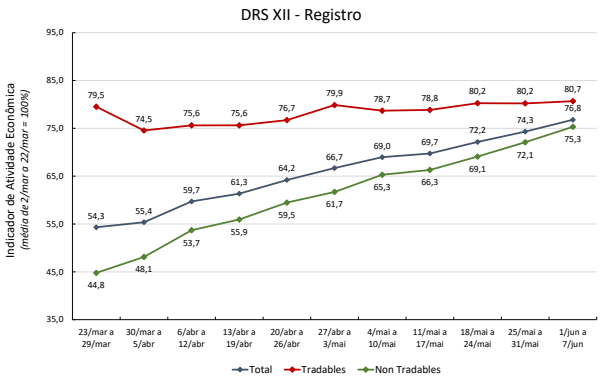


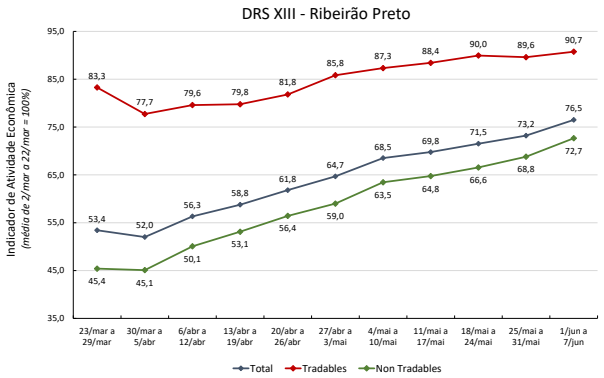


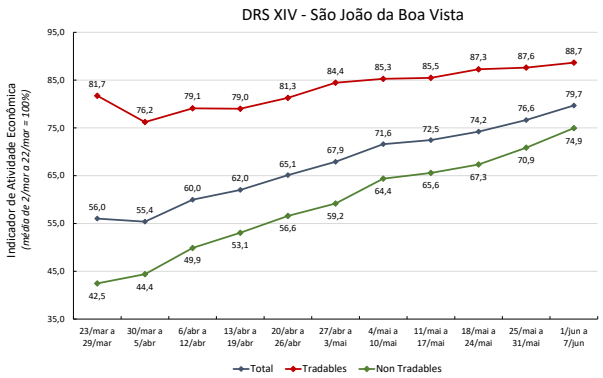


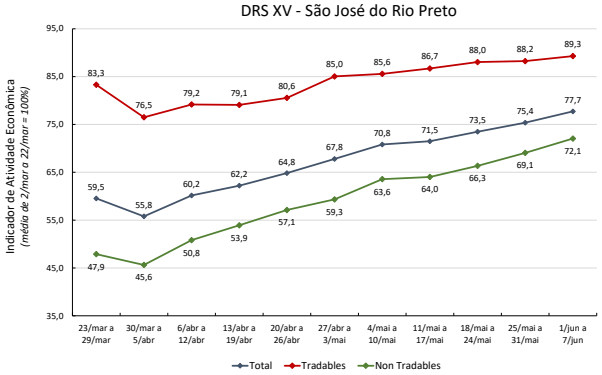
Economic Activity Indicator: State of São Paulo

