The Costing Model

This document describes the costing model that is used in the CEPI application.

1 Parameters

Table 1: Notation and parametric assumptions for inputs to the costing model. Parameters are used as follows: uniform distributions go from Parameter 1 to Parameter 2. Triangular distributions go from Parameter 1 to Parameter 3 with a peak at Parameter 2. Multinomial distributions have equally probable values listed individually. Exponential distributions have as a mean Parameter 1. Inverse Gaussian distributions have as a mean Parameter 1, and as a shape Parameter 2. Log normal distributions have as a mean Parameter 1, and as a standard deviation Parameter 2. Inverse Gamma distributions have shape Parameter 1 and scale Parameter 2. Beta Prime distributions have shape Parameters 1 and 2, and scale Parameter 3. Where given, distributions are truncated at bounds.

Math notation	Description	Distribution	Parameters	Bounds	Source
$W^{(S)}_{0;365}$	SSV preclinical duration (365); weeks	Constant	14		
$W^{(S)}_{0;200}$	SSV preclinical duration (200DM); weeks	Constant	5		
$W^{(S)}_{0;100}$	SSV preclinical duration (100DM); weeks	Constant	5		
$W^{(S)}_{1;365}$	SSV phase I duration (365); weeks	Constant	19		
$W^{(S)}_{1;200}$	SSV phase I duration (200DM); weeks	Constant	7		
$W^{(S)}_{1;100}$	SSV phase I duration (100DM); weeks	Constant	0		
$W^{(S)}_{2;365}$	SSV phase II duration (365); weeks	Constant	19		

Math notation	Description	Distribution	Parameters	Bounds	Source
$W_{2;200}^{(S)}$	SSV phase II duration (200DM); weeks	Constant	0		
$W_{2;100}^{(S)}$	SSV phase II duration (100DM); weeks	Constant	0		
$W_{3;365}^{(S)}$	SSV phase III duration (365); weeks	Constant	16		
$W_{3;200}^{(S)}$	SSV phase III duration (200DM); weeks	Constant	15		
$W_{3;100}^{(S)}$	SSV phase III duration (100DM); weeks	Constant	8		
$V_{L;0}$	Cost of vaccine delivery at start up (0–10%) in LIC; USD per dose	Triangular	1, 1.5, 2		See Table 2
$V_{L;11}$	Cost of vaccine delivery during ramp up (11–30%) in LIC; USD per dose	Triangular	0.75, 1, 1.5		See Table 2
$V_{L;31}$	Cost of vaccine delivery getting to scale (31–80%) in LIC; USD per dose	Triangular	1, 2, 4		See Table 2
$V_{LM;0}$	Cost of vaccine delivery at start up (0–10%) in LMIC; USD per dose	Triangular	3, 4.5, 6		See Table 2
$V_{LM;11}$	Cost of vaccine delivery during ramp up (11–30%) in LMIC; USD per dose	Triangular	2.25, 3, 4.5		See Table 2
$V_{LM;31}$	Cost of vaccine delivery getting to scale (31–80%) in LMIC; USD per dose	Triangular	1.5, 2, 2.5		See Table 2
$V_{UM;0}$	Cost of vaccine delivery at start up (0–10%) in UMIC; USD per dose	Triangular	6, 9, 12		See Table 2

Math notation	Description	Distribution	Parameters	Bounds	Source
$V_{UM;11}$	Cost of vaccine delivery during ramp up (11–30%) in UMIC; USD per dose	Triangular	4.5, 6, 9		See Table 2
$V_{UM;31}$	Cost of vaccine delivery getting to scale (31–80%) in UMIC; USD per dose	Triangular	3, 4, 5		See Table 2
$V_{H;0}$	Cost of vaccine delivery at start up (0–10%) in HIC; USD per dose	Triangular	30, 40, 75		See Table 2
$V_{H;11}$	Cost of vaccine delivery during ramp up (11–30%) in HIC; USD per dose	Triangular	30, 40, 75		See Table 2
$V_{H;31}$	Cost of vaccine delivery getting to scale (31–80%) in HIC; USD per dose	Triangular	30, 40, 75		See Table 2
M_G	Global annual manufacturing volume; billion doses	Constant	15		Linksbridge SPC [2025]
M_C	Current annual manufacturing volume; billion doses	Constant	6.6		Linksbridge SPC [2025]
F	Facility transition start; weeks before vaccine approval	Constant	7		
I_R	Weeks to initial manufacturing, reserved infrastructure	Constant	12		Vaccines Europe [2023]
I_E	Weeks to initial manufacturing, existing and unreserved infrastructure	Constant	30		Vaccines Europe [2023]
I_B	Weeks to initial manufacturing, built and unreserved infrastructure	Constant	48		

Math notation	Description	Distribution	Parameters	Bounds	Source
C_R	Weeks to scale up to full capacity, reserved infrastructure	Constant	10		Vaccines Europe [2023]
C_E	Weeks to scale up to full capacity, existing and unreserved infrastructure	Constant	16		
C_B	Weeks to scale up to full capacity, built and unreserved infrastructure	Constant	16		
P_0	Probability of success; preclinical	Multinomial	0.40, 0.41, 0.41, 0.42, 0.48, 0.57		Gouglas et al. [2018]
P_1	Probability of success; Phase I	Multinomial	0.33, 0.40, 0.50, 0.68, 0.70, 0.72, 0.74, 0.77, 0.81, 0.90		Gouglas et al. [2018]
P_2	Probability of success; Phase II	Multinomial	0.22, 0.31, 0.33, 0.43, 0.46, 0.54, 0.58, 0.58, 0.74, 0.79		Gouglas et al. [2018]
P_3	Probability of success; Phase III	Uniform	0.4, 0.8		Wong et al. [2019]
$T_0^{(e)}$	Cost, preclinical, experienced manufacturer; USD	Exponential	24213683	1700000, 140000000	Gouglas et al. [2018]
$T_0^{(n)}$	Cost, preclinical, inexperienced manufacturer; USD	Inverse Gaussian	7882792, 13455907	1700000, 37000000	Gouglas et al. [2018]
$T_1^{(e)}$	Cost, Phase I, experienced manufacturer; USD	Inverse Gaussian	15339198, 8076755	1900000, 70000000	Gouglas et al. [2018]
$T_1^{(n)}$	Cost, Phase I, inexperienced manufacturer; USD	Inverse Gamma	2.2774, 9799081	1000000, 30000000	Gouglas et al. [2018]
$T_2^{(e)}$	Cost, Phase II, experienced manufacturer; USD	Log normal	28297339, 24061641	3800000, 140000000	Gouglas et al. [2018]
$T_2^{(n)}$	Cost, Phase II, inexperienced manufacturer; USD	Inverse Gaussian	17124622, 35918793	4400000, 54000000	Gouglas et al. [2018]

Math notation	Description	Distribution	Parameters	Bounds	Source
$T_3^{(e)}$	Cost, Phase III, experienced manufacturer; USD	Inverse Gamma	1.3147, 51397313	15000000, 910000000	Gouglas et al. [2018]
$T_3^{(n)}$	Cost, Phase III, inexperienced manufacturer; USD	Beta prime	4.8928, 1.6933, 11400026	2500000, 400000000	Gouglas et al. [2018]
ω	Share of manufacturers that are inexperienced	Constant	0.9		
L	Licensure; USD	Constant	287750		Gouglas et al. [2018]
$Y_0^{(B)}$	BPSV preclinical duration; years	Multinomial	1, 2		CEPI [2022]
$Y_1^{(B)}$	BPSV Phase I duration; years	Multinomial	1, 2		CEPI [2022]
$Y_2^{(B)}$	BPSV Phase II duration; years	Constant	2		CEPI [2022]
$Y_3^{(B)}$	BPSV Phase III duration; weeks	Constant	18		
$L^{(B)}$	Licensure duration; years	Constant	2		CEPI [2022]
G	BPSV cost of goods supplied; USD per dose	Constant	4.68		Kazaz [2021]
A_2	Advanced capacity reservation fee; USD per dose per year	Constant	0.53		Pfizer [2023]
A_1	Stockpiling fee; USD per dose per year	Constant	2		
S_R	SSV procurement price, reserved capacity; USD per dose	Constant	6.29		Kazaz [2021]
S_U	SSV procurement price, reactive capacity; USD per dose	Constant	18.94		Linksbridge SPC [2025]
E	Enabling activities; million USD per year	Constant	700		CEPI [2021]
I	Inflation (2018–2025)	Constant	0.28		U.S. Bureau of Labor Statistics
r	Discount rate	Uniform	0.02, 0.06		Glennerster et al. [2023]
M_p	Profit margin	Constant	0.2		

Math notation	Description	Distribution	Parameters	Bounds	Source
M_f	Fill/finish cost	Constant	0.14		
$N_{HIC}^{(15)}$	Population aged 15 and older, HIC	Constant	1062903718		OWID [2024]
$N_{UMIC}^{(15)}$	Population aged 15 and older, UMIC	Constant	2258682374		OWID [2024]
$N_{LMIC}^{(15)}$	Population aged 15 and older, LMIC	Constant	2292686818		OWID [2024]
$N_{LIC}^{(15)}$	Population aged 15 and older, LIC	Constant	431149981		OWID [2024]
$N_{HIC}^{(65)}$	Population aged 65 and older, HIC	Constant	245880785		OWID [2024]
$N_{UMIC}^{(65)}$	Population aged 65 and older, UMIC	Constant	340100977		OWID [2024]
$N_{LMIC}^{(65)}$	Population aged 65 and older, LMIC	Constant	196323876		OWID [2024]
$N_{LIC}^{(65)}$	Population aged 65 and older, LIC	Constant	23832449		OWID [2024]
$N^{(\text{SSV})}$	Number of SSV candidates	Constant	18		
$N^{(\text{BPSV})}$	Number of BPSV candidates	Constant	8		CEPI [2025]
A_3	Reserved capacity for HIC, billions	Constant	0.5		
λ	Final vaccine coverage, proportion of population	Constant	0.8		Model choice

2 Preparedness cost equation

(BPSV R&D + BPSV Stockpile + SARS-X Reserved capacity + Enabling activities) / (1 + discount rate) ^ (year – 2025)

$$D_y^{(\text{prep})} = \frac{1}{(1+r)^y}\left(D_s^{(\text{BP-adRD})} + D_{s,y}^{(\text{BP-inv})} + D_s^{(\text{S-cap})} + D_{s,y}^{text(en)}\right)$$

- $D_s^{(\text{BP-adRD})}$ is the R&D cost of BPSV prior to an outbreak; see Equation (1)
- $D_{s,y}^{(\text{BP-inv})}$ is the cost of maintaining an investigational reserve of 100,000 BPSV doses; see Equation (2)
- $D_s^{(\text{S-cap})}$ is the cost of reserved capacity for SSV; see Equation (4)
- $D_{s,y}^{text(en)}$ is the annual cost of enabling activities; see Equation (5).

2.1 BPSV advanced R&D

I have set the weight of inexperienced manufacturer to 0.9

Probabilities of success for preclinical, Phase I, Phase II, and Phase III are P_0, P_1, P_2 and P_3. Then probabilities of occurrence are:

$$\hat{P}_i = \begin{cases} 1 & i = 0 \\ \prod_{j=0}^{i-1} P_j & i \in \{1,2,3\} \\ \prod_{j=0}^{3} P_j & i = L \end{cases}$$

and the cost of each phase is T_i, a weighted average of experienced and inexperienced manufacturers (assuming $\omega = 0.9$):

$$T_i = \omega T_i^{(n)} + (1-\omega) T_i^{(e)}.$$

Then the total weighted cost for phases 0 through 2 for $N^{(\text{BPSV})} = 8$ candidates is

$$D_s^{(\text{BP-adRD})} = \begin{cases} N^{(\text{BPSV})} \sum_{i=0}^{2} \hat{P}_i T_i & s \in \{1,2,3\} \\ 0 & s \notin \{1,2,3\} \end{cases} \tag{1}$$

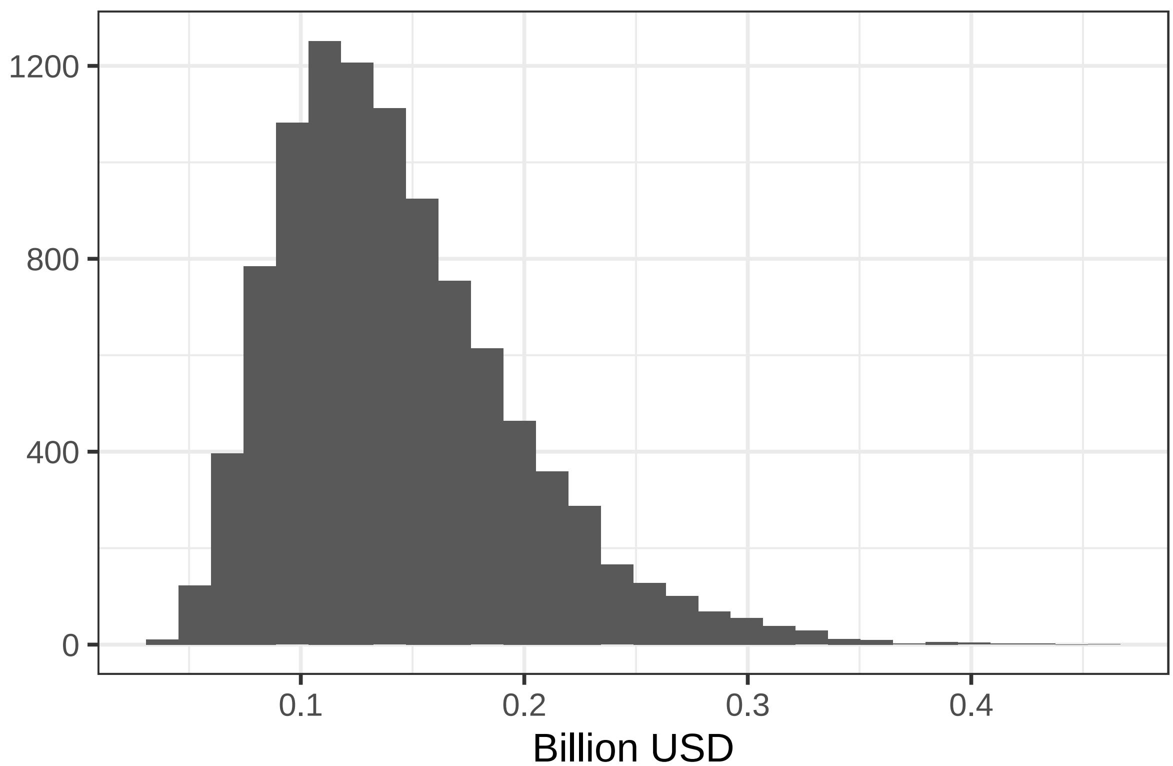


Figure 1: Risk-adjusted R&D cost for 8 BPSV candidates

2.2 BPSV investigational reserve

The cost per dose per year is 2 USD, denoted A_1. Then the cost to maintain the reserve of 100,000 doses is

$$D_{s,y}^{(\text{BP-inv})} = \begin{cases} 100000A_1 & s \in \{1,2,3\} \text{ \& } y > 5 \\ 0 & s \notin \{1,2,3\} \parallel y \leq 5 \end{cases} \tag{2}$$

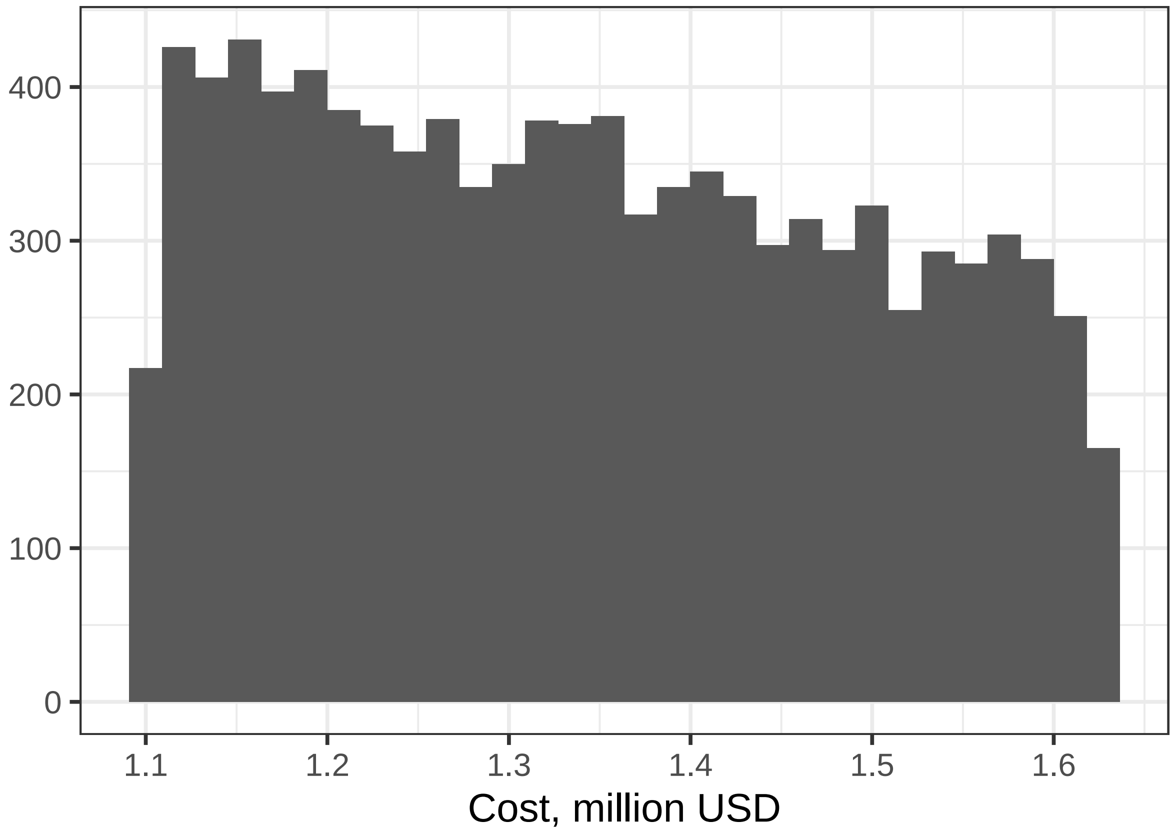


Figure 2: BPSV investigational reserve costs accumulated from year 6 to year 15 with uniformly distributed discount rate.

