Slums and Pandemics

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Introduction

New coronavirus:

- Spread through close contact among people
- Recommendation: social distancing, more handwashing, face cover and avoid crowded places
- Problem in slums:
    - High density; poorer individuals; low access to health care; warm weather
- Over 1 billion people live in slums (UN, 2020)

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- Over 1 billion people live in slums (UN, 2020)

This paper:

- Empirics: daily location of millions of mobile phones in Brazil
- Model: choice-theoretic heterogeneous-agent GE
- Quantitative:
  - Role of slums
  - Policies: lockdowns, cash transfers, public ICU beds

Insights

Empirics:

- Daily location of phones in São Paulo and Rio de Janeiro
- Social distance increases with NPIs
- Social distance increases less in slums and more deaths

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- More deaths (30%) than fraction of population (22%)
- Without slums: similar deaths overall; more in other areas

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- Without slums: similar deaths overall; more in other areas

Policies:

- Public ICUs: both groups are better off
- Mild lockdowns mitigate demand for hospital beds
- Strict confinements mostly delay the pandemic
- Cash transfers: delay and benefits slum dwellers

Economics and infectious diseases

Earlier theory and quantitative work:

- Kremer (1996), Greenwood, Kircher, Santos & Tertilt (2019, 2017, 2013), etc.

Economics and Covid-19 (fast-growing):

- Brotherhood, Kircher, Santos & Tertilt (2020), Alon, Kim, Lagakos & VanVuren (2020), Kaplan, Moll & Violante (2020), Glover, Heathcote, Krueger & Rios-Rull (2020), Brotherhood & Jerbashian (2020), etc.
- Bruce, Cavgias & Meloni (2020), Bruce, Firpo, Franca & Meloni (2020), etc.

Equilibrium models and slums:

- Cavalcanti, Da Mata & Santos (2019), Ferreira, Monge-Naranjo & Pereira (2016)

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Empirics

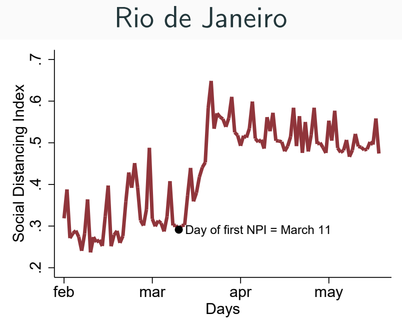
Data source:

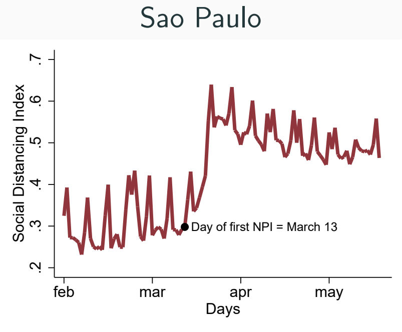
- Provided by Inloco (inloco.com.br)
- Track mobile phones within 3-meter accuracy
- About 60 million mobile phones in Brazil, ensuring privacy

Our data:

- Daily social distance index: % of phones away from home
- Feb 1 to May 30, 2020
- Non-overlapping hexagons for Sao Paulo (1,301) and Rio de Janeiro (841)
- Merge with socioeconomic data from census

Social distance and NPIs





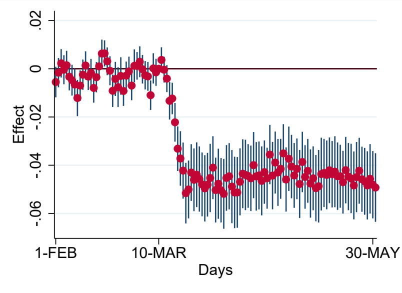
Social distance: slums and other areas (reduced form)

$$Y_{ht} = \sum_{\tau=-K}^{L} \beta_\tau \mathbf{1}\{t_t - t^* = \tau\} + \omega_h + \delta_t + \varepsilon_{ht} \ , \tag{1}$$

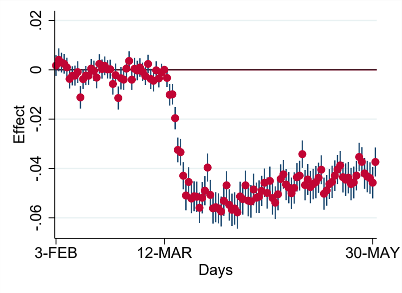
The "treated grou" is composed of hexagons with at least one housing unit in a slum - We also use the share of slums in the hexagons (results are qualitatively similar).

