Determinants of COVID-19 Vaccine Rollouts and Their Effects on Health Outcomes: Annex

Running title: Drivers and Effects of COVID-19 Vaccines: Annex

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Abstract

Background: Vaccination against the coronavirus disease (SARS-CoV -2) is understood to be the key way out of the COVID-19 pandemic. Limited evidence exists on the determinants of vaccine rollouts and their health effects at the country level.

Objective: Examine the determinants of COVID-19 vaccine rollouts and their effects on health outcomes.

Methods: Ordinary least squares regressions with standard errors clustered at the country level for Cross-section and Panel daily data of vaccinations and various health outcomes (new COVID-19 cases, fatalities, intensive care unit (ICU) admissions) for an unbalanced sample of about 200 countries during the period December 16, 2020-June 20, 2021.

Results: We find evidence that: (i) early vaccine procurement, domestic production of vaccines, the severity of the pandemic, a country's health infrastructure, and vaccine acceptance are significant determinants of the speed of vaccination rollouts; (ii) vaccine deployment significantly reduces new COVID-19 infections, Intensive Care Unit (ICU) admissions, and fatalities, and is more effective when coupled with stringent containment measures, or when a country is experiencing a large outbreak; and (iii) COVID-19 cases in neighboring countries can lead to an increase in a country's domestic caseload, and hamper efforts in taming its own local outbreak.

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Conclusions: By providing an early broad overview of the quantitative empirical estimates of the determinants of vaccine rollouts and the effects of COVID-19 vaccines, our paper can help policymakers make informed decisions about local and global distributions of vaccines, as well as related policy tools, such as containment measure.

Key Points for Decision Makers:

1. The success of a country's vaccine deployment in the first half of 2021 was driven by five primary factors: the severity of its pandemic waves in 2020, its procurement strategies, the quantity of locally produced vaccines, the quality of health infrastructure, and vaccine acceptance.

2. Swift and broad administration of vaccines provides a significant boost to health outcomes, particularly in the midst of major outbreaks and accompanied by containment measures.

3. Cross-country health spillovers from vaccine rollouts mean the pandemic will not be over anywhere until it is over everywhere.

JEL Classification Numbers: C31; C33, E65, O50, F4.

Keywords: COVID-19; pandemics; vaccinations; containment measures.

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Annex Table A.1: Country list

Afghanistan	Cameroon	Gabon	Kyrgyz Republic	New Zealand	South Sudan
Albania	Canada	Gambia, The	Lao P.D.R.	Nicaragua	Spain
Algeria	Cayman Islands	Georgia	Latvia	Niger	Sri Lanka
Andorra	Central African Republic	Germany	Lebanon	Nigeria	St. Kitts and Nevis
Angola	Chad	Ghana	Lesotho	North Macedonia	St. Lucia
Anguilla	Chile	Gibraltar	Liberia	Norway	St. Vincent and the Grenadines
Antigua and Barbuda	China	Greece	Libya	Oman	Sudan
Argentina	Colombia	Greenland	Liechtenstein	Pakistan	Suriname
Armenia	Comoros	Grenada	Lithuania	Palestan	Sweden
Aruba	Congo, Democratic Republic of the	Guatemala	Luxembourg	Panama	Switzerland
Australia	Congo, Republic of	Guinea	Macao SAR	Papua New Guinea	Syria
Austria	Costa Rica	Guinea-Bissau	Madagascar	Paraguay	São Tomé and Príncipe
Azerbaijan	Croatia	Guyana	Malawi	Peru	Taiwan Province of China
Bahamas, The	Cuba	Honduras	Malaysia	Philippines	Tajikistan
Bahrain	Curaçao	Hong Kong SAR	Maldives	Poland	Thailand
Bangladesh	Cyprus	Hungary	Mali	Portugal	Timor-Leste
Barbados	Czech Republic	Iceland	Malta	Qatar	Togo
Belarus	Côte d'Ivoire	India	Mauritania	Romania	Tonga
Belgium	Denmark	Indonesia	Mauritius	Russia	Trinidad and Tobago
Belize	Djibouti	Iran	Mexico	Rwanda	Tunisia
Benin	Dominica	Iraq	Moldova	Samoa	Turkey
Bermuda	Dominican Republic	Ireland	Monaco	San Marino	Turkmenistan
Bhutan	Ecuador	Isle of Man	Mongolia	Senegal	Turks and Caicos Islands
Bolivia	Egypt	Israel	Montenegro	Serbia	Tuvalu
Bosnia and Herzegovina	El Salvador	Italy	Montserrat	Seychelles	Uganda
Botswana	Equatorial Guinea	Jamaica	Morocco	Sierra Leone	Ukraine
Brazil	Estonia	Japan	Mozambique	Singapore	United Arab Emirates
British virgin Islands	Eswatini	Jersey	Myanmar	Sint Maarten	United Kingdom
Brunei Darussalam	Ethiopia	Jordan	Namibia	Slovak Republic	United States
Bulgaria	Fiji	Kazakhstan	Nauru	Slovenia	Uruguay
Burkina Faso	Finland	Kenya	Nepal	Solomon Islands	Uzbekistan
Cabo Verde	France	Korea	Netherlands	Somalia	Vanuatu
Cambodia	French Polynesia	Kuwait	New Caledonia	South Africa	Venezuela
Cameroon	Greenland	Maldives	San Marino	United States	
Canada	Grenada	Mali	Senegal	Uruguay	
Cayman Islands	Guatemala	Malta	Serbia	Uzbekistan	
Central African Republic	Guinea	Mauritania	Seychelles	Vanuatu	
Chad	Guinea-Bissau	Mauritius	Sierra Leone	Venezuela	