2.3 SSV capacity reservation

The cost per dose reservation per year is 0.53 USD, denoted A_2. Reservation sizes, in billions, depend on scenarios, including the $A_3 = 0.5$ billion doses reserved for HIC, as follows:

$$M_{R,s} = \begin{cases} A_3 & s \in \{0,1,6,9,12\} \\ A_3 + 0.7 & s \in \{2,4,7,10\} \\ A_3 + 2 & s \in \{3,5,8,11\} \end{cases} \tag{3}$$

Then the total cost per year is

$$D_s^{(\text{S-cap})} = M_{R,s}A_2 \tag{4}$$

The annual costs in billion USD are 0.265, 0.636, and 1.325, respectively.

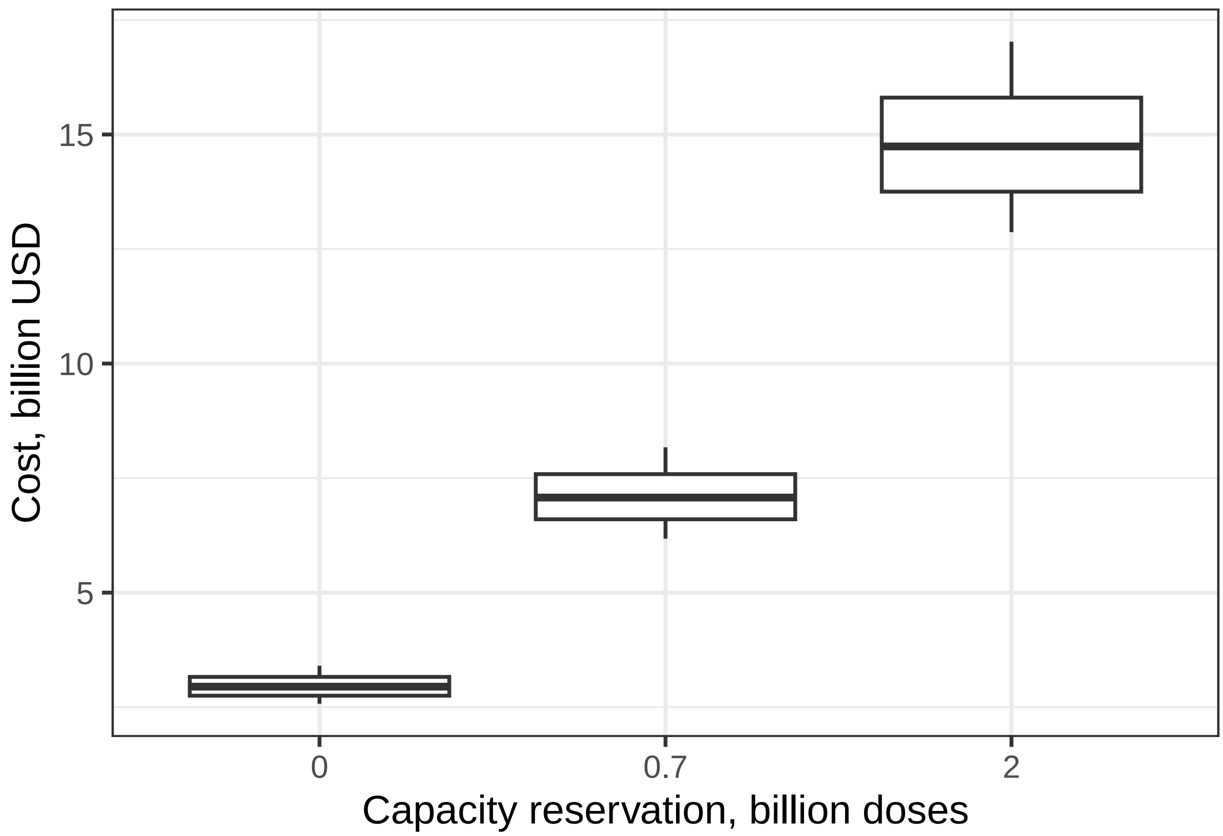


Figure 3: Capacity reservation costs accumulated over 15 years with uniformly distributed discount rate.

2.4 Enabling activities

Denote the "Days Mission" by ζ, so that $\zeta \in \{365, 200, 100\}$. Then annual costs, $E = 700$ million, accumulate depending on the year and the mission:

$$D_{s,y}^{(\mathrm{en})} = \begin{cases} E & \zeta(s) = 200 \ \& \ y \leq 5 \mid \zeta(s) = 100 \ \& \ y \leq 15 \\ 0 & \zeta(s) = 365 \mid y > 15 \mid \zeta(s) = 200 \ \& \ y \ > \ 5 \end{cases} \tag{5}$$

For our scenarios, we have

$$\zeta(s) = \begin{cases} 365 & s \in \{0, 1, 2, 3, 4, 5, 12\} \\ 200 & s \in \{6, 7, 8\} \\ 100 & s \in \{9, 10, 11\} \end{cases} \tag{6}$$

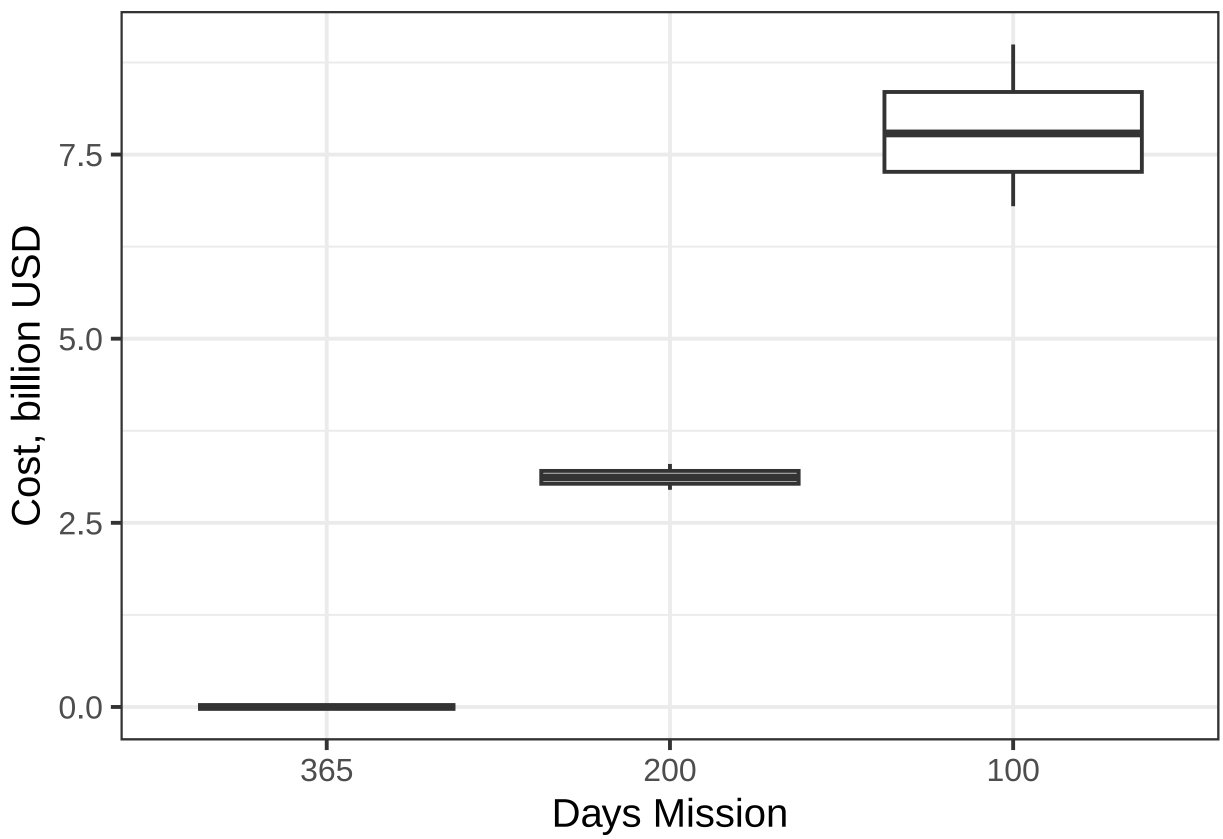


Figure 4: Enabling costs accumulated over 15 years with uniformly distributed discount rate.

3 Response cost equation

(BPSV R&D + SARS-X R&D + BPSV Procurement + SARS-X Procurement + BPSV Delivery + SARS-X Delivery) / (1 + discount rate) ˆ (year − 2025)

$$D_y^{(\mathrm{res})} = \frac{1}{(1+r)^y} \left(D_s^{(\text{BP-resRD})} + D_s^{(\text{S-RD})} + D_s^{(\text{BP-proc})} + D_s^{(\text{S-proc})} + D_s^{(\text{BP-del})} + D^{(\text{S-del})} \right)$$

- $D_s^{(\text{BP-resRD})}$ is the R&D cost of BPSV after an outbreak; see Equation (8)
- $D_s^{(\text{S-RD})}$ is the R&D cost for SSV; see Equation (7)
- $D_s^{(\text{BP-proc})}$ is the cost of procuring BPSV; see Equation (10)
- $D_s^{(\text{S-proc})}$ is the cost of procuring SSV; see Equation (9)
- $D_s^{(\text{BP-del})}$ is the cost of delivering BPSV; see Equation (12)
- $D^{(\text{S-del})}$ is the cost of delivering SSV; see Equation (11)

3.1 Risk-adjusted R&D cost per candidate calculation

Sum of the cost of each phase multiplied by the likelihood of phase occurrence (probability of success for previous phases)

Probability of Occurrence (PoO) = 1 * PoS (PhaseN-1) . . .

$ (Preclin) * PoO (Preclin) + $ (Ph1) * PoO (Ph1) + $ (Ph2) * PoO (Ph2) + $ (Ph3) * PoO (Ph3) + $ (License) * PoO (License)

3.1.1 SSV

Trial costs are adjusted for the duration of the trial, which depend on the R&D investment, denoted $\zeta \in \{365, 200, 100\}$:

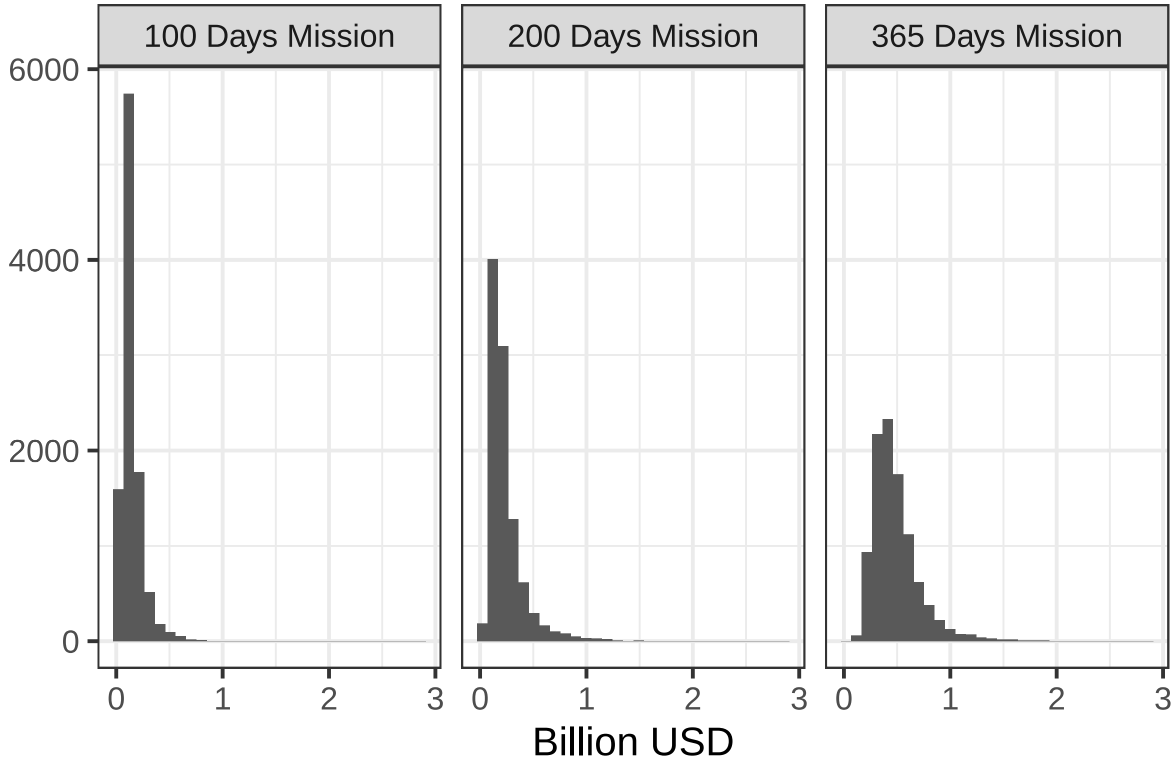
$$T_{\zeta,i} = \frac{W_{i;\zeta}^{(S)}}{W_{i;365}^{(S)}} T_i.$$

Then the total cost is

$$D_s^{(\text{S-RD})} = N^{(\text{SSV})} \left(\sum_{i=0}^{3} \hat{P}_i T_{\zeta(s),i} + (1+I)\hat{P}_L L \right) \tag{7}$$

where I is inflation from 2018 to 2025.

We multiply by the number of candidates, $N^{(\text{SSV})} = 18$, to get the total cost from the weighted average per candidate.



365 Days Mission Min. 1st Qu. Median Mean 3rd Qu. Max. 0.05 0.18 0.24 0.27 0.33 1.99

200 Days Mission Min. 1st Qu. Median Mean 3rd Qu. Max. 0.01 0.07 0.10 0.13 0.16 1.74

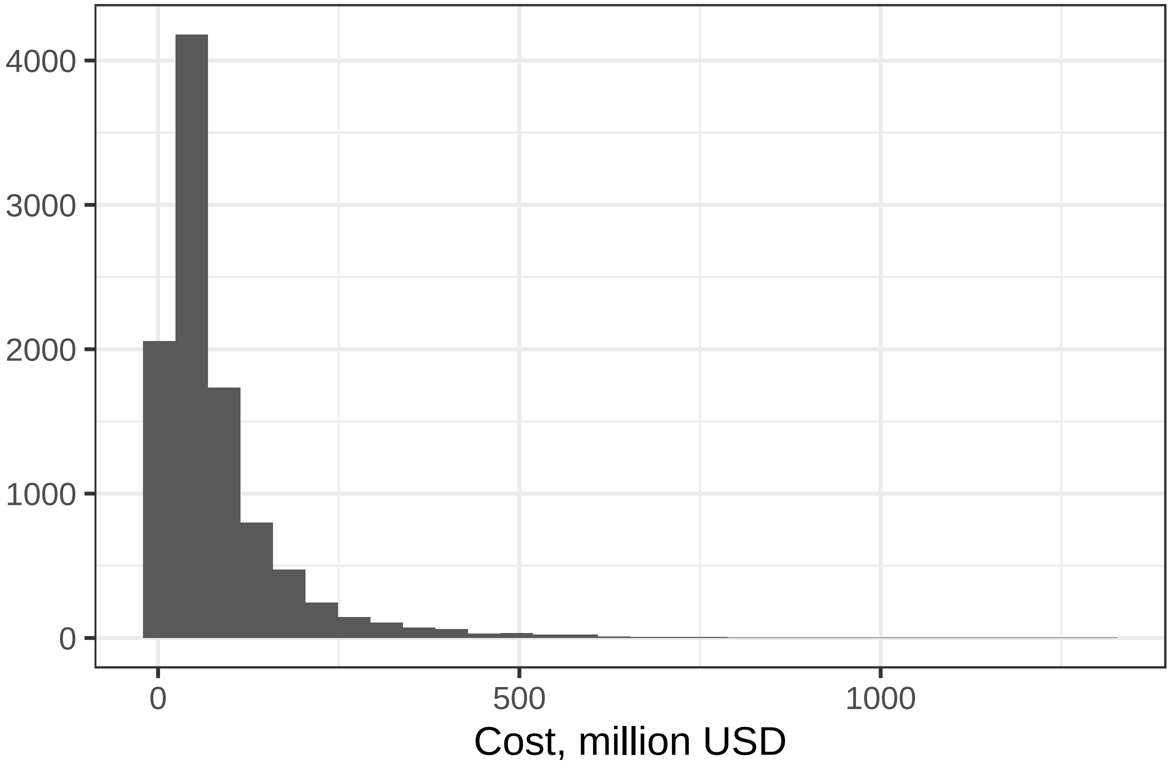
100 Days Mission Min. 1st Qu. Median Mean 3rd Qu. Max. 0.01 0.04 0.07 0.08 0.10 0.93

3.1.2 BPSV

I have basically assumed the same as SSV except for the numbers given (8 candidates and 18 weeks)

The BPSV has $N^{(\text{BPSV})} = 8$ candidates. Those that have passed through Phases 0 to 2 prior to the outbreak go through Phase 3 during the response. The duration is $Y_3^{(B)} = 18$ weeks. Thus we write the BPSV R&D response cost

$$D_s^{(\text{BP-resRD})} = \begin{cases} N^{(\text{BPSV})}\hat{P}_3\left(\frac{18}{W_{3;365}^{(S)}}\left(\omega T_3^{(n)} + (1-\omega)T_3^{(e)}\right) + (1+I)P_3L\right) & s \in \{1,2,3\} \\ 0 & s \notin \{1,2,3\} \end{cases} \tag{8}$$



Min. 1st Qu. Median Mean 3rd Qu. Max. 1 15 29 46 55 907

3.2 Procurement cost calculation

Scenario 1: Annual demand under 6.6B

Annual demand * $6.29 * 1.14 * 1.2

Scenario 2: Annual demand over 6.6B

Annual demand * $18.94

3.2.1 SSV

If we write annual demand in billions as $A_{\cdot,s,y}$, then we would have costs, in billion USD, of:

$$D_s^{\text{(S-proc)}} = \min A_{SSV,s,y}, M_C \cdot S_R \cdot (1 + M_p) \cdot (1 + M_f) + \max A_{SSV,s,y} - M_C, 0 \cdot S_U \tag{9}$$

Here, S_R is the cost per reserved dose and S_U the cost per unreserved dose. Reserved doses are marked up by M_p and M_f.