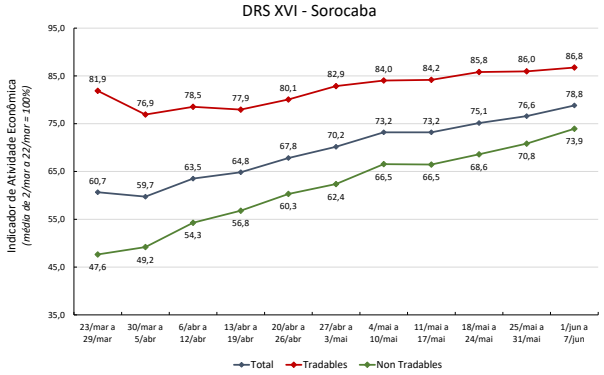
Period: March 23 to June 07, 2020

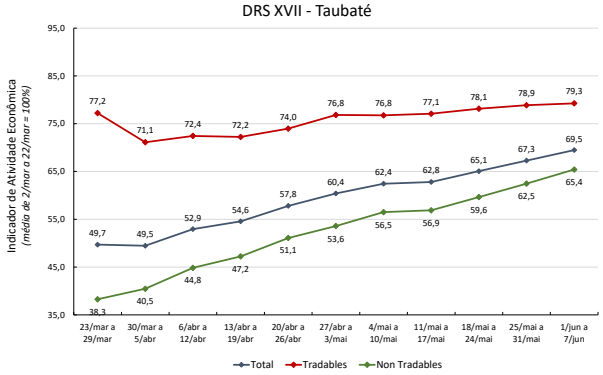






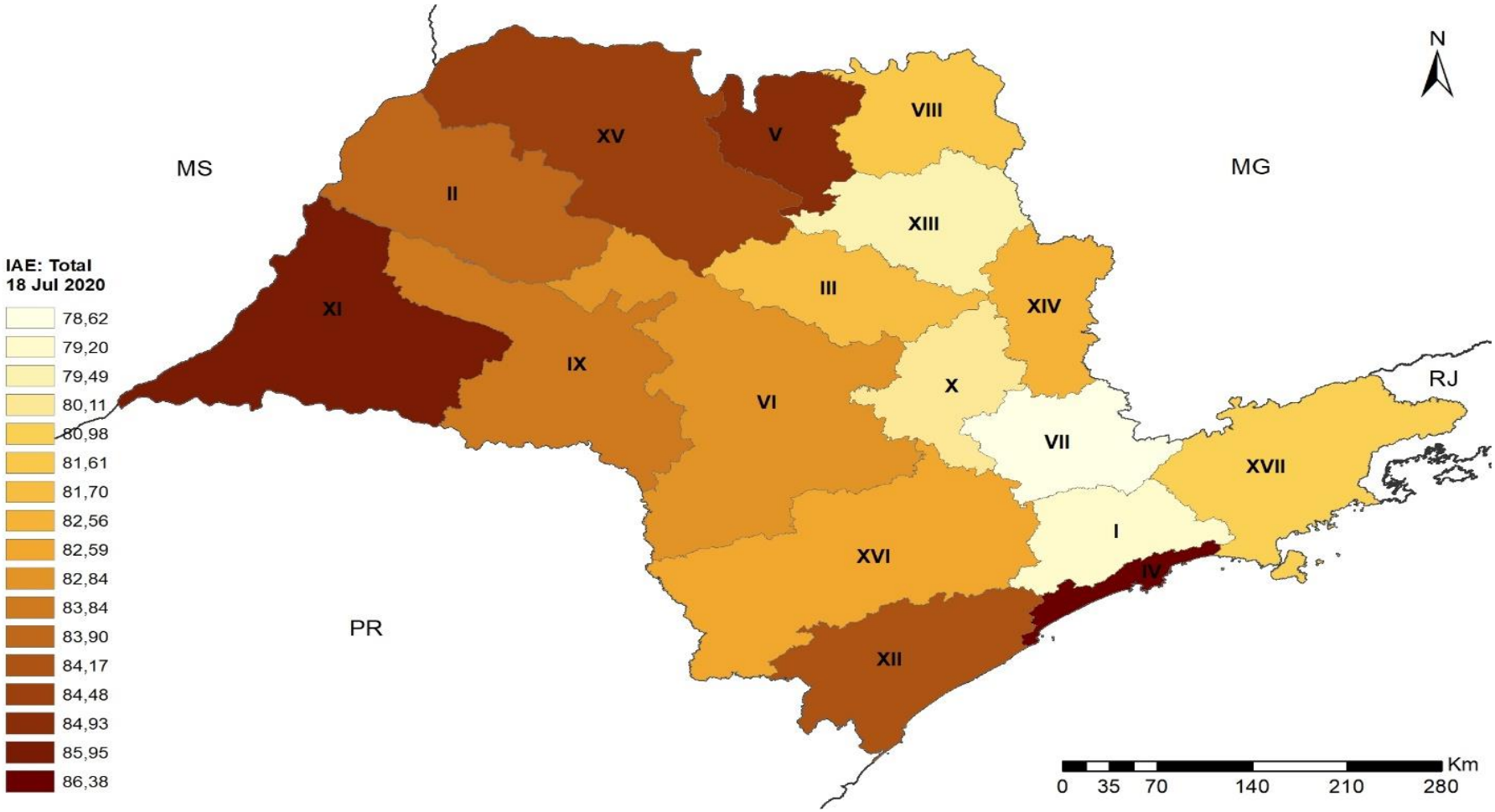






Economic Activity Indicator

July 18, 2020



Validation

Lack of high frequency regional economic data to validate daily estimates

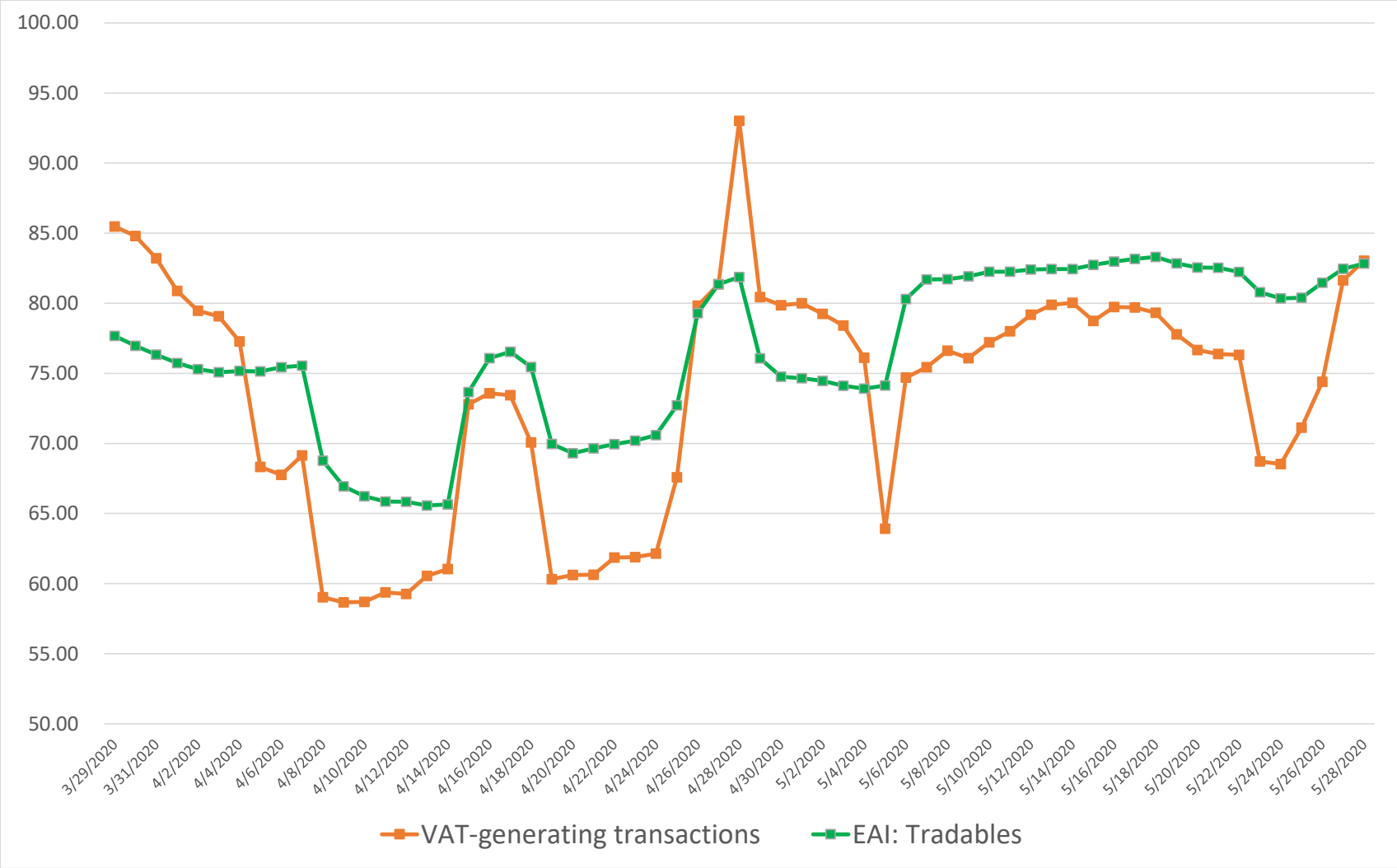
1. Lower frequency data:

   - Tax data
   - Partial sectorial coverage (30% of GRP)

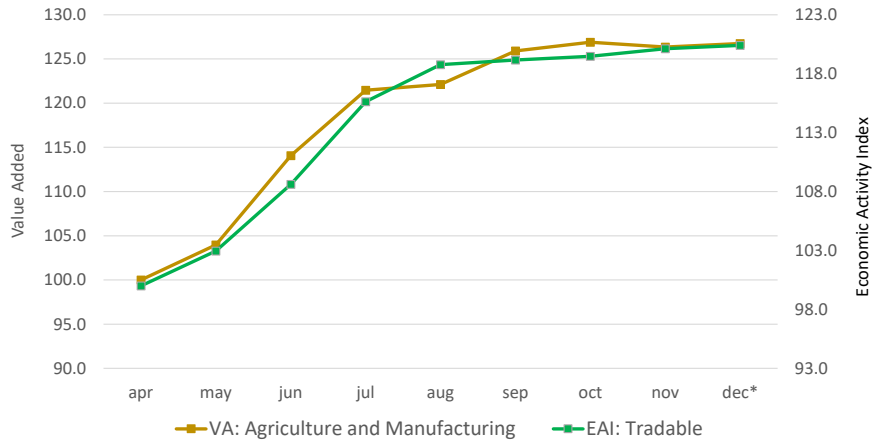
2. State GRP:

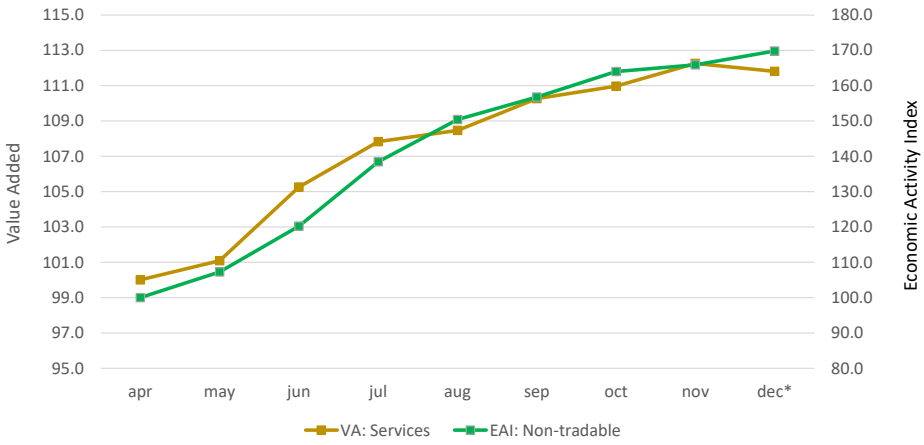
   - Aggregate regional coverage
   - Lower frequency (monthly)
   - 3 months publication lag

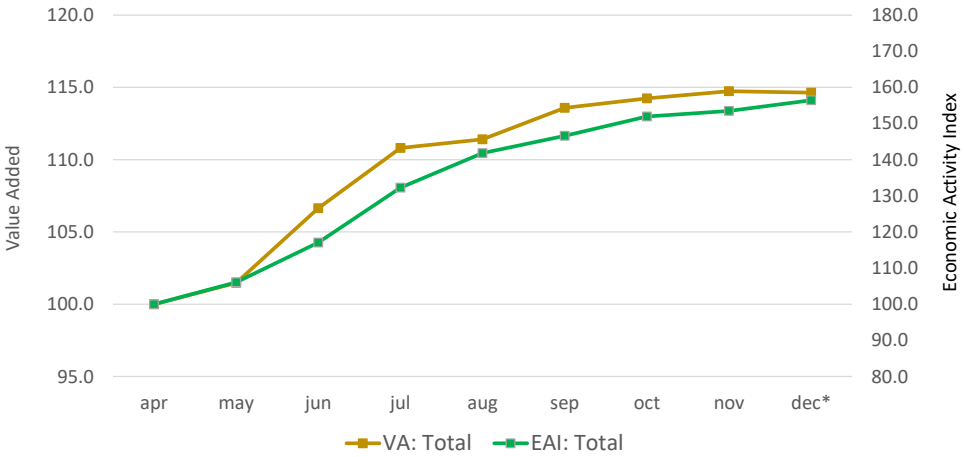
Economic Activity Indicator *versus* VAT-generating transactions (7-day moving average)



Economic Activity Indicator *versus* State GRP (monthly)