Chile	Guyana	Mexico	Singapore	Vietnam	
China	Honduras	Moldova	Sint Maarten	Yemen	

Annex Table A.2: Summary Statistics

Panel A: Summary Statistics for Time-Varying data

	Obs.	Mean	Std. Dev.	Min	Max	Source	Starting Date	No. of countries
New COVID-19 Cases per 10000 population	71,896	1.01	2.34	0.00	182.94	JHU	22-Jan-20	210
New COVID-19 Deaths per 10000 population	46,569	0.03	0.06	0.00	2.67	JHU	22-Jan-20	200
Vaccinations per 100 population (1st dose)	23,257	13.26	17.73	0.00	116.15	OWID	16-Dec-20	202
Vaccinations per 100 population (2nd dose)	15,257	9.59	14.27	0.00	114.86	OWID	27-Dec-20	180
ICU Admissions per 10000	9,680	0.27	0.27	0.00	1.93	OWID	28-Jan-20	23
Procurement per 100 (confirmed)	22,367	42.93	73.09	0.04	520.10	Duke	1-May-20	101
Procurement per 100 (potential)	22,689	55.53	101.88	0.04	824.70	Duke	1-May-20	102
Stringency	90,576	0.56	0.23	0.03	1.00	OxCGRT	20-Jan-20	184
Retail Mobility	63,740	-21.66	25.07	-100.00	181.00	Google	15-Feb-20	135
Vaccine Acceptance	12,972	0.71	0.14	0.20	0.97	UMD	21-Dec-20	100

Panel B: Summary Statistics for Cross-Sectional data

	Obs.	Mean	Std. Dev.	Min	Max	Source	Date
Health Index	137	6.15	0.93	2.67	6.98	WEF	2019
Global Health Security Index	191	40.58	14.41	16.20	83.50	GHS	2019
Beds per 1000 people	204	3.06	2.42	0.10	13.80	World Bank	Latest reported
Physicians per 1000 People	237	1.80	1.60	0.01	8.42	World Bank	Latest reported

Annex Table A3. Robustness Checks - Baseline

	Baseline		Hodrick–Prescott filter		Hamilton Filter	
	(1)	(2)	(3)	(4)	(5)	(6)
	Cases/Pop	Cases/Pop	Cases/Pop	Cases/Pop	Cases/Pop	Cases/Pop
First vaccine dose/population	-0.000986***	-0.000898***	-0.001013***	-0.000919***	-0.000932***	-0.000860***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Second vaccine dose/population		-0.000222		-0.000238		-0.000171
		(0.000)		(0.000)		(0.000)
Containment measures	-0.009603	-0.010365	-0.011902	-0.012719*	-0.007678	-0.008276
	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)
Mobility	0.000100**	0.000103***	0.000092**	0.000095**	0.000073*	0.000074*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Lagged cases/pop	0.00161	0.001816	0.002888	0.003070	-0.001994	-0.001904
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Constant	-1.973306	-1.318626	-3.394891***	-3.146237***	-3.345503***	-3.145070***
	(1.544)	(1.768)	(0.671)	(0.767)	(0.683)	(0.764)
Observations	13,542	13,455	13,542	13,455	13,542	13,455
R-squared	0.624	0.625	0.794	0.794	0.390	0.390
Lags 1st dose/2nd dose	21	21/7	21	21/7	21	21/7
Health policy controls	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Time FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of countries	126	126	126	126	126	126