The total number of doses produced in week w in scenario s is $Z_{T,s,w}$ (see Equation (16)). The total in a one-year period is

$$A_{SSV,s,y} = \sum_{w \in y} Z_{T,s,w}.$$

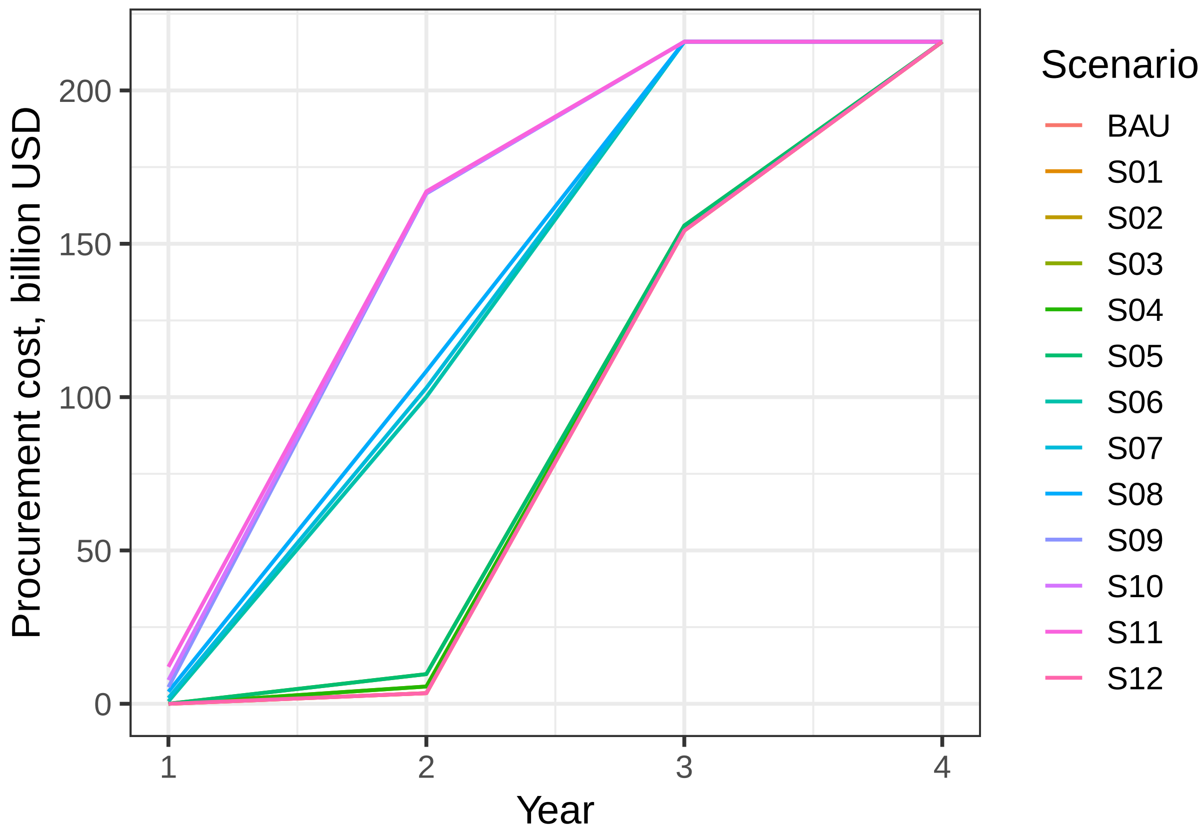


Figure 5: SSV procurement cost

3.2.2 BPSV

$$D_s^{(\text{BP-proc})} = \begin{cases} A_{BPSV,s} \cdot G & s \in \{1,2,3\} \\ 0 & s \notin \{1,2,3\} \end{cases} \tag{10}$$

For a world population aged 65 and over of 0.8 billion, and a cost per dose of 4.68 USD, and uptake of 80%, the procurement cost for BPSV is 3.02 billion USD.

Min. 1st Qu. Median Mean 3rd Qu. Max. 1.26 1.45 1.68 1.70 1.93 2.24

3.3 Delivery Cost Equation

WB status demand/0.8 * 0.1 * (0-10% cost) + WB status demand/0.8 * 0.2 * (11-30% cost) + WB status demand/0.8 * 0.5 * (30-80% cost)

3.3.1 SSV

For populations aged 15 and above $N_i^{(15)}$ in income group $i \in$ {LIC, LMIC, UMIC, HIC}, and delivery cost D:

$$D^{(\text{S-del})} = \sum_i N_i^{(15)} \left(\frac{1}{8} V_{i;0} + \frac{2}{8} V_{i;11} + \frac{5}{8} V_{i;31} \right) \tag{11}$$

We set

$$V_{LLMIC;j} = \frac{1}{N_{LMIC}^{(15)} + N_{LIC}^{(15)}} \left(N_{LMIC}^{(15)} V_{LMIC;j} + N_{LIC}^{(15)} V_{LIC;j} \right)$$

3.3.2 BPSV

For the BPSV, which goes only to people aged 65 or older, with populations $N_i^{(65)}$, coverage is reached earlier in the process, so the cost is weighted more heavily towards start up and ramp up:

$$D_s^{(\text{BP-del})} = \begin{cases} \sum_i D_{\text{BPSV},i} & s \in \{1,2,3\} \\ 0 & s \notin \{1,2,3\} \end{cases} \tag{12}$$

$$D_{\text{BPSV},i} = \begin{cases} N_i^{(65)} V_{i;0} & N_i^{(65)} \leq \frac{1}{10} N_i^{(15)} \\ \frac{N_i^{(15)}}{10} V_{i;0} + \left(N_i^{(65)} - \frac{N_i^{(15)}}{10} \right) V_{i;11} & \frac{1}{10} N_i^{(15)} \leq N_i^{(65)} \leq \frac{3}{10} N_i^{(15)} \\ \frac{N_i^{(15)}}{10} V_{i;0} + \frac{2}{10} N_i^{(15)} V_{i;11} + \left(N_i^{(65)} - \frac{3}{10} N_i^{(15)} \right) V_{i;31} & N_i^{(65)} > \frac{3}{10} N_i^{(15)} \end{cases} \tag{13}$$

The logic of this is as follows:

- The increments in cost correspond to numbers of eligible people in the whole population, namely those aged 15 and above.
- If the number of people eligible for the BPSV is less than 10% of the population aged 15 and over, then all doses cost the “start up” amount.

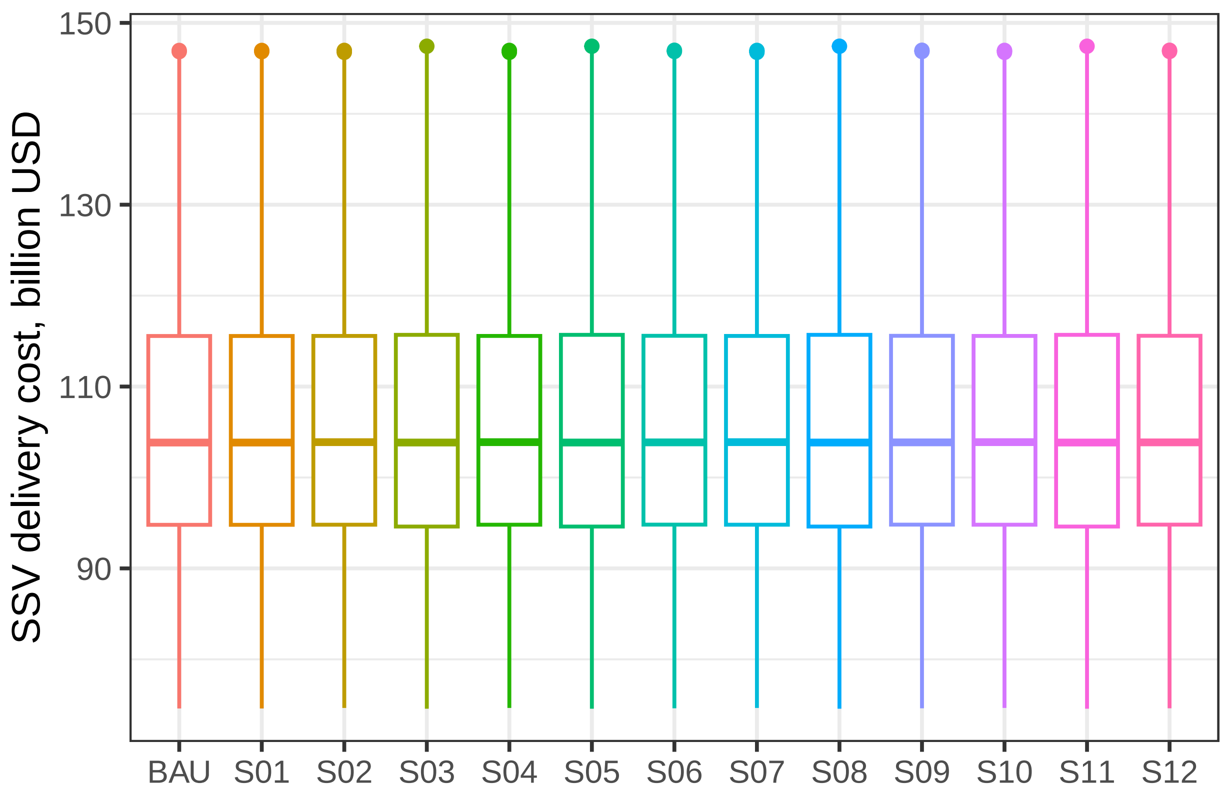
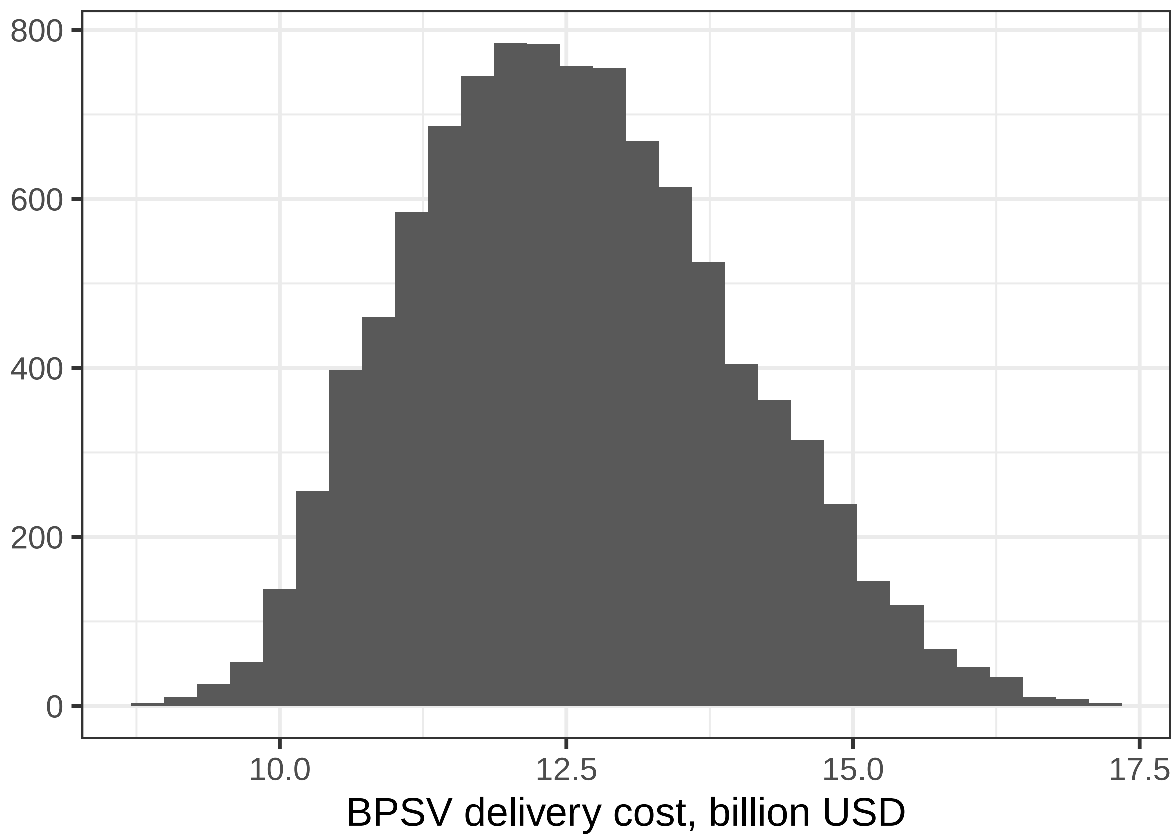


Figure 6: SSV delivery cost

- If the number of people eligible for the BPSV is more than 10% and less than 30% of the 15+ population, then cost of the first doses, a number equal to 10% of the 15+ population, is the "start up" amount. All remaining doses cost the "ramp up" amount.
- If the number of people eligible for the BPSV is more than 30% of the 15+ population, then the cost of the first doses, a number equal to 10% of the 15+ population, is the "start up" amount. The cost of the second tranche of doses, a number equal to 20% of the 15+ population, is the "ramp up" amount. All remaining doses cost the "getting to scale" amount.



Min. 1st Qu. Median Mean 3rd Qu. Max. 3.89 5.98 6.94 7.08 8.05 12.09

Table 2: Literature review of global and country-specific delivery costs

Country	Country status	Study type	Financial Cost per dose (USD)	Source
WHO, Gavi, and UNICEF AMC Estimate	AMC	Top down	1.66	Griffiths et al. [2021]
UNICEF Global Estimate	All	Model	0.73	Oyatoye [2023]
DRC	LIC	Bottom up	1.91	Moi et al. [2024]
Malawi	LIC	Bottom up	4.55	Ruisch et al. [2025]
Mozambique	LIC	Bottom up	0.5	Namalela et al. [2025]
Uganda	LIC	Bottom up	0.79	Tumusiime et al. [2024]

Country	Country status	Study type	Financial Cost per dose (USD)	Source
Bangladesh	LMIC	Bottom up	0.29	Yesmin et al. [2024]
Cote d'Ivoire	LMIC	Bottom up	0.67	Vaughan et al. [2023]
Nigeria	LMIC	Bottom up	0.84	Noh et al. [2024]
Philippines	LMIC	Bottom up	2.16	Banks et al. [2023]
Vietnam	LMIC	Bottom up	1.73	Nguyen et al. [2024]
Ghana	LMIC	CVIC tool	2.2–2.3	Nonvignon et al. [2022]
Lao PDR	LMIC	CVIC tool	0.79–0.81	Yeung et al. [2023]
Kenya	LMIC	Top down	3.29–4.28	Orangi et al. [2022]
Botswana	UMIC	Mixed	19	Vaughan et al. [2025]
South Africa	UMIC	Top down	3.84	Edoka et al. [2024]

4 SSV delivery

Table 3: Manufacturing response timeline assumptions

Category	Reserved capacity	Private response (existing capacity)	Private response (built capacity)
Annual manufacturing volume	By scenario (0.5–2.5B)	2.5B minus reserved volume	6B
Facility transition start	7 weeks before vaccine approval	7 weeks before vaccine approval	7 weeks before vaccine approval
Weeks to initial manufacturing	12	30	48
Scale-up weeks to full capacity	10	16	16

Table 4: Vaccine Production Timeline

Weeks from transition start	Reserved Capacity (%)	Private Capacity (Existing; %)	Private Capacity (Response; %)
0–11			
12–21	Scaling from 0-100		
22–29	100		
30–45	100	Scaling from 0-100	
46–47	100	100	
48–63	100	100	Scaling from 0-100
64+	100	100	100

4.1 Timing

Facility transition occurs $F = 7$ weeks before vaccine approval, which in turn depends on R&D investments. We have three levels in our scenarios, corresponding to a 100 Days Mission, 200 days, and 365 days. The total weeks taken for vaccine approval can be written as follows:

$$W_j^{(S)} = \sum_{i=0}^{3} W_{i;j}^{(S)}$$

for $j \in$
$365, 200, 100$. These work out as 68, 27, and 13 weeks, respectively. Thus "week 0" for manufacturing occurs 61, 20, and 6 weeks, respectively, after the new pathogen has been sequenced. We denote this variable $w_s^{(0)}$.