Applications

Regional economic monitoring

- State Treasury
- State Secretariat of Finance

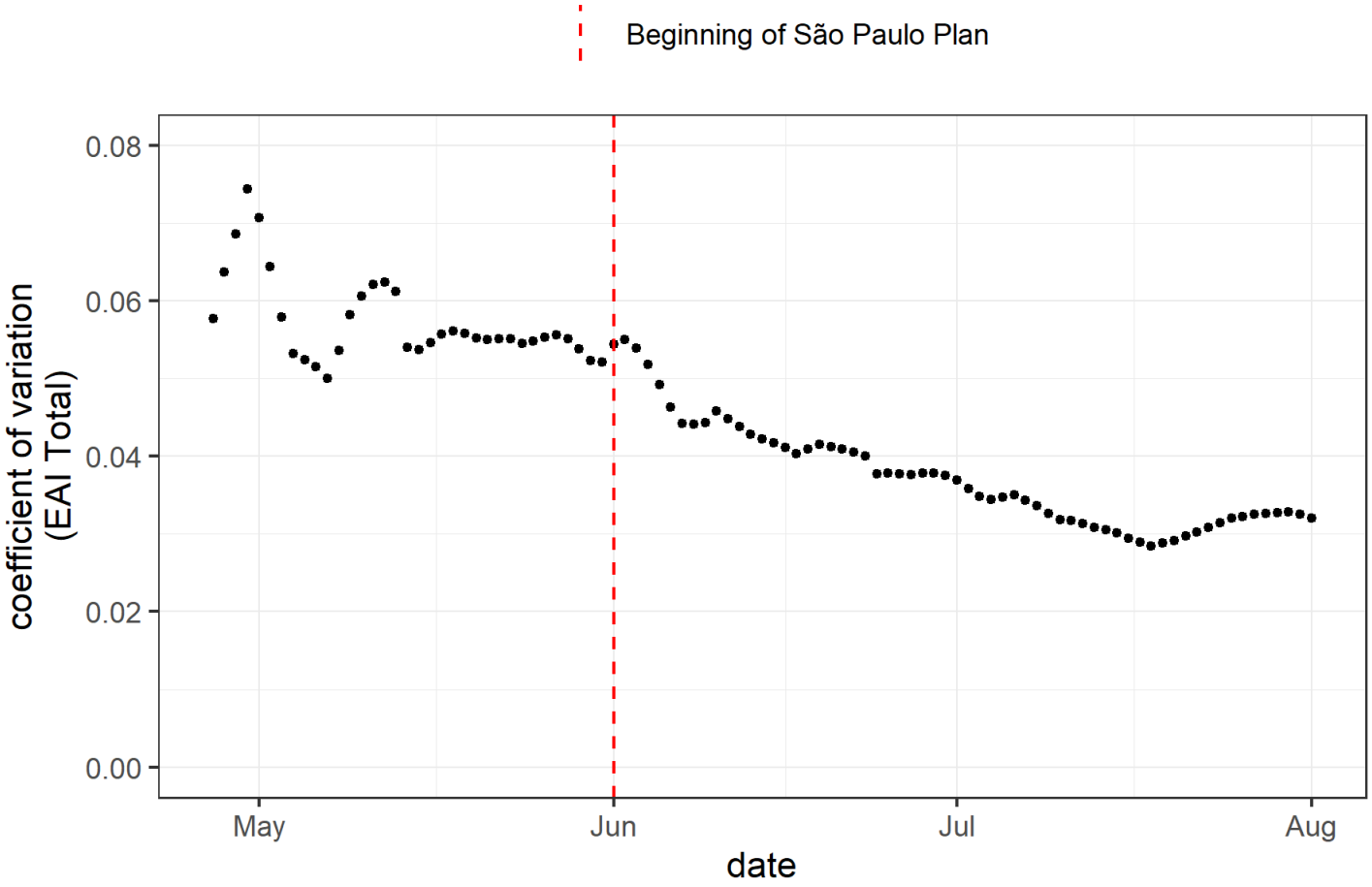
Assessment of the effectiveness of exit strategies

- Use EAI combined with hospitalization rates to provide a first assessment of the São Paulo Plan, the COVID-19 exit strategy designed to gradually lifting interventions introduced to control the outbreak in the State.
- Forthcoming in the *Annals of Regional Science*

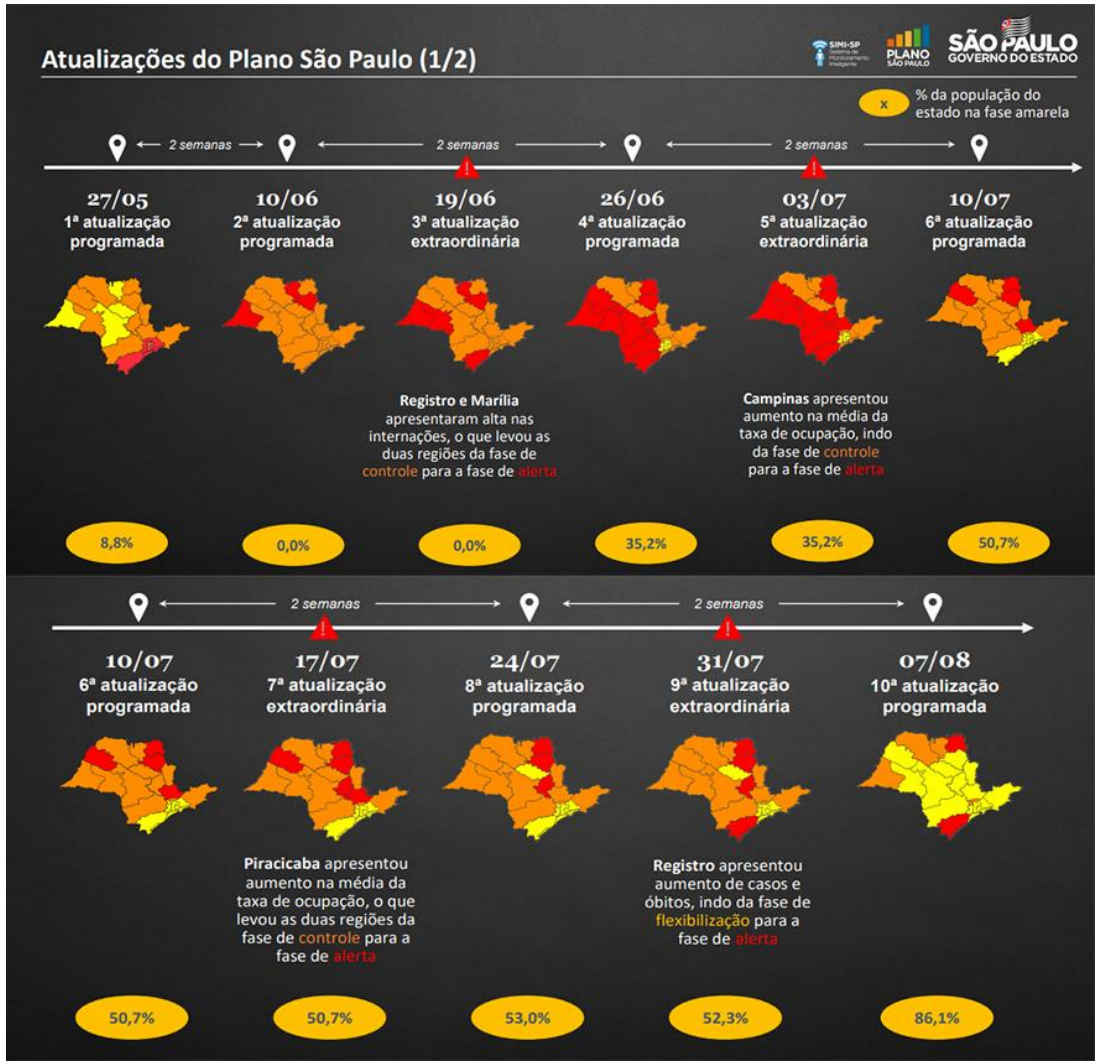
Defining clear rules improved the predictability of economic agents