Note: Table reports results baseline results for equation (2) when filtering the dependant variable using the Hodrick-Prescott filter (columns 3,4) and the Hamilton filter (columns 5,6). The dependent variable is new COVID-19 cases, The regressions control for stringency of containment measures, other non-pharmaceutical interventions and health policy controls, mobility, lagged cases, country specific time trends, as well as country and time fixed effects. Standard errors are clustered at the country level. ***, **, and * represent statistical significant at 1, 5 and 10 percent respectively.

Annex Table A4. Robustness Checks - Rollout

	(1) Confirmed Procurement - Jan 2021	(2) Confirmed Procurement - Oct 2020	(3) Potential Procurement - Oct 2020	(4) Confirmed Procurement - latest	(5) Procurement - Airfinity	(6) GHS Health	(7) Doctors	(8) Hospital Beds
Procurement (Jan 2021)	0.0669***							
	(0.0207)							
Cumulative cases (end-2020)	5.502***	5.173***	5.154***	5.242***	5.782***	5.639***	3.771***	6.425***
	(0.978)	(0.941)	(0.937)	(0.990)	(1.436)	(1.016)	(1.097)	(0.985)
Health index (WEF)	8.327***	9.547***	9.715***	9.201***	9.880***			
	(2.318)	(2.334)	(2.340)	(2.428)	(3.226)			
Vaccine acceptance (Jan 2021)	30.80***	30.11***	29.91***	30.58***	3.269	16.20	41.54***	42.54***
	(10.93)	(11.21)	(11.23)	(11.26)	(14.10)	(10.76)	(9.758)	(12.05)
Procurement (Oct 2020)		0.0802***						
		(0.0271)						
Potential procurement (Oct 2020)			0.0570***					
			(0.0167)					
Potential procurement (latest)				0.0300**				
				(0.0128)				
Procurement (Airfinity)					0.0298***			
					(0.0108)			
Potential procurement (Jan 2021)						0.0392**	0.0480***	0.0619***
						(0.0165)	(0.0164)	(0.0133)
Health index (GHS)						0.489***		
						(0.148)		
Doctors per capita							6.567***	
							(1.268)	
Hospital beds per capita								1.125*
								(0.580)
Constant	-62.74***	-68.05***	-68.86***	-67.23***	-57.21***	-23.13***	-28.38***	-23.63***
	(14.16)	(14.00)	(13.98)	(14.44)	(20.36)	(6.292)	(6.443)	(8.139)
Observations	85	85	85	85	54	92	91	90
R-squared	0.577	0.558	0.560	0.557	0.494	0.601	0.684	0.554

Note: Table reports results for equation (1). The dependent variable is the share of population that is vaccinated with at least one dose. Robust standard errors. ***, **, and * represent statistical significant at 1, 5 and 10 percent respectively.

Annex Table A5. Robustness Checks - Rollout

	(1) Latest caseload	(2) Average cases in 2020	(3) Peak cases in 2020	(4) Deaths in 2020	(5) Daily vaccinations	(6) Trust in Government	(7) Political Stability
Potential procurement (Jan 2021)	0.0497***	0.0387**	0.0480***	0.0337*	3.587**	0.0312*	0.0356**
	(0.0141)	(0.0169)	(0.0151)	(0.0199)	(1.468)	(0.0172)	(0.0177)
Cumulative cases (latest)	2.917***						
	(0.459)						
Health index (WEF)	7.660***	10.97***	8.760***	13.98***	931.1***	8.612***	6.274***
	(2.153)	(2.506)	(2.347)	(3.099)	(249.0)	(1.489)	(1.197)
Vaccine acceptance (Jan 2021)	30.10***	26.07**	29.80***	27.03**	2,152**		
	(11.14)	(10.63)	(11.19)	(12.96)	(914.7)		
Average cases (2020)		18.54***					
		(4.270)					
Peak cases (2020)			5.401***				
			(0.977)				
Cumulative deaths (end-2020)				64.31			
				(54.74)			
Cumulative cases (end-2020)					438.5***	3.361***	2.941***
					(102.2)	(0.907)	(0.936)
Trust in Government (WEF)						3.792***	
						(1.126)	
Political Stability (World Bank)							8.914***
							(1.815)
Constant	-59.38***	-73.49***	-64.32***	-86.96***	-6,035***	-48.75***	-21.25***
	(14.00)	(15.27)	(14.29)	(18.13)	(1,365)	(7.669)	(6.464)
Observations	85	85	85	85	86	133	133
R-squared	0.607	0.549	0.570	0.408	0.448	0.479	0.540