4.2 Production

The total global manufacturing volume is $M_G = 15$ billion doses. The amount that is reserved, in billion doses, including the HIC-specific reservation of $A_3 = 0.5$ billion doses, depends on the scenarios as follows:

$$M_{R,s} = \begin{cases} A_3 & s \in \{0, 1, 6, 9, 12\} \\ A_3 + 0.7 & s \in \{2, 4, 7, 10\} \\ A_3 + 2 & s \in \{3, 5, 8, 11\} \end{cases} \tag{14}$$

where $s = 0$ denotes the BAU scenario. By definition, $M_{E,s} = M_C - M_{R,s}$, and $M_B = M_G - M_C$.

Then the number of doses, in billions, that are made from capacity $x \in$
R, E, B in week w of scenario s is:

$$Z_{x,s,w} = \begin{cases} 0 & w - w_s^{(0)} < I_x \\ \frac{1}{52} \frac{w - w_s^{(0)} - I_x + 1}{C_x} M_{x,s} & w - w_s^{(0)} \in [I_x, I_x + C_x) \\ \frac{1}{52} M_{x,s} & w - w_s^{(0)} \geq I_x + C_x \end{cases} \tag{15}$$

where $I_R = 12$ is the number of weeks to initial manufacturing for reserved capacity, $C_R = 10$ is the number of weeks to scale up to full capacity; $I_E = 30$ is the number of weeks to initial manufacturing for existing and unreserved capacity, $C_E = 16$ is the number of weeks to scale up to full capacity; $I_B = 48$ is the number of weeks to initial manufacturing for built and unreserved capacity, $C_B = 16$ is the number of weeks to scale up to full capacity.

Then the total number of doses produced in week w is

$$Z_{T,s,w} = Z_{R,s,w} + Z_{E,s,w} + Z_{B,s,w}. \tag{16}$$

In Figure 7, the following scenarios have identical supply (because they have the same capacity reservations and R&D investments): BAU & S01 & S12; S02 & S04; and S03 & S05.

4.3 Allocation

Denote the weekly allocated doses at week w from capacity x to income level $k_{s,x,i,w}$, and the cumulative number $K_{s,i,w}$, such that

$$K_{s,i,w} = \sum_{x \in R,E,B} \sum_{j=0}^{w} k_{s,x,i,j}.$$

We write $X_i = 2 \cdot \lambda \cdot N_i^{(15)}$ as the maximum demand for income group i, representing two doses each for $\lambda = 80\%$ of the population.

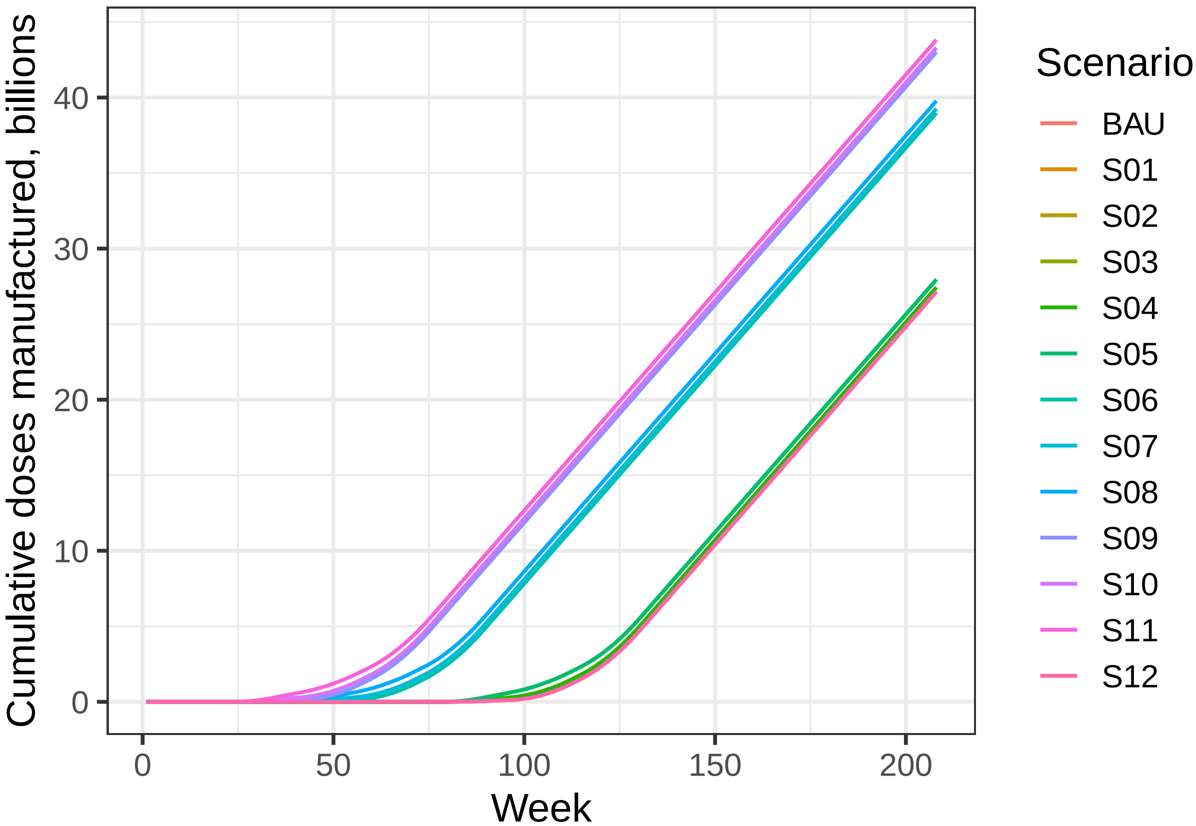


Figure 7: Doses made available from manufacturing per scenario. Weeks are in reference to the sequencing of the pathogen.

$$
k_{s,R,i,w} = \begin{cases} Z_{R,s,w} & K_{s,\text{HIC},w} < A_3 \ \& \ i = \text{HIC} \\ 0 & K_{s,\text{HIC},w} < A_3 \ \& \ i \neq \text{HIC} \\ \frac{N_i}{N_{HIC}+N_{UMIC}+N_{LLMIC}} Z_{R,s,w} & A_3 < K_{s,\text{HIC},w} < X_{\text{HIC}} \\ \frac{N_i}{N_{UMIC}+N_{LLMIC}} Z_{R,s,w} & K_{s,\text{HIC},w} \geq X_{\text{HIC}} \ \& \ K_{s,\text{UMIC},w} < X_{\text{HIC}} \ \& \ i \neq \text{HIC} \\ Z_{R,s,w} & K_{s,\text{UMIC},w} \geq X_{\text{UMIC}} \ \& \ i = \text{LLMIC} \end{cases} \tag{17}
$$

The logic of this reads as follows:

- The first $A_3 = 0.5$ billion doses from reserved capacity go exclusively to HIC
- None go to UMIC and LLMIC
- When HIC coverage is between 500 million and its total demand, reserved capacity doses are allocated according to population
- Once HIC reach their total demand, doses from reserved capacity are split proportional to population between UMIC and LLMIC
- Once UMIC reach their total demand, all doses from reserved capacity go to LLMIC

For $x \in$
E, B,

$$
k_{s,x,i,w} = \begin{cases} Z_{x,s,w} & K_{s,\text{HIC},w} < X_{\text{HIC}} \ \& \ i = \text{HIC} \\ 0 & K_{s,\text{HIC},w} < X_{\text{HIC}} \ \& \ i \neq \text{HIC} \\ Z_{x,s,w} & K_{s,\text{HIC},w} \geq X_{\text{HIC}} \ \& \ K_{s,\text{UMIC},w} < X_{\text{UMIC}} \ \& \ i = \text{UMIC} \\ 0 & K_{s,\text{HIC},w} \geq X_{\text{HIC}} \ \& \ K_{s,\text{UMIC},w} < X_{\text{UMIC}} \ \& \ i \neq \text{UMIC} \\ Z_{x,s,w} & K_{s,\text{UMIC},w} \geq X_{\text{UMIC}} \ \& \ i = \text{LLMIC} \\ 0 & K_{s,\text{UMIC},w} \geq X_{\text{UMIC}} \ \& \ i \neq \text{LLMIC} \end{cases} \tag{18}
$$

The logic of this reads as follows:

- Until HIC demand is reached, all doses from unreserved capacity go to HIC
- None go to UMIC and LLMIC
- Once HIC demand has been met and until UMIC demand is reached, all doses from unreserved capacity go to UMIC
- None go to HIC and LLMIC
- Once HIC and UMIC demand have been met, all remaining doses from unreserved capacity go to LLMIC
- None go to UMIC and HIC

4.4 Delivery

5 BPSV delivery

5.1 Timing

The duration of the Phase three trial is 18 weeks. **The time to manufacturing transition is 12 weeks, and the time to manufacturing scale-up 10 weeks; these are the same as the reserved-capacity times for SSV. Are these reservations included in the preparedness cost?**