São Paulo Plan helped anchoring expectations

Coefficient of Variation of Total EAI – (April, 21 – August 1, 2020)

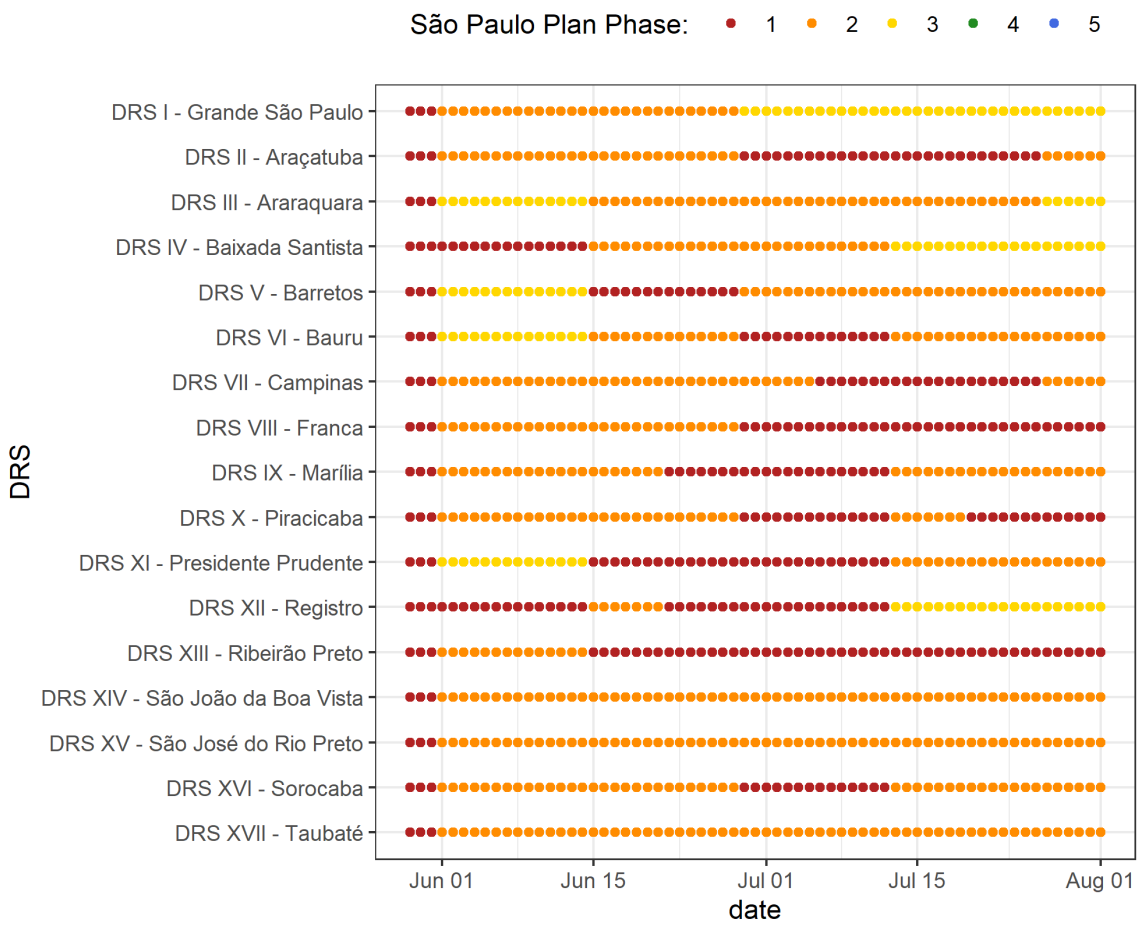


Changes of Phases in each DRS in the São Paulo Plan

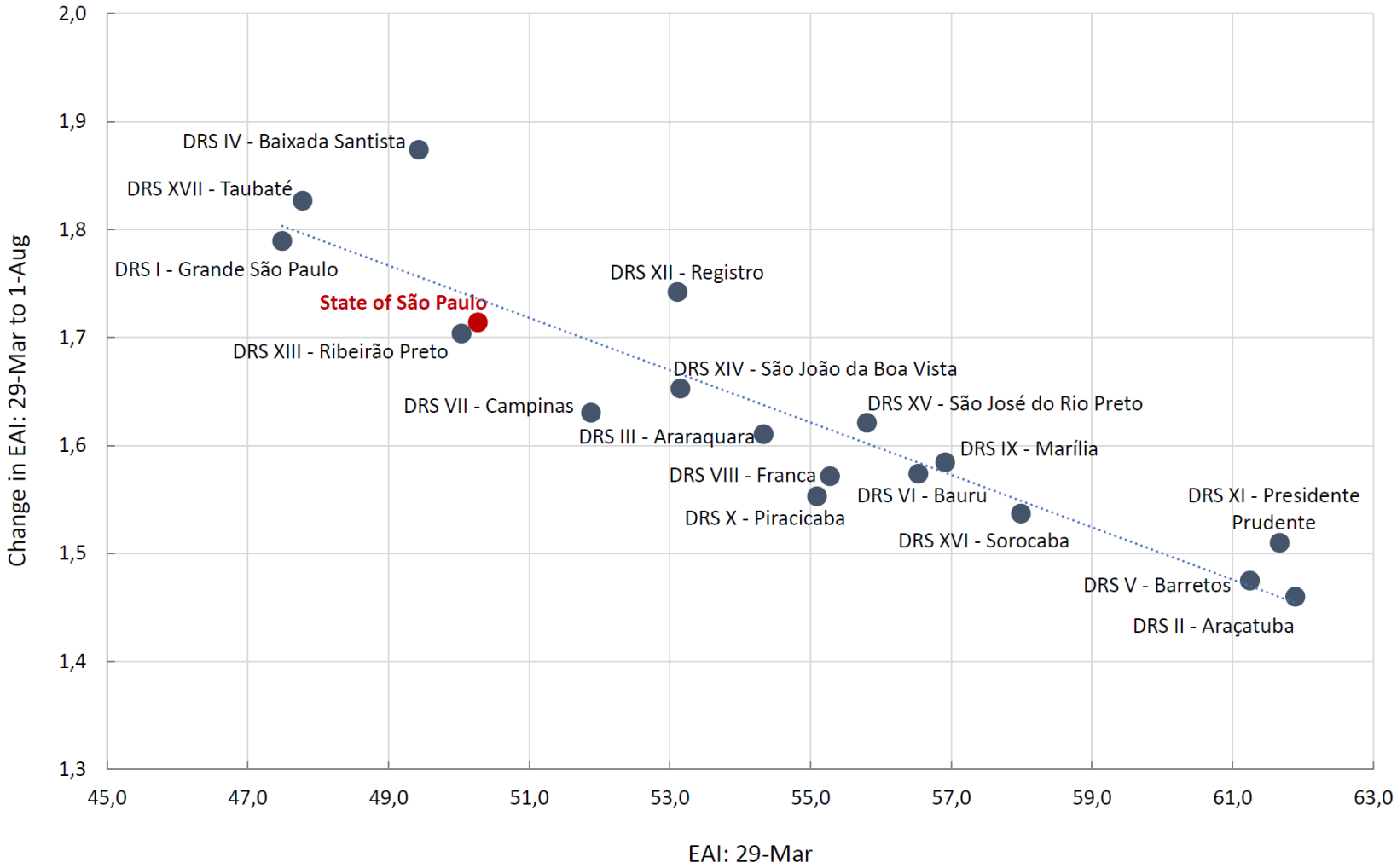


The regions that had greater adherence to restrictive measures also showed greater consistency in maintaining phases ...

Changes of Phases in Each DRS in the São Paulo Plan



... and increased their economic activity more quickly, in a more sustainable way



Have the changes of phases affected the COVID-19 spread through an increase in the economic activity?

Estimation using an integrated model of fixed effects:

Phase
↓
EAI
↓
Health

$$IAE_{dia,DRS} = \alpha_{DRS} + \tau_{dia} + \beta_2 F2_{t,DRS} + \beta_3 F3_{t,DRS} + \varepsilon_{dia,DRS}$$