Social distance: slums and other areas (reduced form)

Rio de Janeiro



Sao Paulo



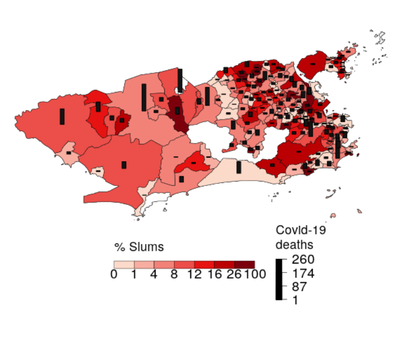
Social distance: slums and other areas (reduced form)

Table 1: Average impact of NPIs on social distancing

	Dependent variable: Social distancing index		
	(i)	(ii)	(iii)
Post $\times$ Slum	-0.0386***	-0.0429***	-0.0429***
	(0.0050)	(0.0021)	(0.0021)
Post $\times$ Slum $\times$ Rio			0.0043
			(0.0054)
Control group mean	0.2989	0.2820	0.2903
Hexagon FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Time FE $\times$ Rio	-	-	Yes
Observations	97,684	151,504	249,188
Number of Hexagons	841	1,301	2,142
City	Rio de Janeiro	Sao Paulo	Rio de Janeiro & Sao Paulo

Slums and Covid-19 fatalities

Rio de Janeiro



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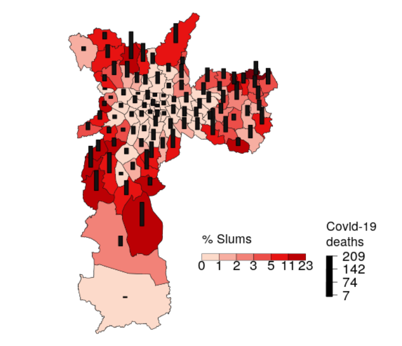

Sao Paulo: Hexagons with slums have 11% more hospitalizations and 10% more deaths by Covid-19 – and 36% more hospitalizations and 7% more deaths by other respiratory diseases

Model overview

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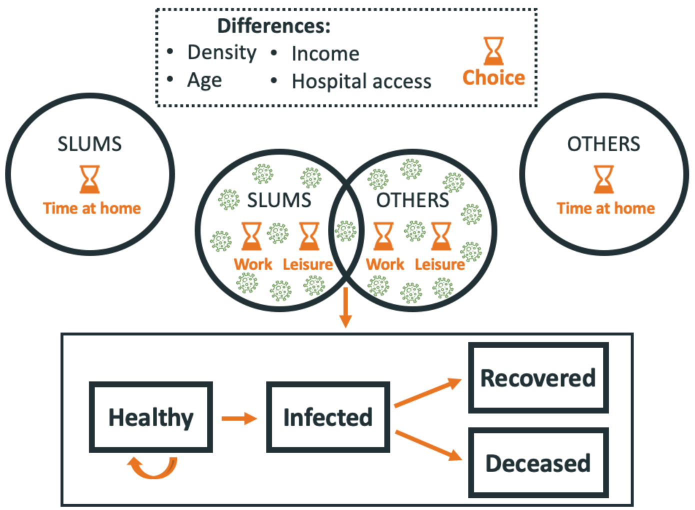

Model environment

Discrete time

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Different groups (g): Slums/*favelas* (f) and others (o)

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Health status (j):

- healthy (h)
- infected (i): recovery ($\phi(0, g)$) or serious symptoms ($\alpha(g)$)
- symptoms (s): recovery ($\phi(1, g)$) or death ($\delta_t(g)$)
- recovered (r): immune forever

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Slums:

- Higher population density (ξ_g)
- Younger individuals: ($\phi(0, g)$), ($\alpha(g)$), ($\phi(1, g)$), ($\delta_t(g)$)
- Poorer individuals ($w(g)$)
- Harder access to ICU
    - Death prob: $\delta_t(g)$