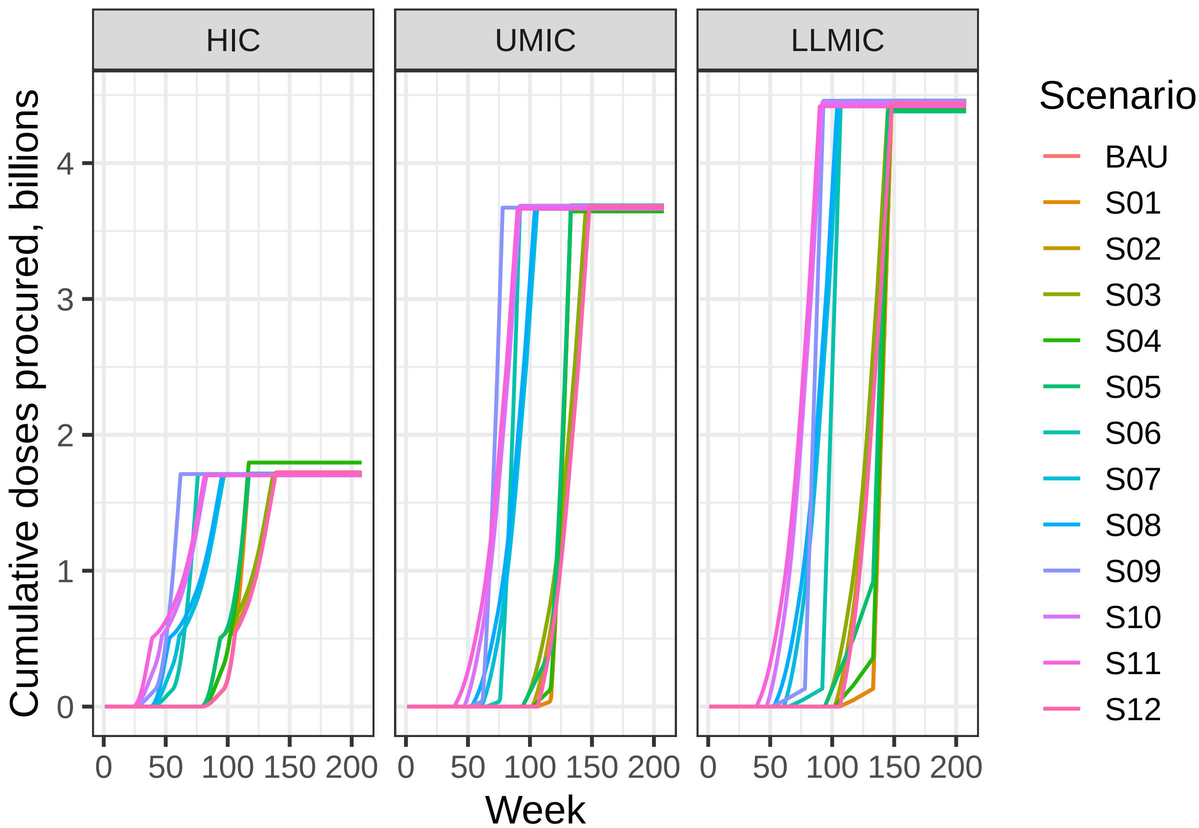


Figure 8: Doses procured by country income level

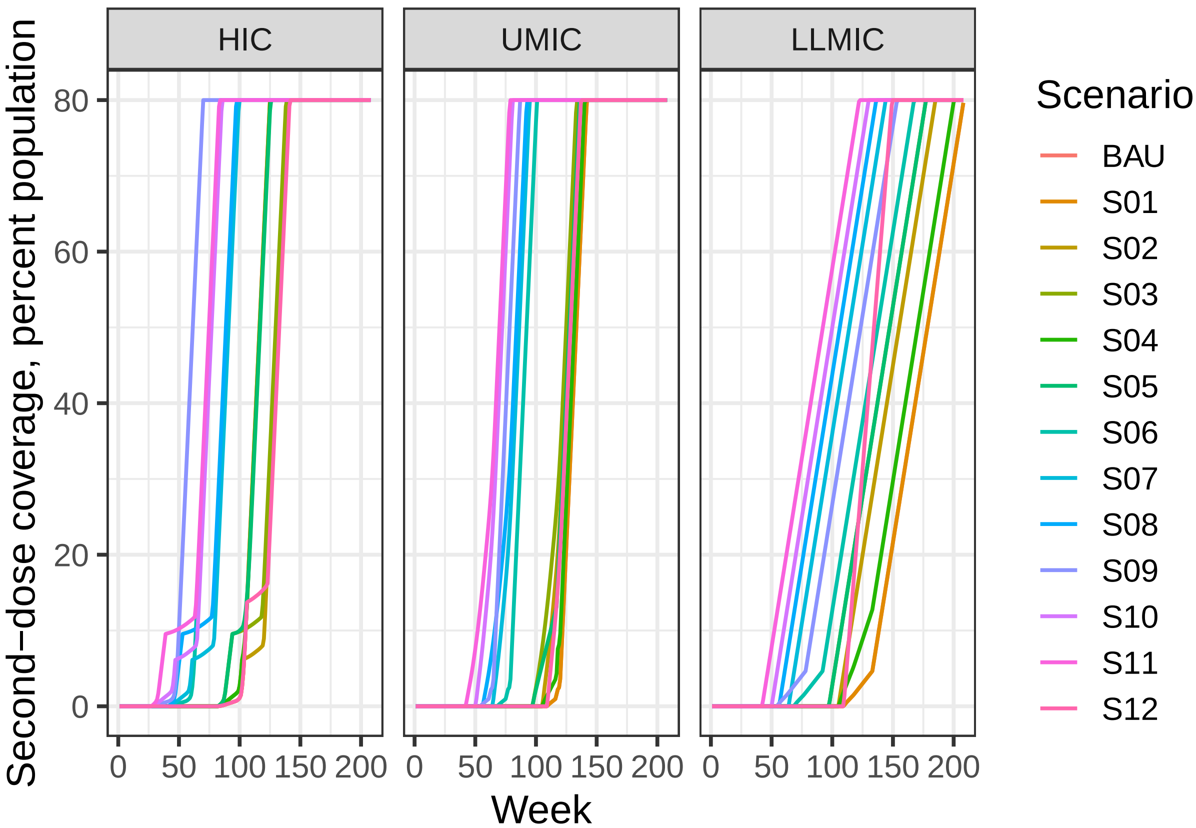
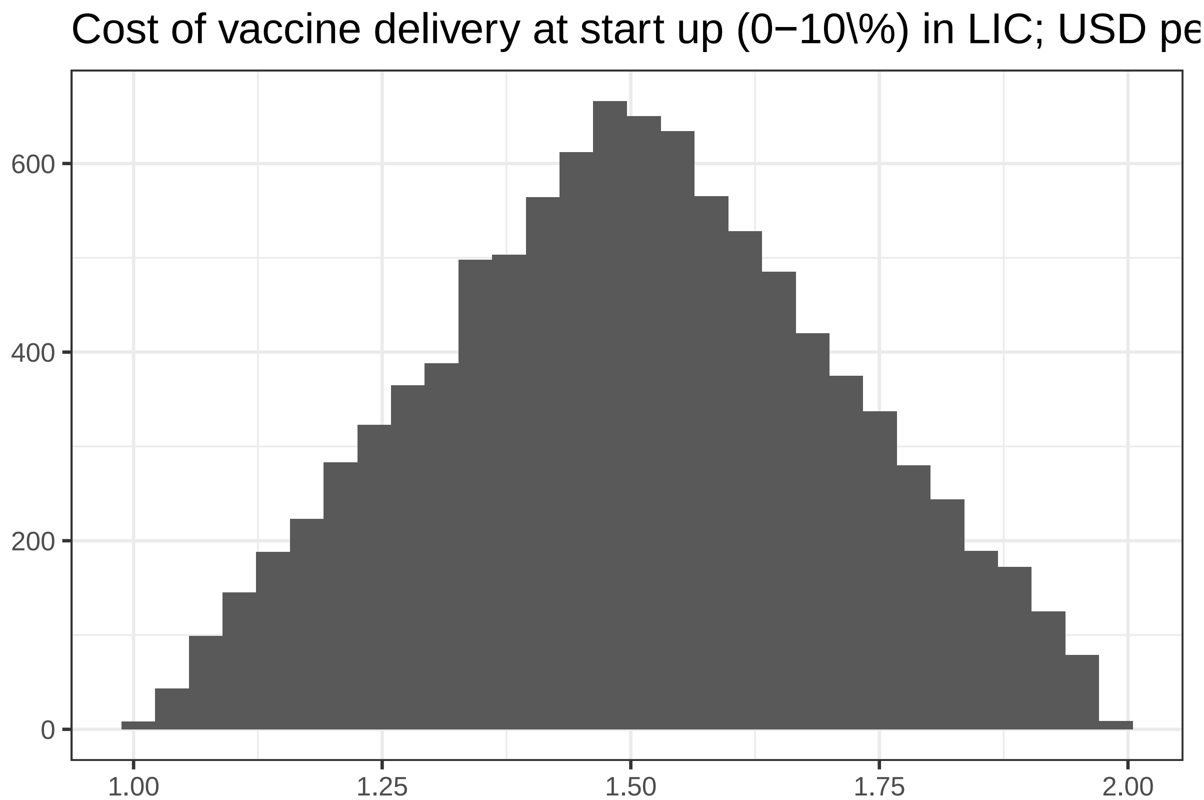
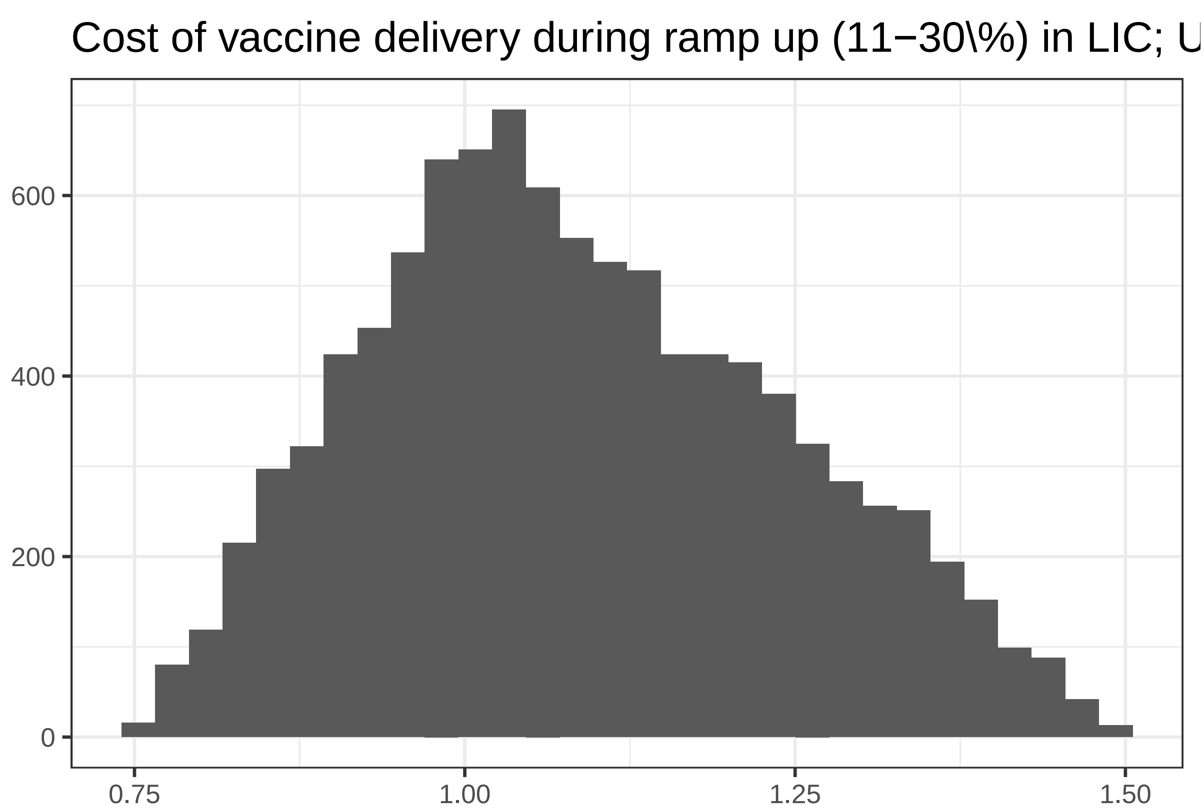
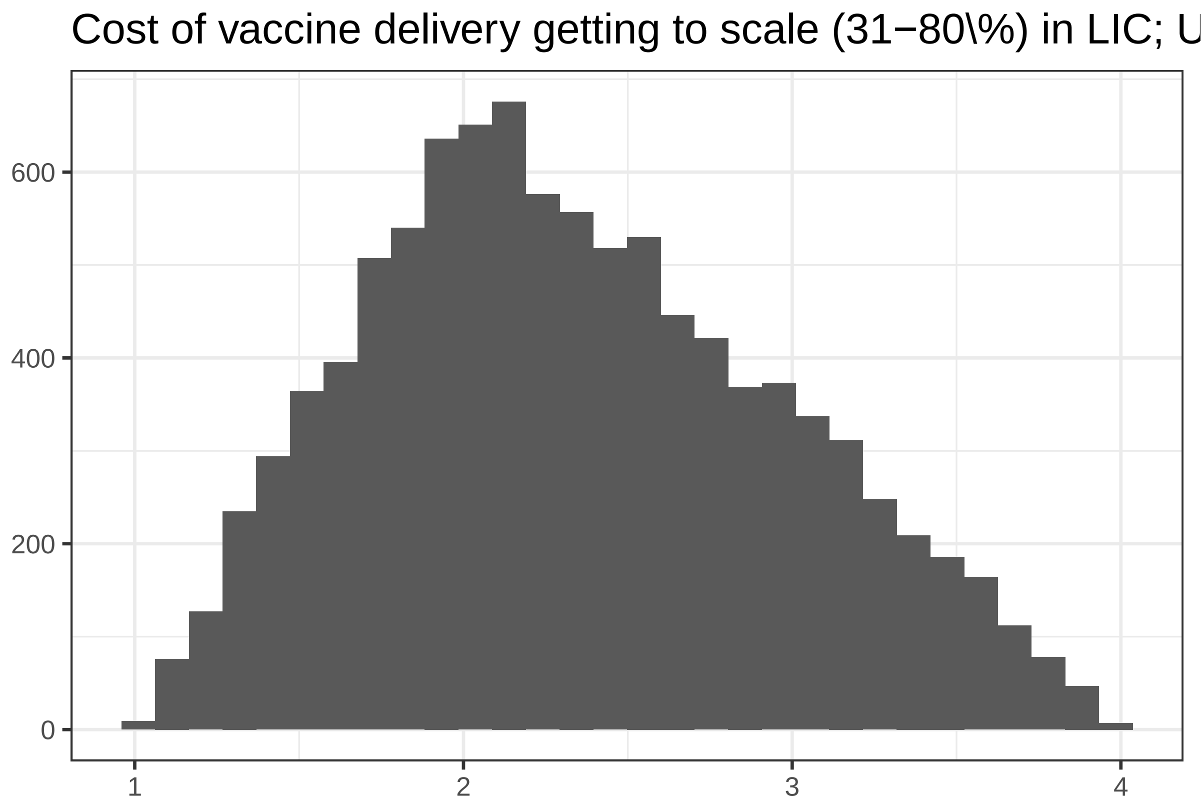


Figure 9: Cumulative vaccine coverage (second SSV dose) by country income level

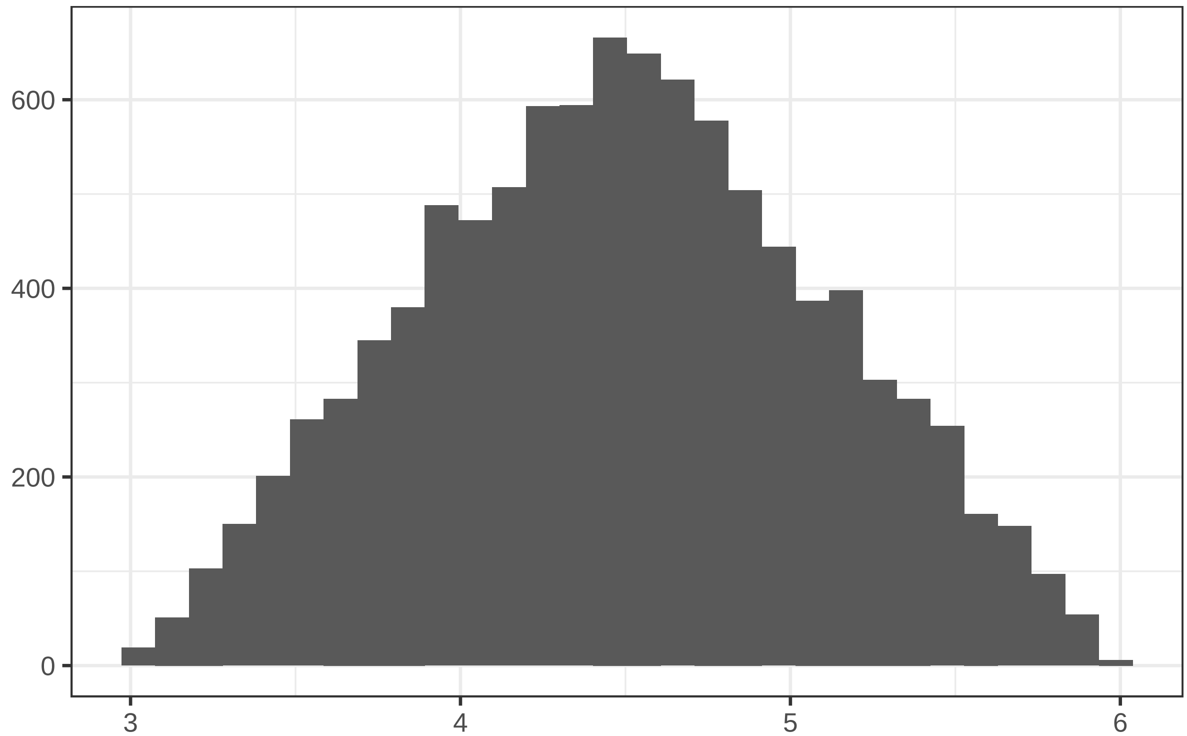
6 Parameter samples

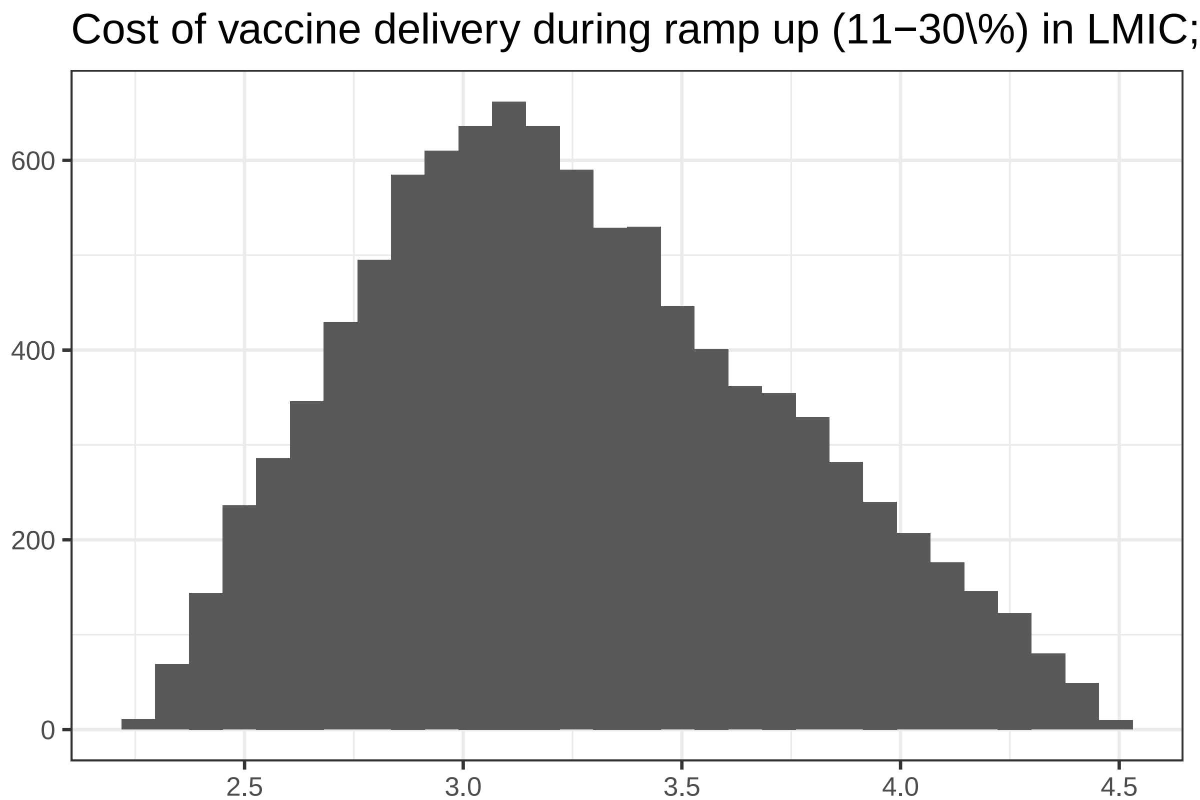


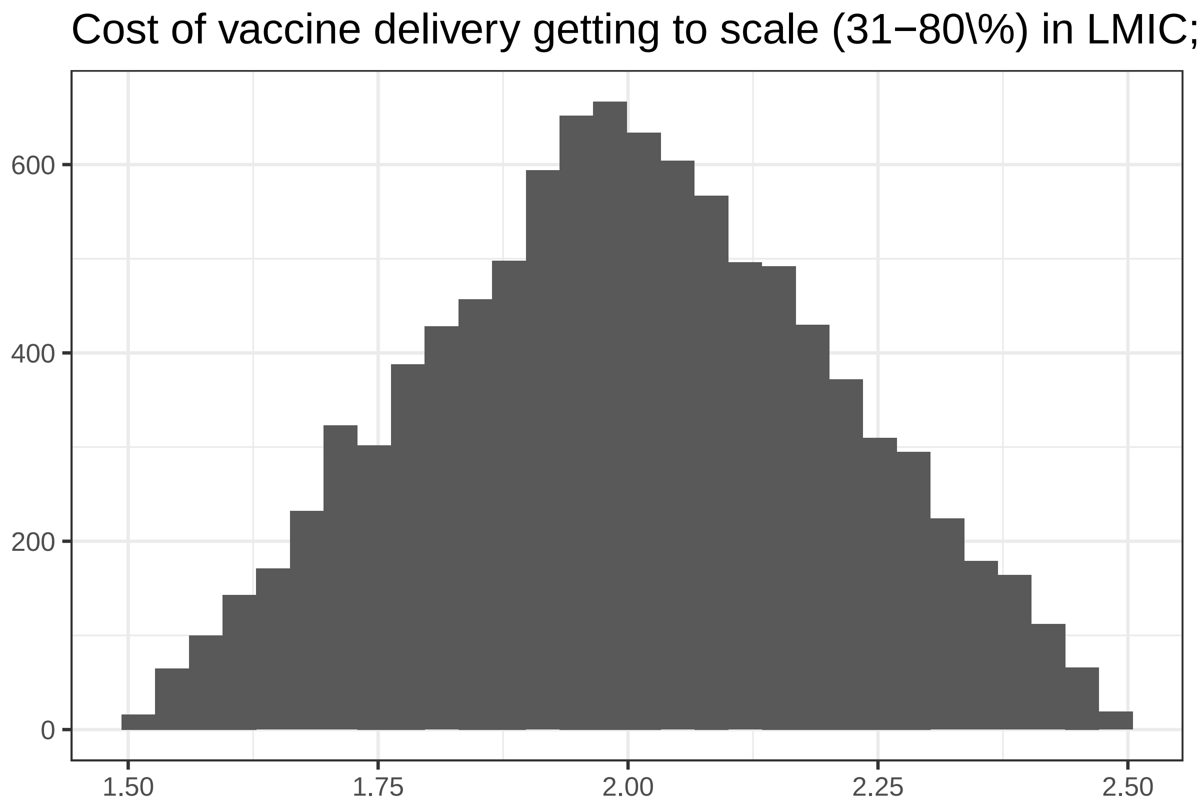


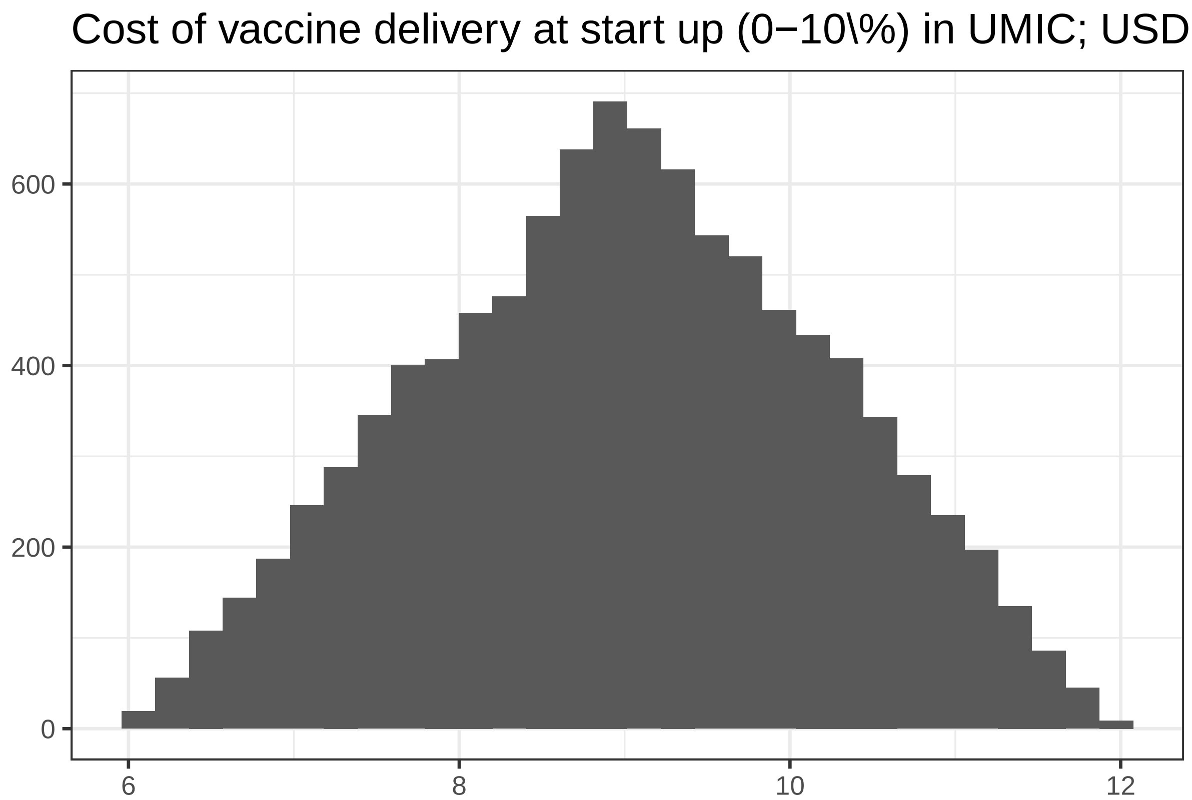

Cost of vaccine delivery getting to scale (31−80\%) in LIC; U
600
400
200
0
1
2
3
4