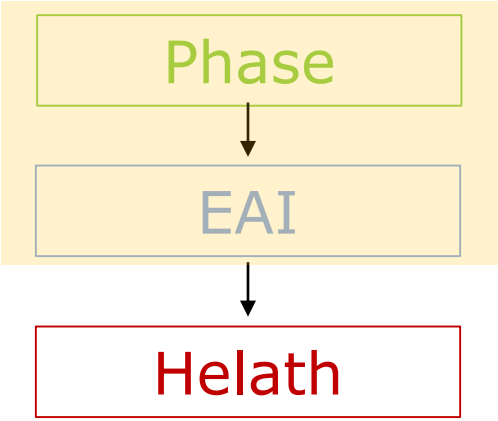
$$Saúde_{dia,DRS} = \left(\sum_q \gamma_q \, S_{q,dia,t-7,DRS}\right) + \phi IAE_{dia-t,DRS} + \epsilon_{dia,DRS}$$

Flaxman et al. (2020) + micro data

<u>Assumptions</u>:

- Phase change affects economic activity
- Increase in economic activity may affect the epidemiological curve

First estimation: effect of change in phase on EAI



$$IAE_{dia,DRS} = \alpha_{DRS} + \tau_{dia} + \beta_2 F2_{t,DRS} + \beta_3 F3_{t,DRS} + \varepsilon_{dia,DRS}$$

<u>Model</u>: Average effect of phase change controlling for:

- General trend in the EAI
- Regional activity level

<u>Results</u>:

- Gradual impacts
- Phase 2 increases total EAI by 1,11 pp compared to Phase 1
- Phase 2 increases total EAI by 2,32 pp compared to Phase 1