Note: Table reports results for equation (1). The dependent variable is the share of population that is vaccinated with at least one dose, except for column (5) where it is the average number of daily vaccinations since the start of the vaccination campaign in the country. Robust standard errors. ***, **, and * represent statistical significant at 1, 5 and 10 percent respectively.

Annex Table A6. Robustness Checks – Impact of Vaccines on Health Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	1% winsorized	drop late: start after March 1	drop early: 5% before Feb 1	without APD	without EUR	without MCD	without WHD	without AFR
Vaccine 1st dose per capita	-0.000910***	-0.001011***	-0.000681**	-0.001014***	-0.000200	-0.001029***	-0.001217***	-0.001009***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Containment measures (21 days lag)	-0.011812	-0.011802	-0.007546	0.001206	0.001201	0.000418	0.001791	0.001885
	(0.008)	(0.010)	(0.008)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Mobility (21 days lag)	0.000089**	0.000114**	0.000119***	-0.013693	-0.005394	-0.005564	-0.012225	-0.013662
	(0.000)	(0.000)	(0.000)	(0.012)	(0.005)	(0.008)	(0.009)	(0.010)
Lagged cases/pop	-0.003545*	0.002013	0.001909	0.000093**	0.000052*	0.000108**	0.000128***	0.000110***
	(0.002)	(0.003)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-2.078319	-1.915697	-1.935092	-1.368766	-6.560121***	-1.575337	4.209801*	-2.041791
	(1.468)	(1.353)	(1.250)	(1.617)	(1.913)	(1.455)	(2.464)	(1.400)
Observations	13,542	11,093	12,711	11,307	8,414	11,905	10,692	11,845
R-squared	0.587	0.605	0.597	0.609	0.782	0.605	0.598	0.608
Health policy controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of countries	126	90	119	104	88	108	100	104