Cost of vaccine delivery at start up (0−10\%) in LMIC; USD |

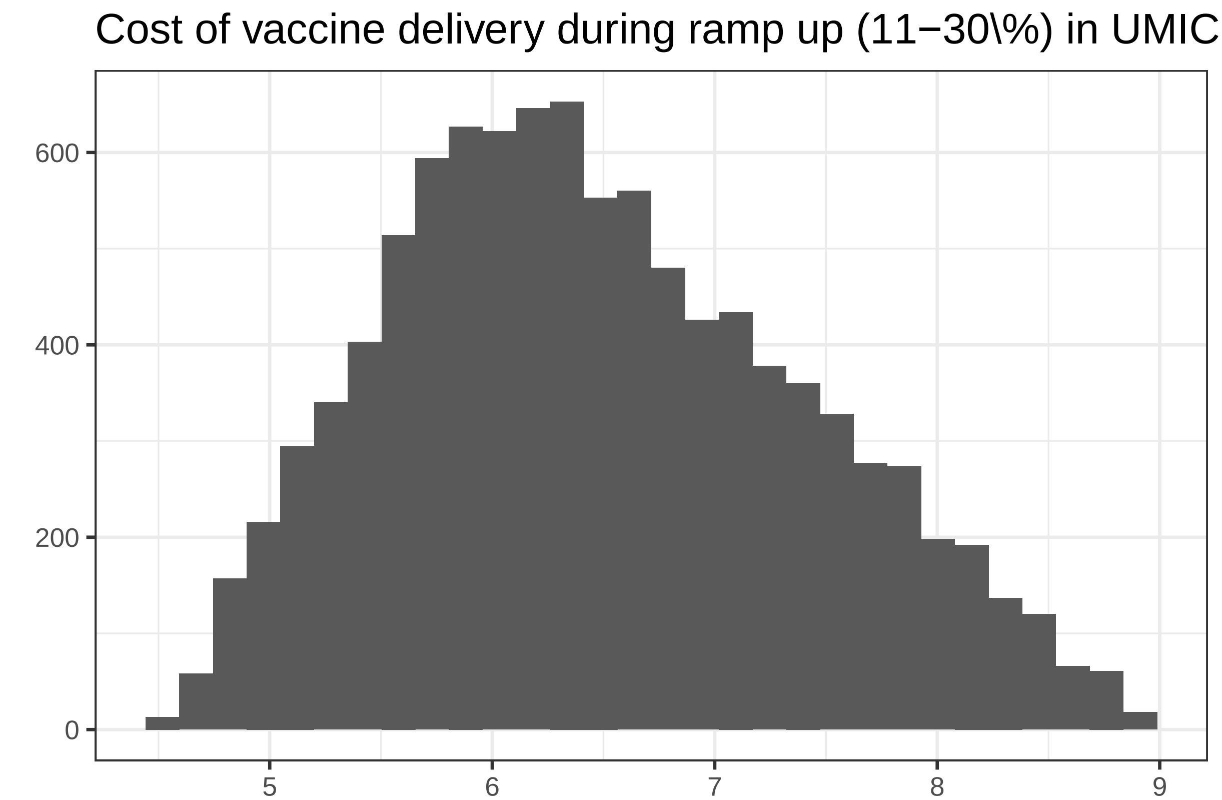


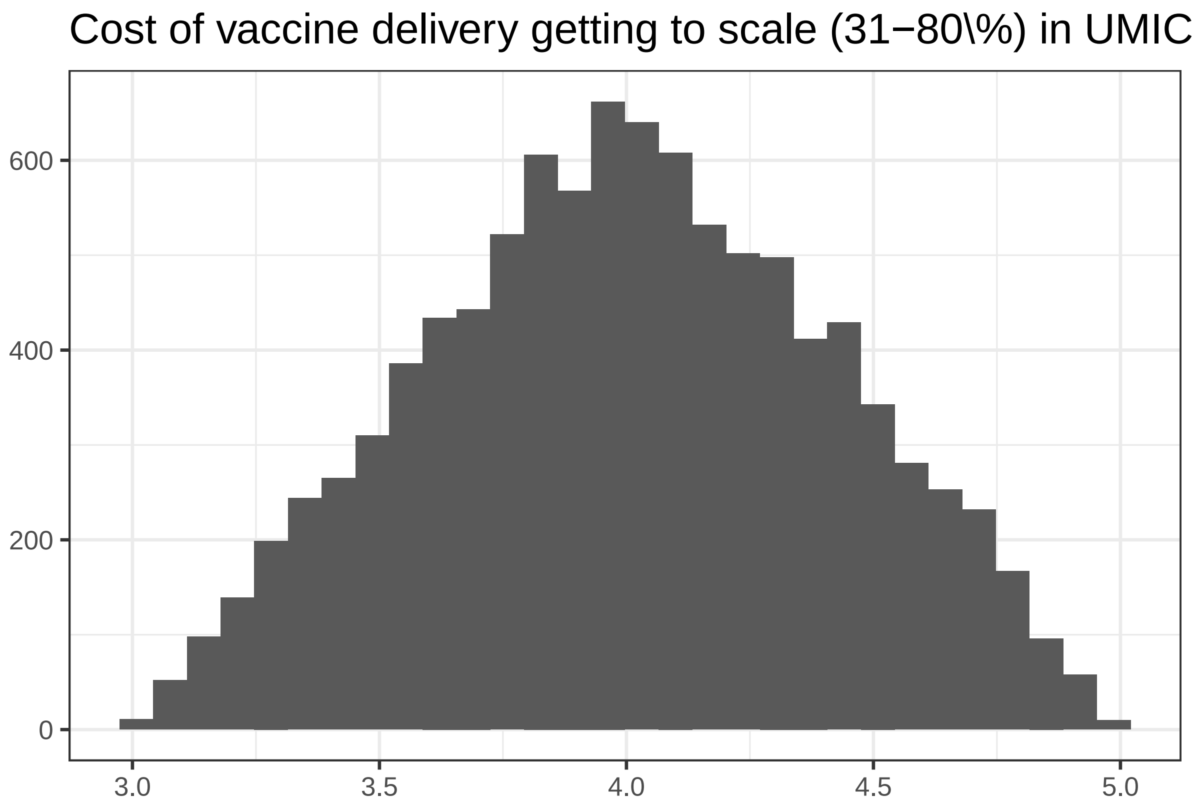

Cost of vaccine delivery during ramp up (11−30\%) in LMIC;
600
400
200
0
2.5
3.0
3.5
4.0
4.5


Cost of vaccine delivery getting to scale (31−80\%) in LMIC;
600
400
200
0
1.50
1.75
2.00
2.25
2.50

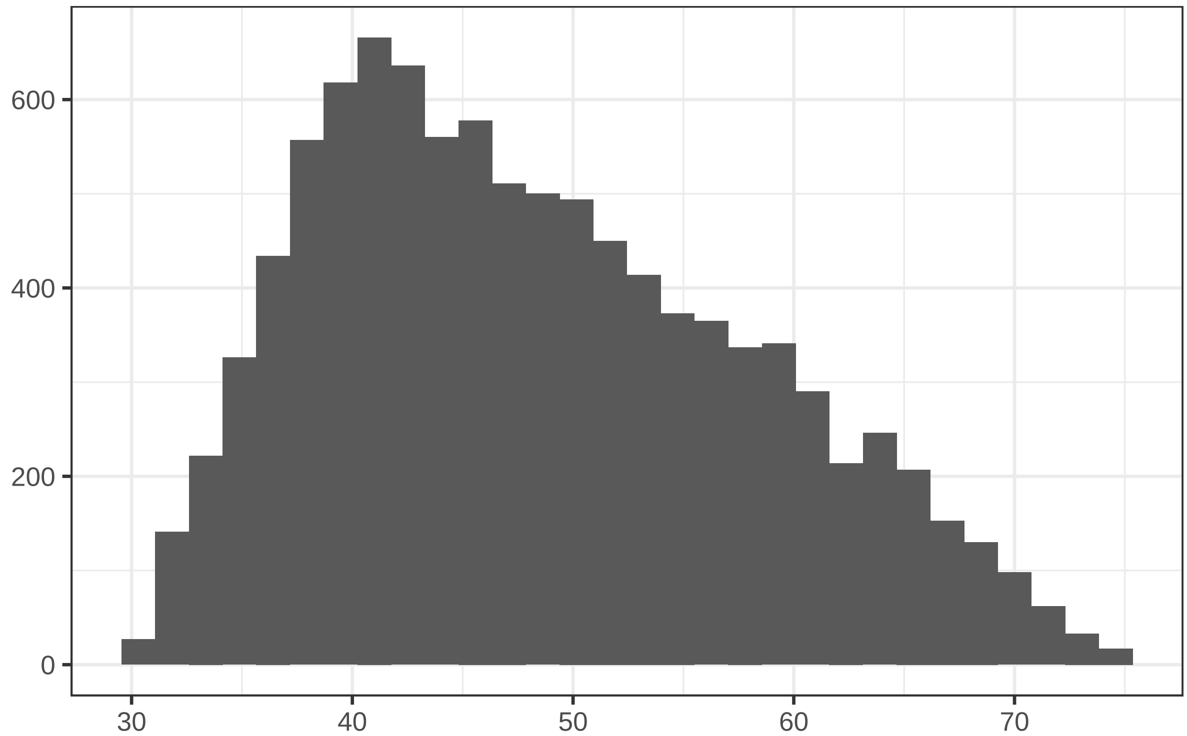


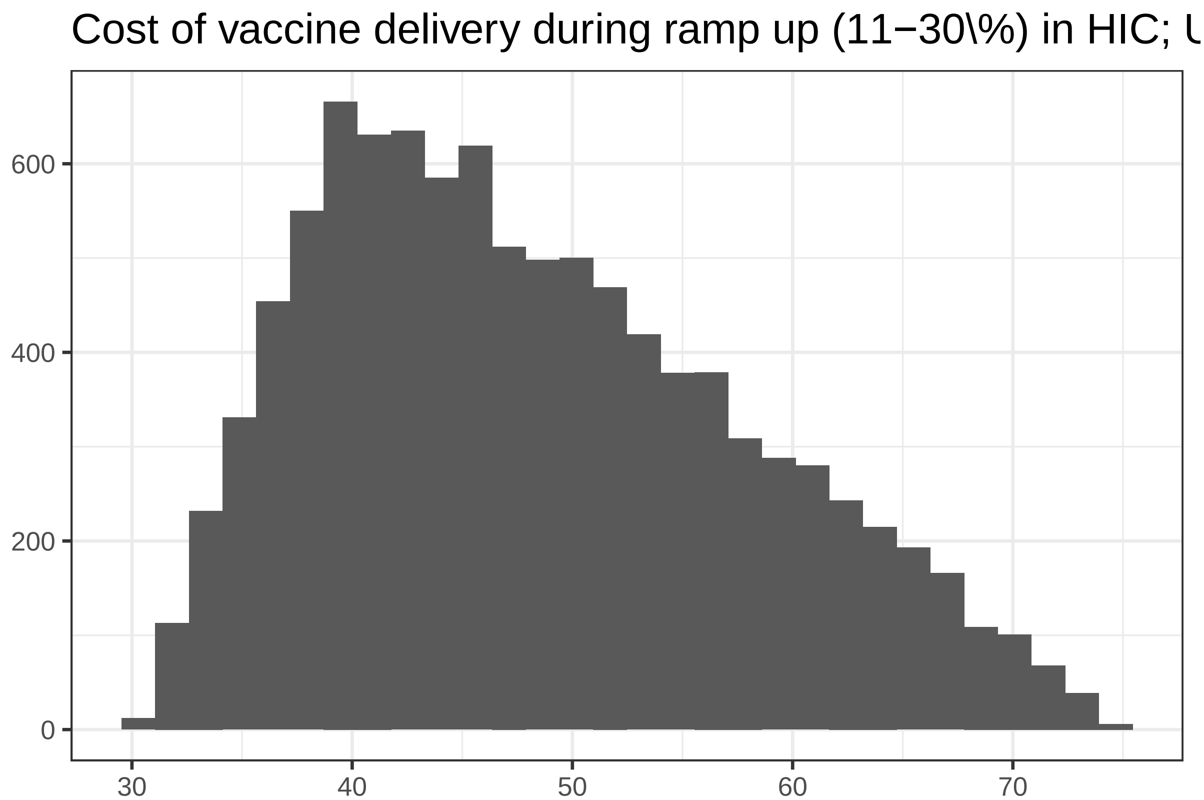
Cost of vaccine delivery at start up (0−10\%) in UMIC; USD
600
400
200
0
6
8
10
12

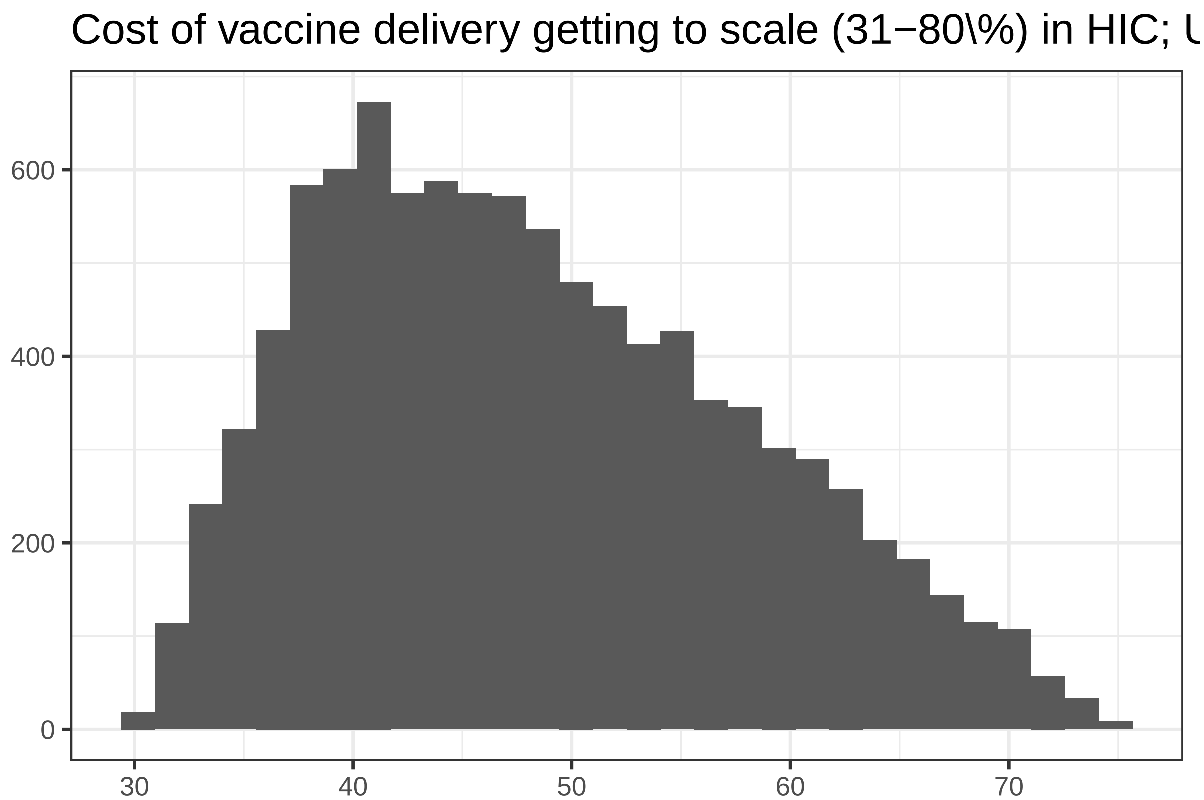

Cost of vaccine delivery during ramp up (11−30\%) in UMIC
600
400
200
0
5
6
7
8
9