Households

Time: work n, leisure outside ℓ, leisure at home d

Time constraint (TC): $n + \ell + d = 1$

Leisure goods outside the house a:

$$a(x,\ell) = [\theta x^{\rho} + (1-\theta)\ell^{\rho}]^{1/\rho}$$

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Preferences:

$$u(c, a, d; j, g, p) = \ln c + \gamma \ln a + [\lambda_d + \lambda(j) + \lambda_p(j, g)] \ln(d) + b$$

Discount factor β

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Discount factor β

Budget constraint (BC):

$$c+x=w_p(g)+w(g)n$$

Infections

Prob of infection:

$$\pi(n+\ell, \Pi_t(g)) = (n+\ell)\Pi_t(g)$$

Details:

$$\hat{\Pi}_t(g) = \Pi_0 \sum_{\tilde{g}\in\{f,o\}, j\in\{i,s\}} \left(n_t(j,\tilde{g}) + \ell_t(j,\tilde{g})\right) M_t(j,\tilde{g})$$

$$\Pi_t(g) = 1 - e^{-\hat{\Pi}_t(g)}$$

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Details:

$$\hat{\Pi}_t(g) = (1-\zeta)\Pi_0 \sum_{\tilde{g}\in\{f,o\}, j\in\{i,s\}} \left(n_t(j,\tilde{g}) + \ell_t(j,\tilde{g})\right) M_t(j,\tilde{g}) + \zeta\Pi_0 \sum_{j\in\{i,s\}} \frac{1}{\xi_g} \left(n_t(j,g) + \ell_t(j,g)\right) M_t(j,g).$$

$$\Pi_t(g) = 1 - e^{-\hat{\Pi}_t(g)}$$

Decision making

Healthy:

$$V_t(h,g) = \max_{c,x,n,\ell,d} u(c, a(x,\ell), d; h, g, p_t) +$$
$$\beta\{[1-\pi(n+\ell,\Pi_t(g))]V_{t+1}(h,g) + \pi(n+\ell,\Pi_t(g))V_{t+1}(i,g)\}$$

subject to (TC) and (BC).

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subject to (TC) and (BC).

Infected:

$$V_t(i,g) = \max_{c,x,n,\ell,d} u(c, a(x,\ell), d; i, g, p_t) + \beta\phi(0,g)V_{t+1}(r,g) +$$
$$\beta(1-\phi(0,g))[\alpha(g)V_{t+1}(s,g) + (1-\alpha(g))V_{t+1}(i,g)]$$

subject to (TC) and (BC).

Decision making

Symptoms:

$$V_t(s,g) = \beta\left[\phi(1,g)V_{t+1}(r,g) + (1-\phi(1,g))(1-\delta_t(g))V_{t+1}(s,g)\right]$$

subject to (TC) and (BC).

Decision making

Symptoms:

$$V_t(s,g) = \beta \left[\phi(1,g) V_{t+1}(r,g) + (1-\phi(1,g))(1-\delta_t(g)) V_{t+1}(s,g)\right]$$

subject to (TC) and (BC).

Recovered:

$$V_t(r,g) = \max_{c,x,n,\ell,h} u(c, a(x,\ell), d; r, g, p_t) + \beta V_{t+1}(r,g)$$

subject to (TC) and (BC).

Hospital access and death probabilities

Hospital users (public and private):

$$U_{pub} = M_t(s,f) + (1-\psi)M_t(s,o)$$
$$U_{priv} = \psi M_t(s,o)$$

Death prob (measure of hospital beds Z):

$$\delta(f) = \tilde{\delta}_1(f)\min\left\{\frac{Z_{pub}}{U_{pub}},1\right\} + \tilde{\delta}_2(f)\max\left\{\frac{U_{pub}-Z_{pub}}{U_{pub}},0\right\},$$

$$\begin{aligned}\delta(o) = \psi &\left[\tilde{\delta}_1(o)\min\left\{\frac{Z_{priv}}{U_{priv}},1\right\} + \tilde{\delta}_2(o)\max\left\{\frac{U_{priv}-Z_{priv}}{U_{priv}},0\right\}\right] \\ &+ (1-\psi)\left[\tilde{\delta}_1(o)\min\left\{\frac{Z_{pub}}{U_{pub}},1\right\} + \tilde{\delta}_2(o)\max\left\{\frac{U_{pub}-Z_{pub}}{U_{pub}},0\right\}\right].\end{aligned}$$