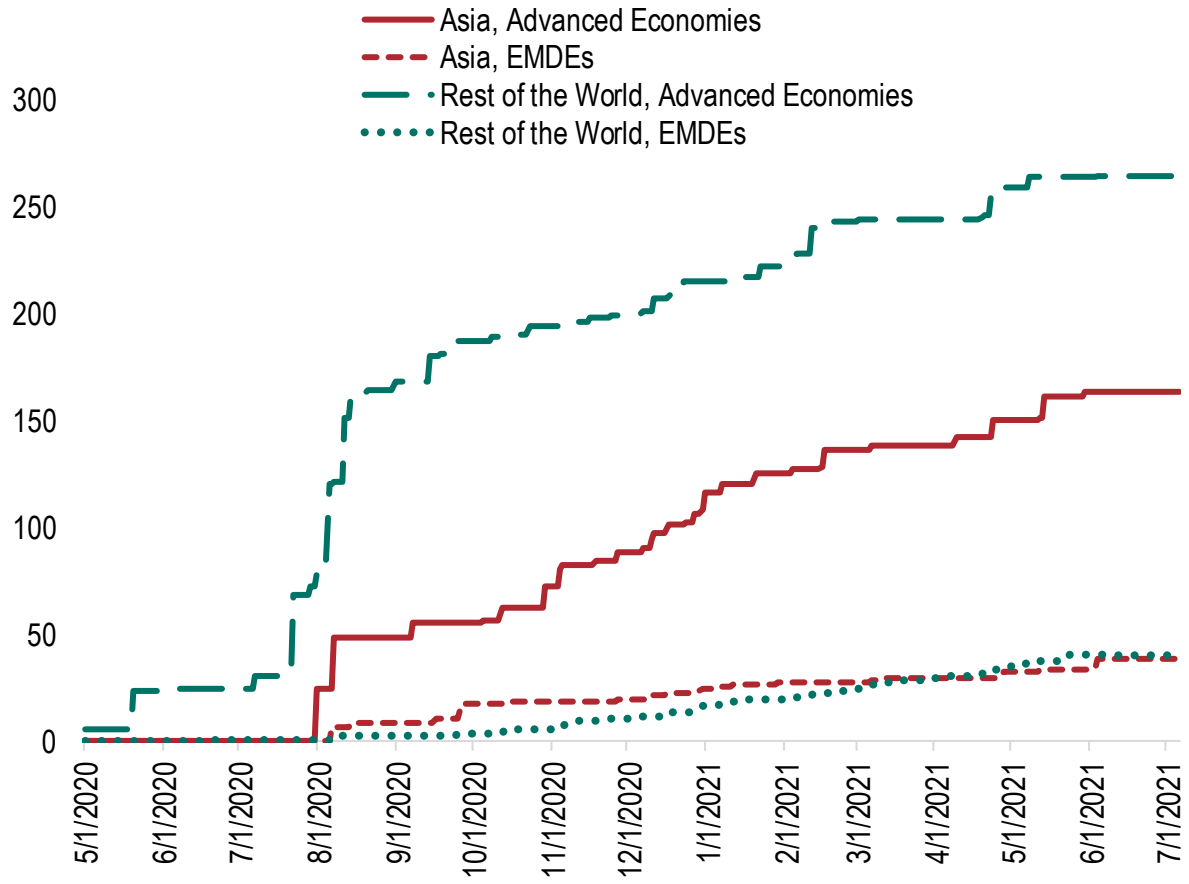
Notes: Table reports results for equation (2). The dependent variable is new COVID-19 cases per capita. Vaccine 1st dose per capita is lagged 21 days. The regressions control for stringency of containment measures, other non-pharmaceutical interventions and health policy controls (21 lags), lags of mobility (21 lags), lagged cases or reproduction rate, country specific time trends, as well as country and time fixed effects. Standard errors are clustered at the country level. ***, **, and * represent statistical significant at 1, 5 and 10 percent respectively. APD denotes Asia-Pacific, EUR denotes Europe, MCD denotes Middle East & Central Asia, WHD denotes Western Hemisphere and AFR denotes Africa.

Annex Table A7. Effect of neighboring COVID-19 cases on domestic COVID-19 cases, using alternative weights

	(1)	(2)	(3)	(4)
	New COVID-19 Cases	New COVID-19 Cases	New COVID-19 Cases	New COVID-19 Cases
Vaccinated persons, 1 dose	-0.000930***	-0.000824***	-0.000818***	-0.000801***
	(0.000)	(0.000)	(0.000)	(0.000)
Vaccinated persons, 2 doses		-0.000282		-0.000051
		(0.000)		(0.000)
Neighbor cases (all capital cities, 7 days lag)	1.393726***	1.415165***		
	(0.521)	(0.520)		
Neighbor cases (trade weights, 7 days lag)			4.287295***	4.295574***
			(0.966)	(0.984)
COVID-19 cases (lag)	-0.001302	-0.001059	-0.000987	-0.000874
	(0.003)	(0.003)	(0.003)	(0.003)
Containment measures index (lag)	-0.009292	-0.010286	-0.008972	-0.009220
	(0.008)	(0.008)	(0.008)	(0.008)
Mobility (lag)	0.000106***	0.000111***	0.000102***	0.000105***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	13,241	13,154	13,468	13,381
R-squared	0.635	0.635	0.634	0.634
Health Policy Controls	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
No. of countries	123	123	124	124