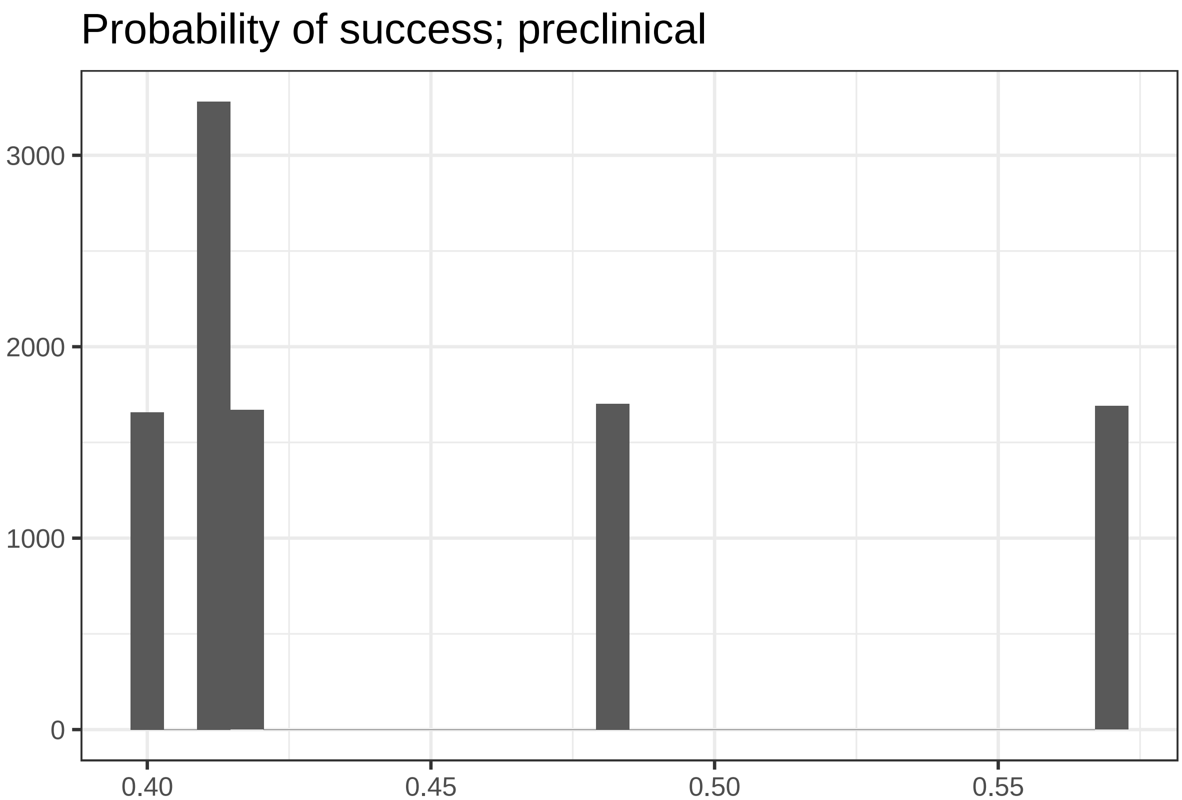

Cost of vaccine delivery getting to scale (31−80\%) in UMIC:
600
400
200
0
3.0
3.5
4.0
4.5
5.0

Cost of vaccine delivery at start up (0−10\%) in HIC; USD pe

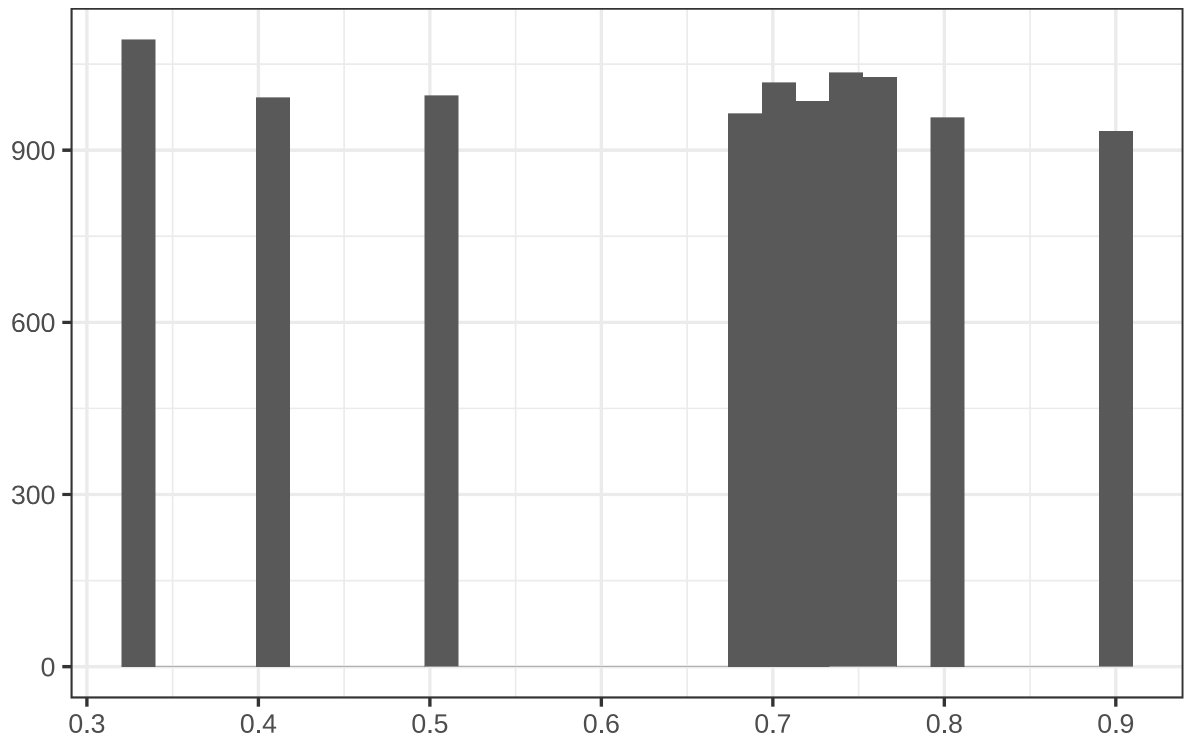


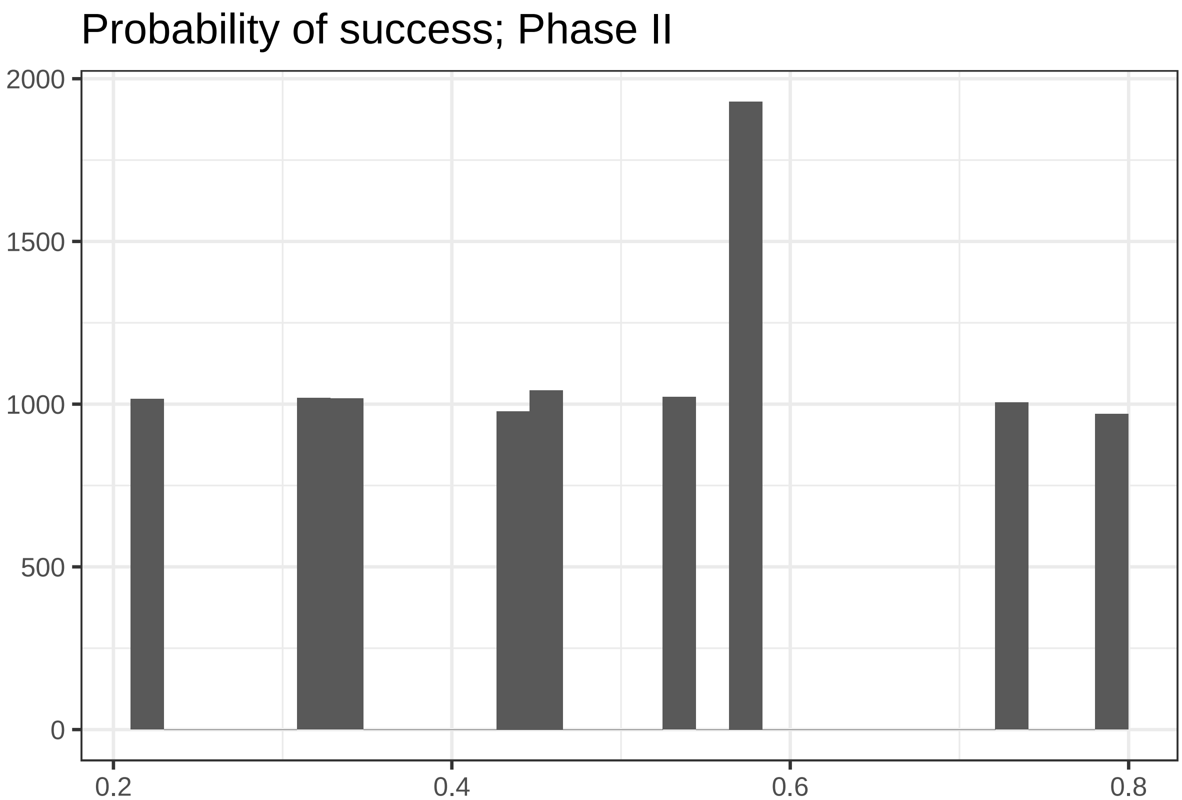

Cost of vaccine delivery during ramp up (11−30\%) in HIC; U
600
400
200
0
30
40
50
60
70

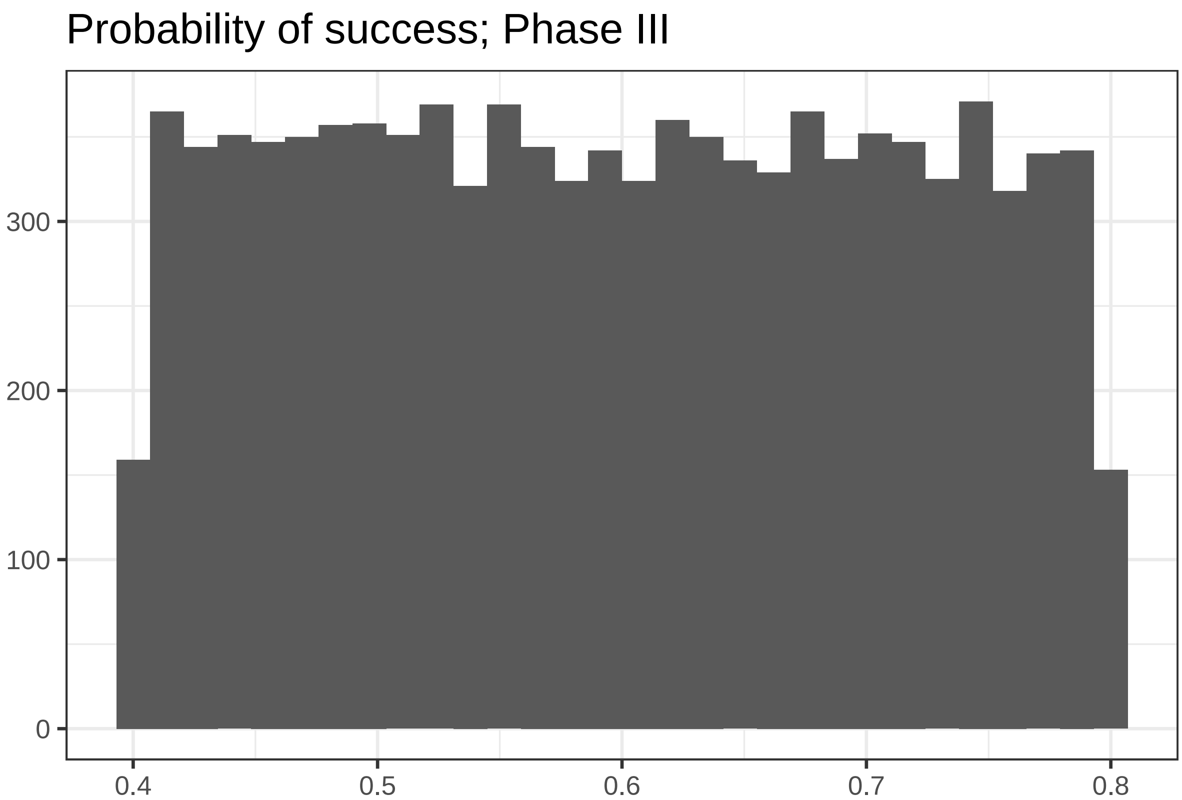

Cost of vaccine delivery getting to scale (31−80\%) in HIC; U
600
400
200
0
30
40
50
60
70