Aggregation

Output:

$$Q_t = \sum_{j,g} w(j,g) n_t(j,g) M_t(j,g)$$

Laws of motion:

$$\mathscr{M}_{t+1} = T(\mathscr{M}_t, \mathscr{N}_t, \Pi_t(o), \Pi_t(f)).$$

Example: law of motion for healthy individuals of a group g

$$M_{t+1}(h,g) = M_t(h,g)\left[1 - \pi(n_t(h,g) + \ell_t(h,g), \Pi_t(g))\right].$$

Equilibrium

A rational-expectations equilibrium in this economy with initial number of agents $M_0(j, g)$ consists of a sequence of infection and death rates $\{\Pi_t(g), \delta_t(g)\}_{t=0}^{\infty}$ and equilibrium time allocations $\{n_t(j, g), \ell_t(j, g)\}_{t=0}^{\infty}$ such that:

- these time allocations are part of the solutions to the individual optimization problems, and
- the resulting laws of motion and their aggregation indeed give rise to the sequence $\{\Pi_t(g), \delta_t(g)\}_{t=0}^{\infty}$.

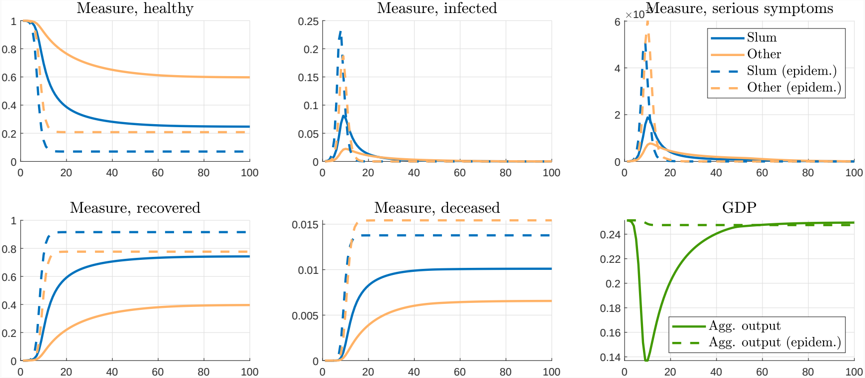
Fitting the Model to the Data - Model period is one week

Table 2: Moments – model vs. data

Moment	Model	Data (ranges)
Share of individuals living in slums	22%	22%
Pop. density in slums/Pop. density in non-slum areas	4.5	4.5
Relative hourly labor income of individuals in slums	27.7%	27.7%
R_0, Covid-19	2.5	1.6-4
% of infected in critical care	3.6	3.6
Weeks in critical care	3.5	3-6
% in critical care who die	20.24	10.6-31.8
Hours/day interacting while in ICU	3.8	7.6 (controlled)
Hours of work per week	34.2	34.2
Hours of outside activities per week	17.2	17.2
% of income on goods outside	27.28	27.28
% ↑ in time @ home – mild symptoms	26	26 (Influenza)
% ↑ in time @ home – outset of Covid-19	15.7	15.7
% of non-slum agents with priv. insurance	15.21	15.21

Parameters

Baseline results



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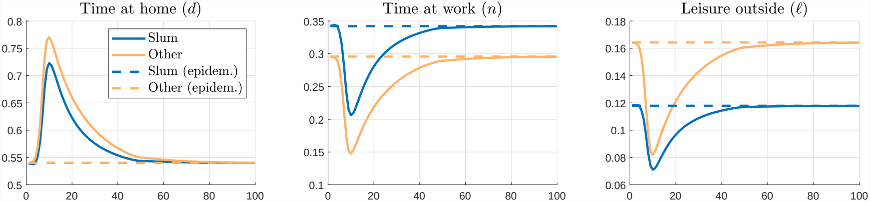