First estimation: results

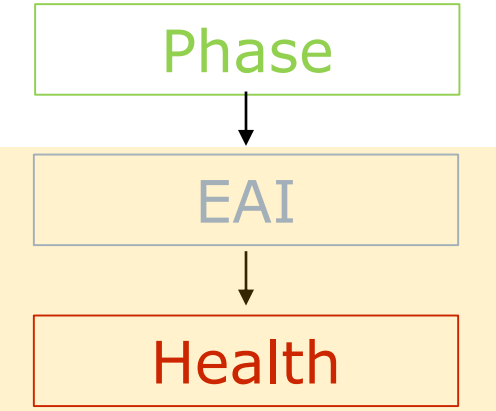
	EAI			Mobility Index	
	Tradables	Non-tradables	Total	Freight	Passengers
	(1)	(2)	(3)	(4)	(5)
Phase 2	0.412 ***	1.476 ***	1.110 ***	0.622 ***	2.212 ***
	(0.052)	(0.115)	(0.095)	(0.187)	(0.186)
Phase 3	0.718 ***	2.442 ***	2.322 ***	1.591 ***	3.666 ***
	(0.076)	(0.168)	(0.140)	(0.275)	(0.274)
Fixed effects:					
DRS	yes	yes	yes	yes	yes
date	yes	yes	yes	yes	yes
Obs.	1,751	1,751	1,751	1,751	1,751
R^2	0.992	0.978	0.981	0.941	0.953

*Note: *p<0.1; **p<0.01; ***p<0.001.*

<u>Results</u>:

- Bigger effects on services
- Bigger effects on mobility of people (1pp ~100K people in the SPMR)

Second estimation: effect of EAI on the epidemiological curve (per capita hospitalizations)



$$Saúde_{dia,DRS} = \left(\sum_q \gamma_q \, S_{q,dia,t-7,DRS}\right) + \phi IAE_{dia-t,DRS} + \epsilon_{dia,DRS}$$

<u>Model</u>: Average effect of EAI on total per capita hospitalizations 12 days later controlling for:

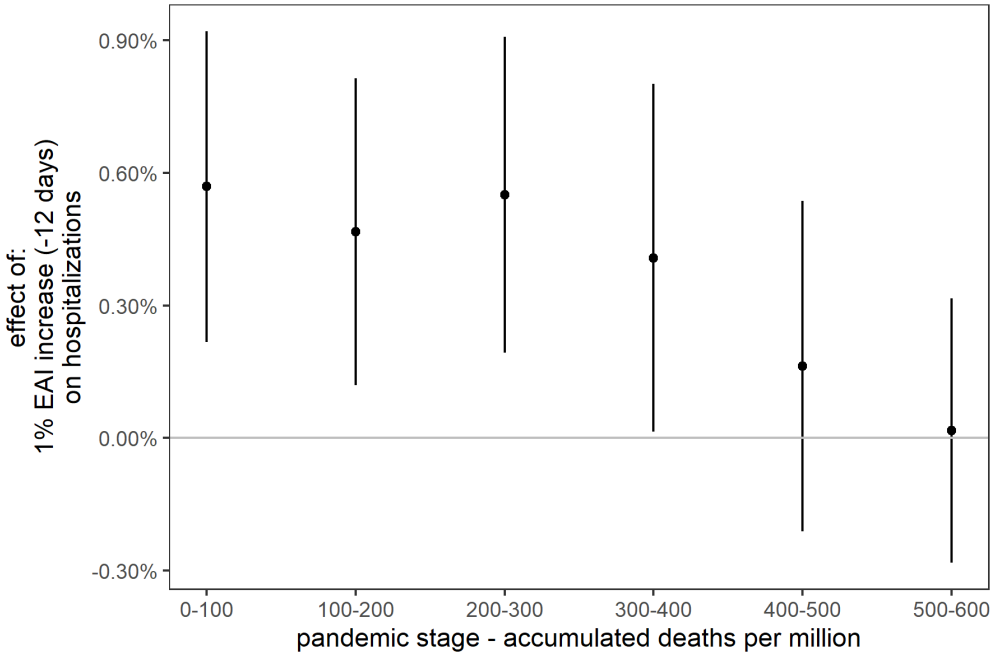
- Stage of the pandemic in each DRS (non-linear)

$$Saúde_{dia,DRS} = \left(\sum_q \gamma_q \, S_{q,dia,t-7,DRS}\right) + \left(\sum_q \phi_q \, S_{q,dia,t-7,DRS} IAE_{dia-t,DRS}\right) + \epsilon_{dia,DRS}$$

<u>Results</u>:

- An increase of 1 pp in the EAI is associated with an increase in daily hospitalizations up to 0,5% (+12 days)
- Bigger effects at the initial stages of the pandemic

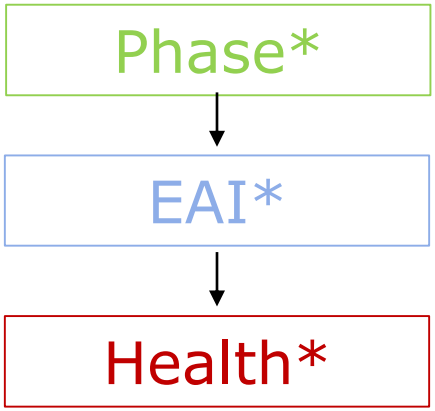
Second estimation: results



Results:

- An increase of 1 pp in the EAI is associated with an increase in daily hospitalizations up to 0,5% (+12 days)
- **Bigger effects at the initial stages of the pandemic**

What would have been the evolution of health indicators if the phase changes had not occurred?