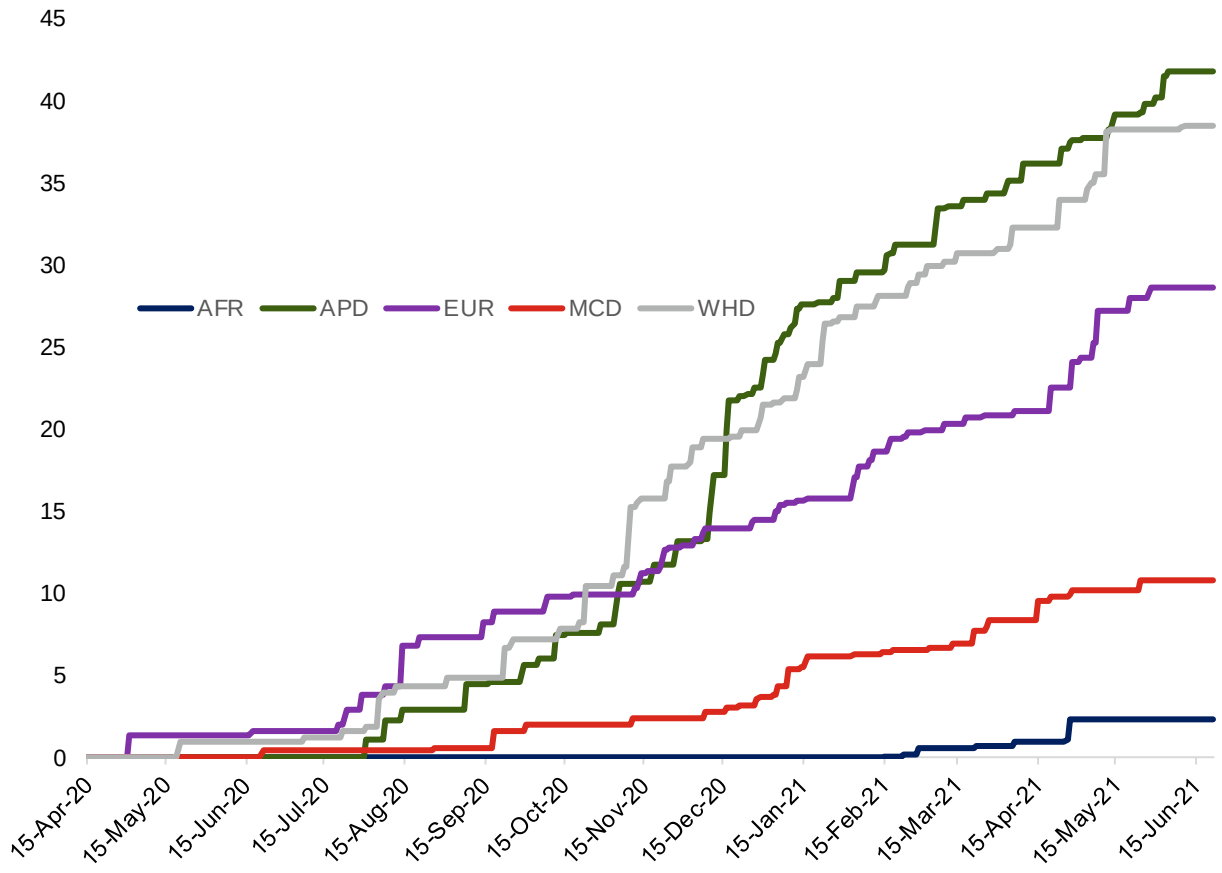
Note: Table reports results for equation (7). The dependent variable is new COVID-19 cases. A spillover term "Neighbor cases" (lag 7 days) is introduced to the equation to capture the effects of neighboring COVID-19 new cases on a country's own caseload using bilateral distance weights (equation 6). The regressions control for stringency of containment measures, other non-pharmaceutical interventions and health policy controls (21 lags), lags of mobility (21 lags), lagged new cases, country-specific time-trends, as well as country and time fixed-effects. Standard errors are clustered at the country level. ***, **, and * represent statistical significant at 1, 5 and 10 percent respectively.

Annex Figure A1. Vaccine Procurement Deals by Income Groups (weighted average, percent of the population to be vaccinated)



Note: countries are grouped per income level and weighted by population. Procurement deals include those already confirmed, potential deals, and donations. Source: Duke University Heath Innovation Center and author calculations.