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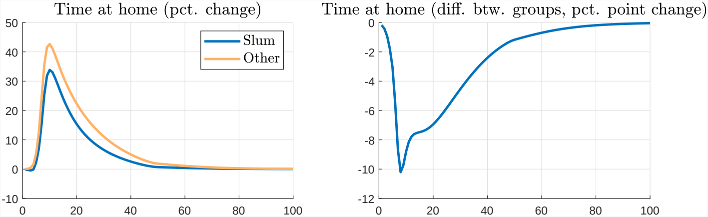


Baseline results

	Benchmark	Epidem.	No slum	Homog. densities	Homog. wage rates	Homog. age struct.
Wks to peak srsly ill (slum)	10.00	9.00	–	15.00	10.00	10.00
Wks to peak srsly ill (other)	11.00	10.00	14.00	14.00	11.00	11.00
Dead p/ 1,000 1year (slum)	10.04	13.78	–	6.32	8.87	13.49
Dead p/ 1,000 1year (other)	6.35	15.43	6.87	6.86	6.78	6.57
Dead p/ 1,000 1year (all)	7.16	15.06	6.87	6.74	7.25	8.11
Dead p/ 1,000 LR (slum)	10.11	13.78	–	6.53	9.07	13.68
Dead p/ 1,000 LR (other)	6.57	15.43	7.47	7.30	7.13	6.83
Dead p/ 1,000 LR (all)	7.35	15.06	7.47	7.13	7.56	8.34
Immune in LR (slum), %	74.33	91.60	–	51.78	70.11	72.37
Immune in LR (other), %	39.69	77.66	46.01	44.72	43.03	40.76
Immune in LR (all), %	47.36	80.75	46.01	46.28	49.03	47.76
GDP at peak - rel to BM	1.00	1.82	1.48	1.23	1.29	1.03
GDP 1year - rel to BM	1.00	1.14	1.17	1.00	1.17	0.99
Hrs @ home (slum) - peak	80.95	60.48	–	69.19	86.38	83.22
Hrs @ home (other) - peak	86.28	60.48	78.00	80.00	82.26	84.90
Value - healthy (slum)	1968.10	1962.10	–	1976.60	4305.90	1960.20
Value - healthy (other)	4317.40	4283.10	4315.00	4315.30	4315.60	4316.50
Value - healthy (all)	3797.00	3769.00	4315.00	3797.20	4313.50	3794.50

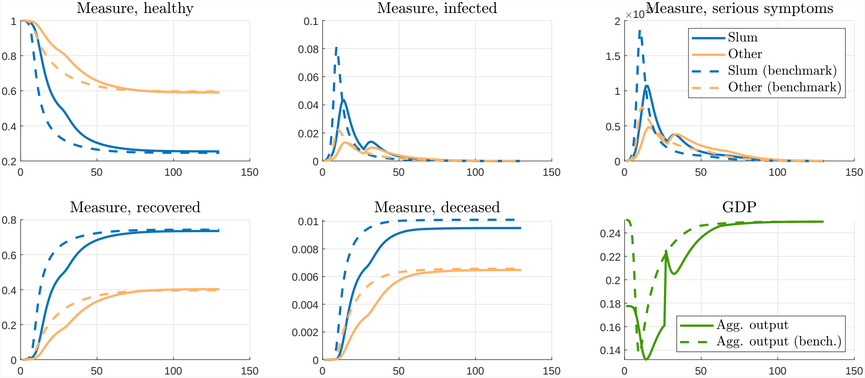
Policy experiments

- All ICU beds made public
- Shelter-at-home policies; i.e. lockdowns
- Cash transfers

All hospital beds used by the public system

	Benchmark	All beds public
Wks to peak srsly ill (slum)	10.00	10.00
Wks to peak srsly ill (other)	11.00	11.00
Dead p/ 1,000 1year (slum)	10.04	6.84
Dead p/ 1,000 1year (other)	6.35	4.82
Dead p/ 1,000 1year (all)	7.16	5.27
Dead p/ 1,000 LR (slum)	10.11	6.85
Dead p/ 1,000 LR (other)	6.57	4.86
Dead p/ 1,000 LR (all)	7.35	5.30
Immune in LR (slum), %	74.33	77.03
Immune in LR (other), %	39.69	42.89
Immune in LR (all), %	47.36	50.46
GDP at peak - rel to BM	1.00	1.02
GDP 1year - rel to BM	1.00	1.04
Hrs @ home (slum) - peak	80.95	80.26
Hrs @ home (other) - peak	86.28	85.01
Value - healthy (slum)	1968.10	1974.90
Value - healthy (other)	4317.40	4325.80
Value - healthy (all)	3797.00	3805.10