Step 1: estimate the counterfactual EAI had all DRS remained in Phase 1 (red)

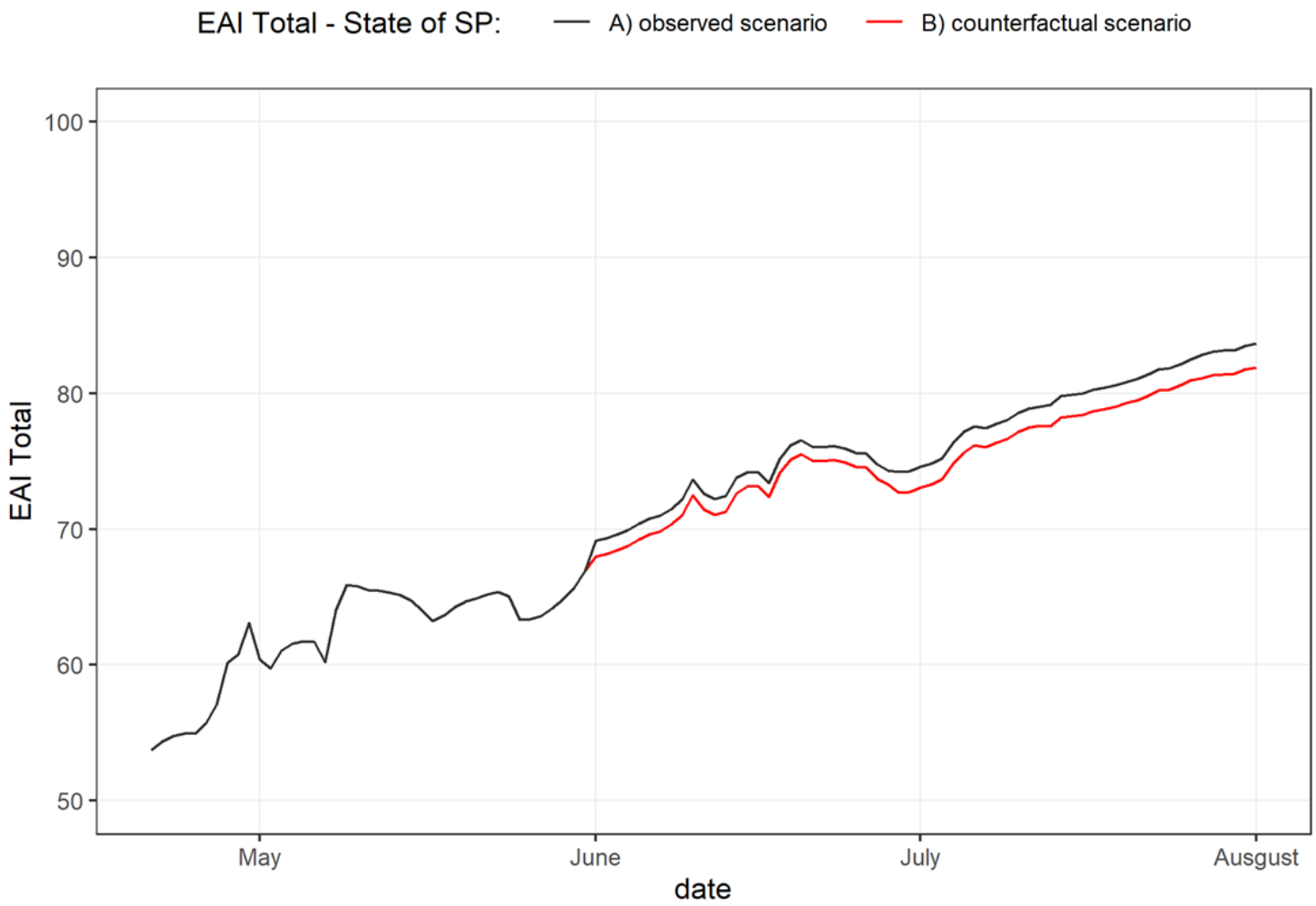
Step 2: compare the estimated number of hospitalizations given both the observed and the counterfactual EAI

Step 3: compare the difference in total hospitalizations between the two scenarios

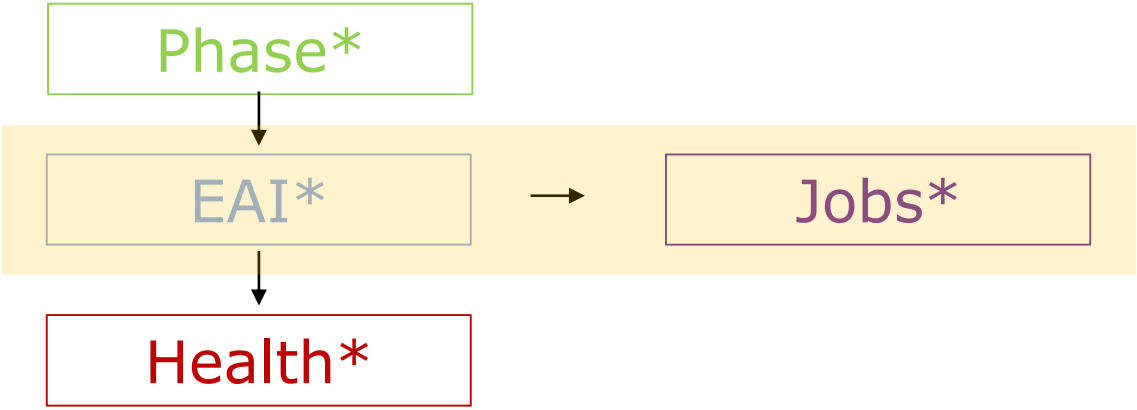
Results:

- Changes in phases led to an increase in the EAI
- The increase in the EAI, on its turn, would be associated with a 0,21-0,52% increase in total COVID-related hospitalizations in the state since the beginning of the São Paulo Plan

The impact of the DRS phase changes was gradual and differentiated between sectors and regions ...



... helping to preserve jobs in the state



Results:

- By stimulating the economic recovery, the São Paulo Plan helped to preserve 318 thousand jobs
- 95% of jobs (~ 303 thousand) maintained with the gradual recovery of the São Paulo economy are concentrated in service activities

Key messages

São Paulo Plan helped to preserve jobs

The regions that had greater adherence to restrictive measures also showed greater consistency in maintaining phases, and increased their economic activity more quickly, in a more sustainable way

- **Expectations** anchored with the São Paulo Plan
- **Communication** worked and saved lives (and jobs)

NEREUS

Núcleo de Economia Regional e Urbana da Universidade de São Paulo

The University of São Paulo Regional and Urban Economics Lab

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