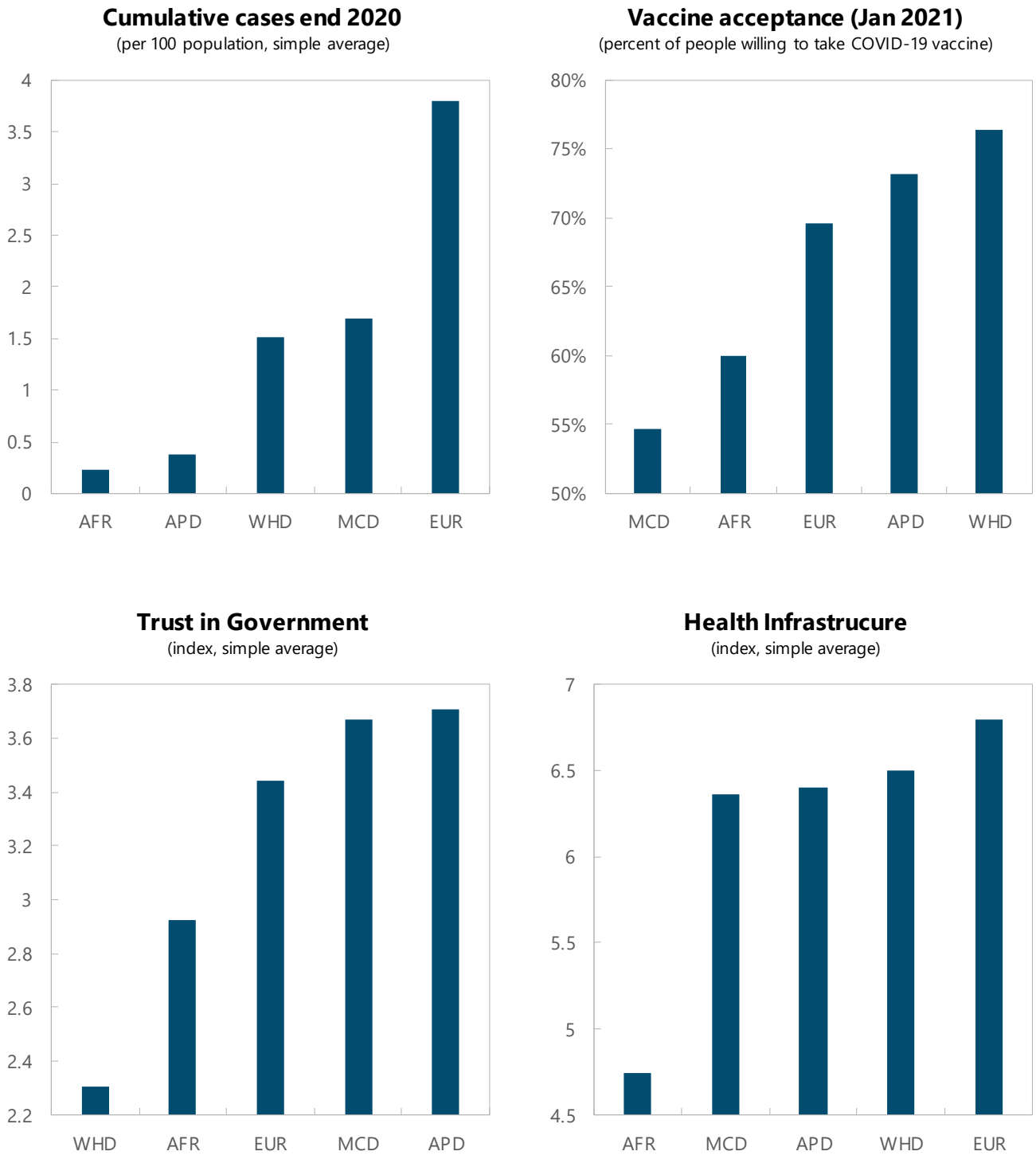
Annex Figure A2. Procurement per 100 population by region (orders, excluding potential orders)



Note: The chart includes confirmed orders, potential deals, and donations. AFR: Sub-Saharan Africa; APD: Asia Pacific Department; EUR: European Department; MCD: Middle East and Central Asia Department; WHD: Western Hemisphere Department.

Source: Duke University Heath Innovation Center and author calculations.

Annex Figure A3. Determinants of vaccine rollout



Note: AFR: Sub-Saharan Africa; APD: Asia Pacific Department; EUR: European Department; MCD: Middle East and Central Asia Department; WHD: Western Hemisphere Department.

Sources: Johns Hopkins University; University of Maryland and Global Competitiveness Report.