Shelter-at-home policies (25% ↑ time at home, 26 weeks)



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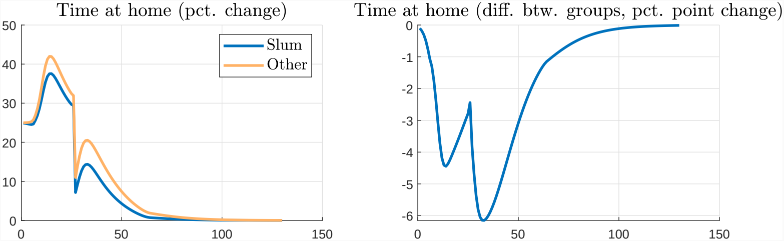

Shelter-at-home policies

		Immediate lockdown				6-week late lockdown
		25%, all	25%, slums	25%, non-slum	75%, all	25%, all
	Benchmark	26 weeks	26 weeks	26 weeks	35 weeks	26 weeks
Wks to peak srsly ill (slum)	10.00	14.00	13.00	11.00	66.00	11.00
Wks to peak srsly ill (other)	11.00	16.00	14.00	12.00	67.00	12.00
Dead p/ 1,000 1year (slum)	10.04	9.21	9.13	10.00	0.00	8.68
Dead p/ 1,000 1year (other)	6.35	5.84	6.92	5.28	0.00	5.26
Dead p/ 1,000 1year (all)	7.16	6.58	7.41	6.33	0.00	6.02
Dead p/ 1,000 LR (slum)	10.11	9.51	9.29	10.19	10.10	9.29
Dead p/ 1,000 LR (other)	6.57	6.48	7.22	5.91	6.56	6.34
Dead p/ 1,000 LR (all)	7.35	7.15	7.68	6.86	7.35	7.00
Immune in LR (slum), %	74.33	73.58	70.96	76.68	74.36	73.29
Immune in LR (other), %	39.69	40.32	42.96	38.18	39.67	40.57
Immune in LR (all), %	47.36	47.69	49.16	46.71	47.35	47.82
GDP at peak - rel to BM	1.00	0.96	1.12	0.86	0.99	0.95
GDP 1year - rel to BM	1.00	0.87	0.98	0.89	0.47	0.87
Hrs @ home (slum) - peak	80.95	83.18	84.40	79.79	80.19	83.76
Hrs @ home (other) - peak	86.28	85.87	81.83	89.56	85.95	86.16
Value - healthy (slum)	1968.10	1964.40	1964.20	1968.20	1863.20	1964.40
Value - healthy (other)	4317.40	4312.90	4315.30	4314.80	4213.00	4313.30
Value - healthy (all)	3797.00	3792.70	3794.50	3795.00	3692.50	3793.10

Cash transfers

		Only financial aid			Aid and 25% lockdown for all		
		300R$, all	300R$, slums	600R$, slums	300R$, all	300R$, slums	600R$, slums
	Benchmark	26 weeks	26 weeks	26 weeks	26 weeks	26 weeks	26 weeks
Wks to peak srsly ill (slum)	10.00	15.00	14.00	32.00	32.00	32.00	32.00
Wks to peak srsly ill (other)	11.00	16.00	15.00	19.00	33.00	33.00	33.00
Dead p/ 1,000 1year (slum)	10.04	8.99	8.94	8.81	9.01	8.96	9.07
Dead p/ 1,000 1year (other)	6.35	6.40	6.94	6.89	5.49	5.98	5.88
Dead p/ 1,000 1year (all)	7.16	6.97	7.39	7.31	6.27	6.64	6.59
Dead p/ 1,000 LR (slum)	10.11	9.28	9.16	9.15	9.54	9.40	9.58
Dead p/ 1,000 LR (other)	6.57	6.91	7.30	7.36	6.48	6.72	6.70
Dead p/ 1,000 LR (all)	7.35	7.43	7.71	7.76	7.15	7.32	7.34
Immune in LR (slum), %	74.33	71.90	70.69	70.33	73.58	72.44	72.27
Immune in LR (other), %	39.69	41.95	43.41	43.96	40.35	41.39	41.55
Immune in LR (all), %	47.36	48.58	49.45	49.80	47.71	48.27	48.36
GDP at peak - rel to BM	1.00	1.16	1.24	1.30	1.10	1.20	1.12
GDP 1year - rel to BM	1.00	0.94	0.99	0.98	0.84	0.89	0.91
Hrs @ home (slum) - peak	80.95	78.61	80.46	77.55	78.85	77.99	80.36
Hrs @ home (other) - peak	86.28	77.74	77.99	80.32	83.88	82.00	84.49
Value - healthy (slum)	1968.10	1985.60	1985.70	1998.80	1982.40	1982.60	1996.70
Value - healthy (other)	4317.40	4322.20	4315.70	4315.60	4320.70	4315.10	4316.70
Value - healthy (all)	3797.00	3804.60	3799.60	3802.40	3802.80	3798.50	3802.80

Conclusions

Slums:

- High-density areas populated by poorer and younger individuals
- Faster spread of diseases such as Covid-19 - but not necessarily more death rates (although still higher in our model)

This paper:

- Rich daily location data: slum dwellers $\rightarrow$ less social distance
- Model:
  - More infections (and deaths) in slums
  - World wo slums: distributional health effects
- Policies:
  - Reallocation of ICUs: all groups better off
  - Shelter-at-home: delay; small overall effects, redistribution
  - Cash transfers: delay; small effects (or backfire); redistribution

Parameters (Rio de Janeiro) - City Parameters

Parameter	Value	Interpretation
Panel A: City parameters (6 parameters)		
$\sum_j M_0(j,f)$	0.222	Fraction of people living in slums (calibrated)
$w(o)$	1	Wage rate of non-slum agents (calibrated)
$w(f)$	0.277	Wage rate of slum agents (calibrated)
ξ_f	0.065	Frac. of space assigned to slums (calibrated)
ξ_o	0.934	Frac. of space assigned to areas wo slums (calibrated)
ζ	0.334	Prop. of time spent within group (calibrated)

Parameters (Rio de Janeiro) - Disease Parameters

Parameter	Value	Interpretation
Panel B: Disease parameters (15 parameters)		
Π_0	11.43	Infectiousness of Covid-19 (internally estimated)
$\alpha(o)$, $\alpha(f)$	1	Prob. (serious symptoms | no recovery from mild) (calibrated)
$\phi(0, o)$	0.971	Prob. of recovery from mild Covid-19, other (calibrated)
$\phi(0, f)$	0.979	Prob. of recovery from mild Covid-19, slum (calibrated)
$\phi(1, o)$, $\phi(1, f)$	0.284	Prob. of recovery from serious Covid-19 (calibrated)
$\tilde{\delta}_1(o)$	0.118	Wkly death rate, other; critically ill with ICU (calibrated)
$\tilde{\delta}_1(f)$	0.073	Wkly death rate, slum; critically ill with ICU (calibrated)
$\tilde{\delta}_2(o)$, $\tilde{\delta}_2(f)$	1.0	Wkly death rate; critically ill wo ICU (calibrated)
$\bar{\ell}$	0.158	Infections through the health care system (calibrated)
ψ	0.152	Prop. non-slum agents with priv. insurance (calibrated)
Z_{pub}	8.12e-5	Measure of beds in public system (calibrated)

Parameters (Rio de Janeiro) - Preference Parameters

Parameter	Value	Interpretation
Panel C: Preference parameters (7 parameters)		
ρ	-1.72	Elast. of subst. bw leisure time and goods (calibrated)
θ	0.108	Production of leisure goods (internally estimated)
γ	1.089	Rel. utility weight–leisure goods (internally estimated)
λ_d	2.453	Rel. utility weight–leisure at home (internally estimated)
λ_a	1.995	Rel. utility weight–leisure at home; infected (calibrated)
β	$0.96^{1/52}$	Discount factor (calibrated)
b	8.575	Value of being alive (internally estimated)

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