Probability of success; preclinical
3000
2000
1000
0
0.40
0.45
0.50
0.55

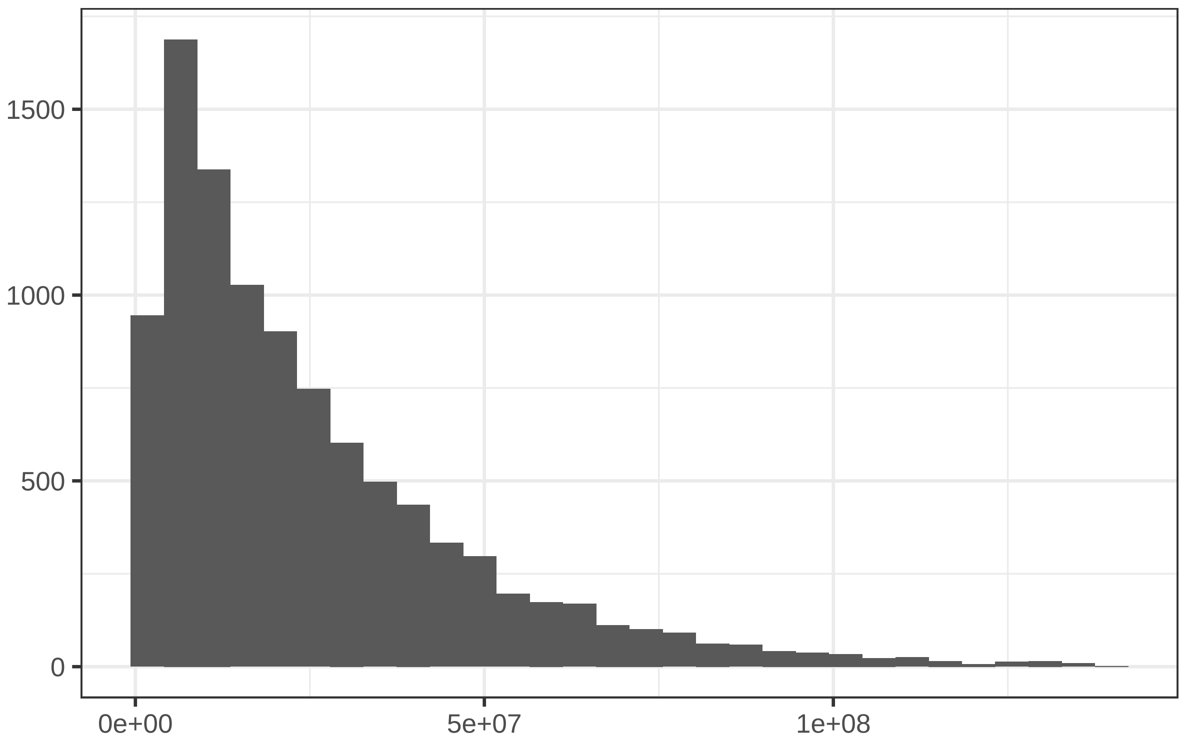
Probability of success; Phase I

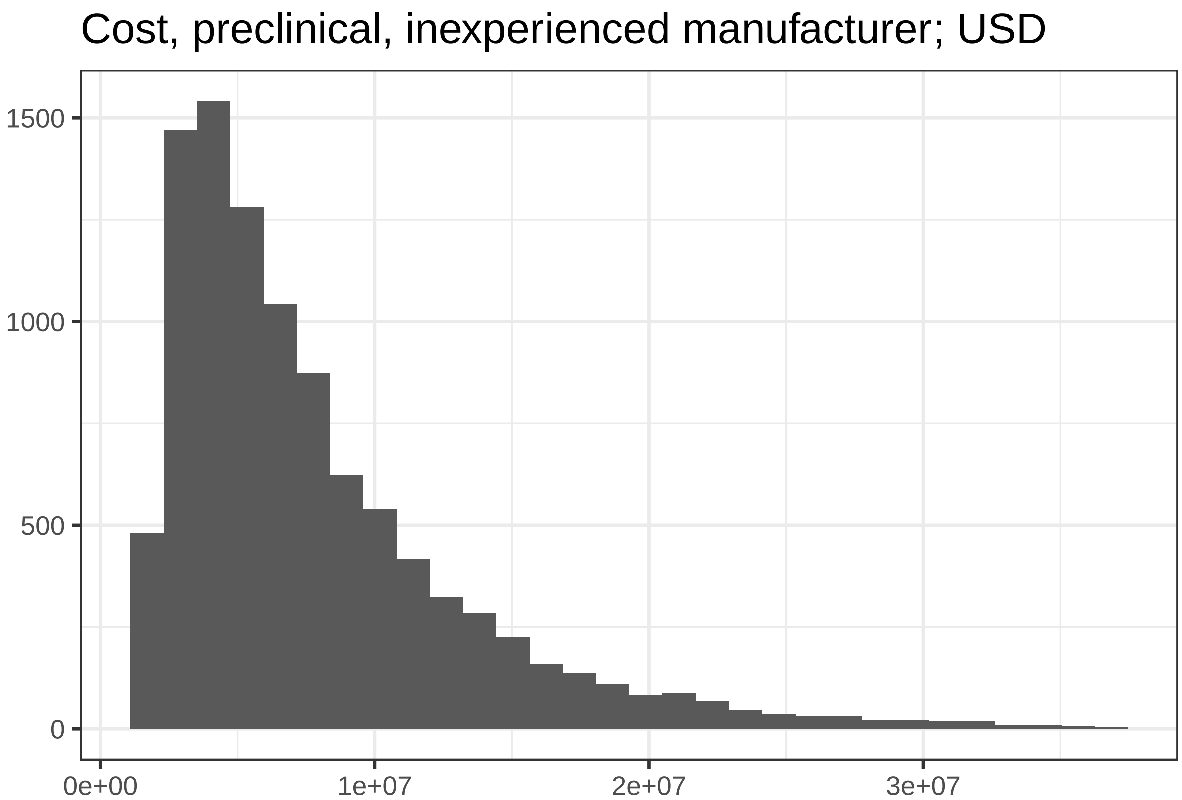


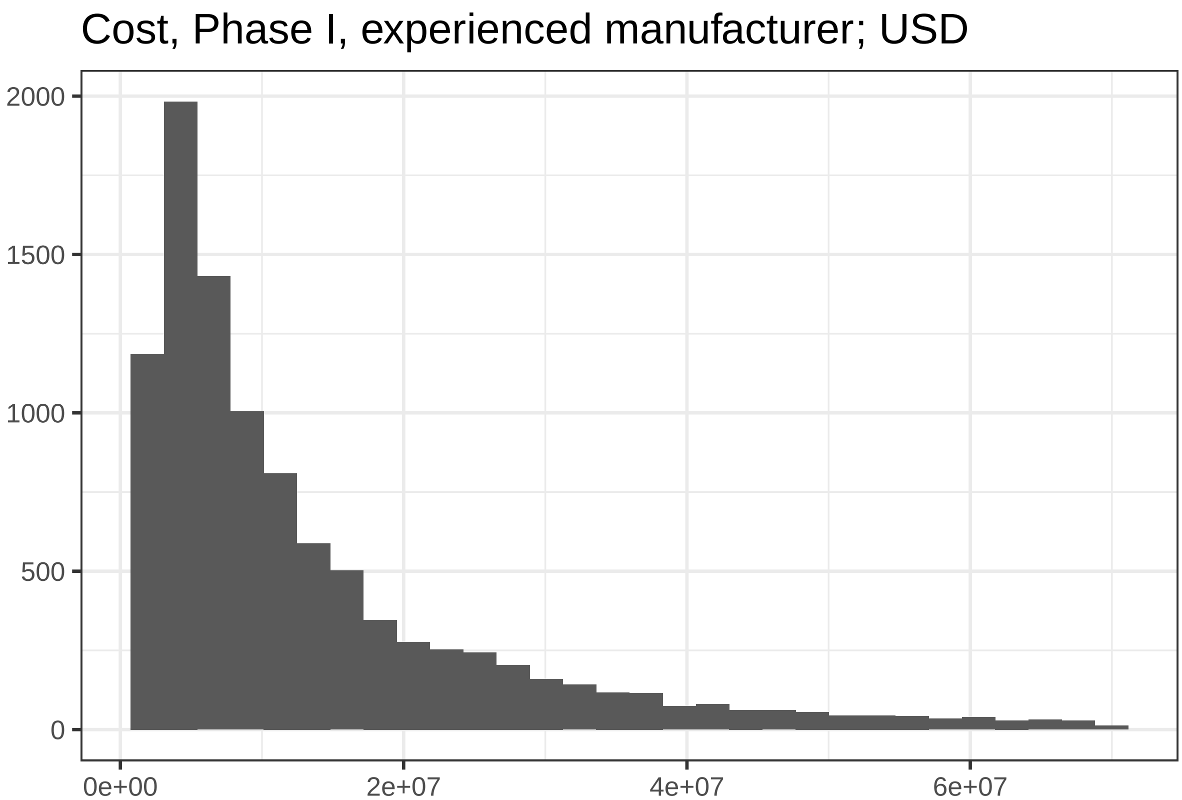

Probability of success; Phase II
2000
1500
1000
500
0
0.2
0.4
0.6
0.8

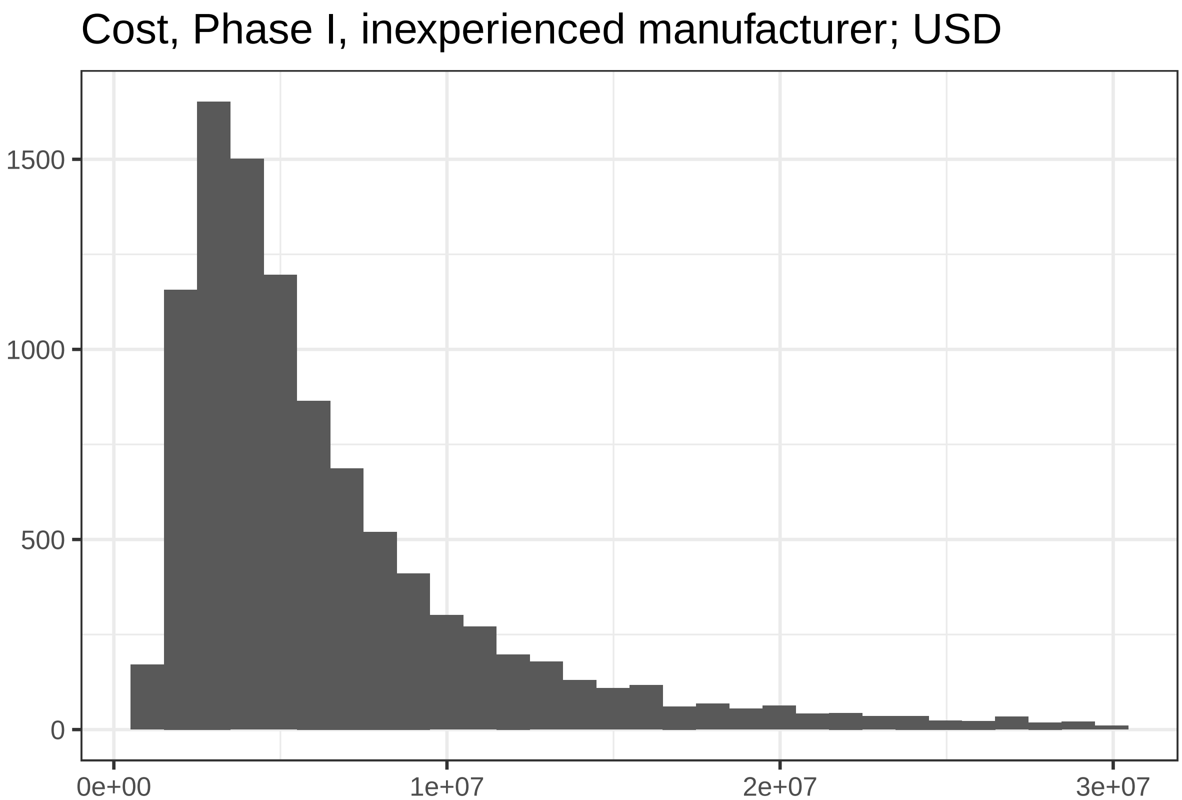

Probability of success; Phase III
300
200
100
0
0.4
0.5
0.6
0.7
0.8

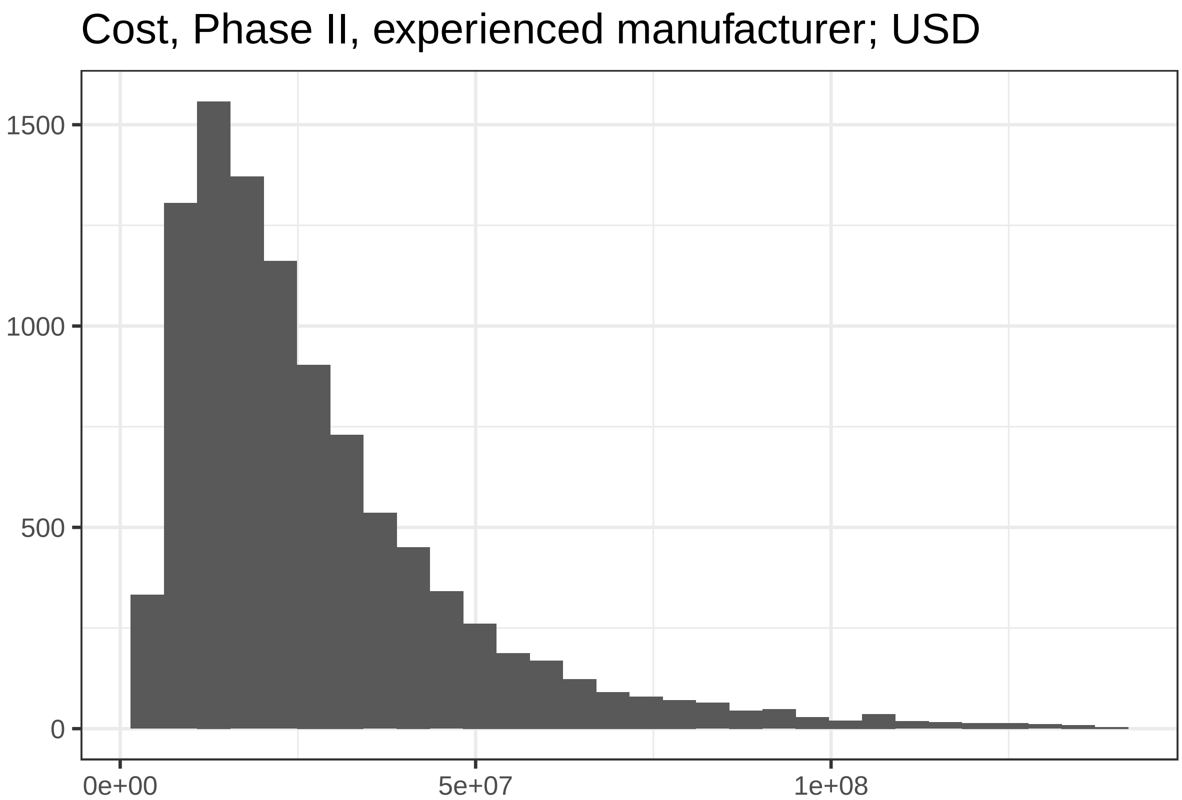
Cost, preclinical, experienced manufacturer; USD

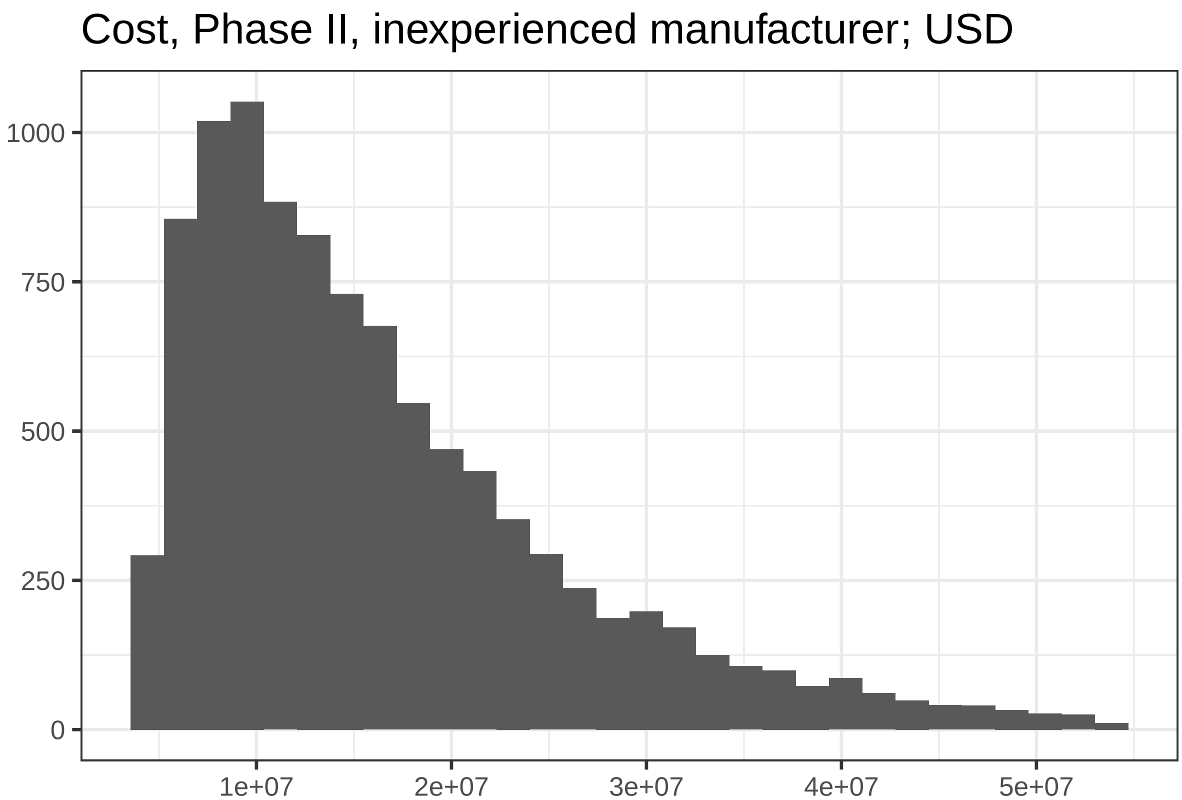



Cost, preclinical, inexperienced manufacturer; USD
1500
1000
500
0
0e+00
1e+07
2e+07
3e+07


Cost, Phase I, experienced manufacturer; USD
2000
1500
1000
500
0
0e+00
2e+07
4e+07
6e+07

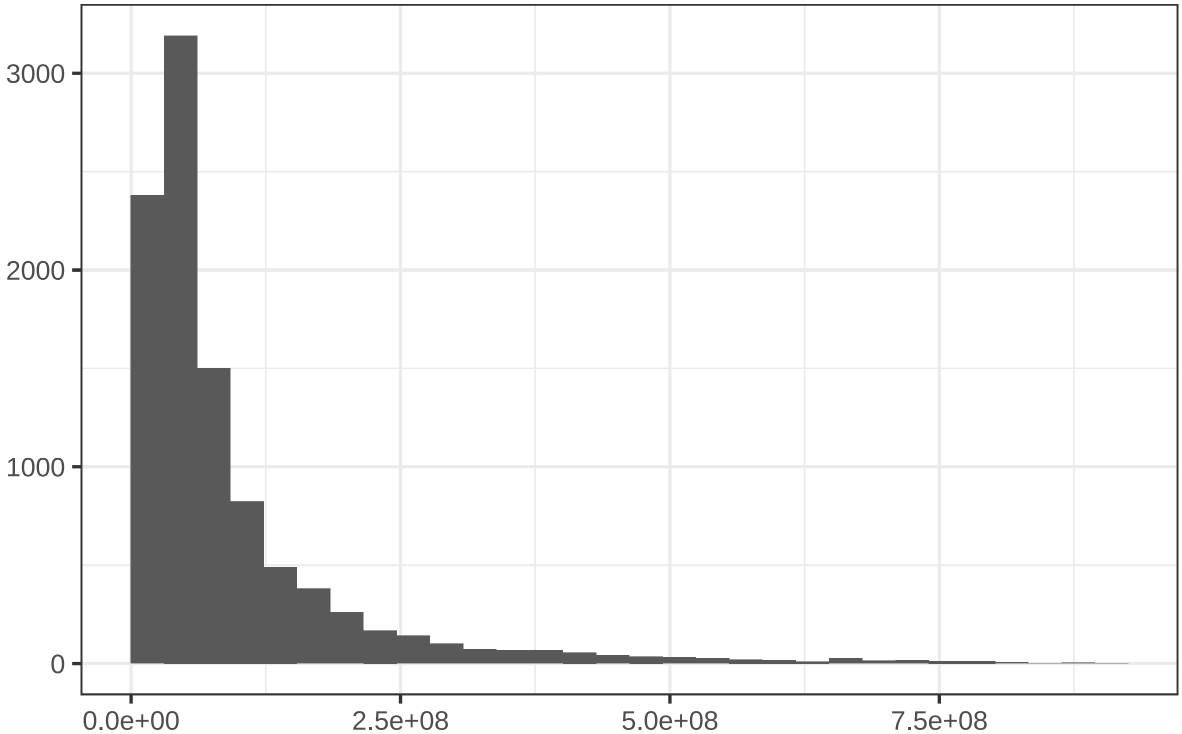

Cost, Phase I, inexperienced manufacturer; USD
1500
1000
500
0
0e+00
1e+07
2e+07
3e+07

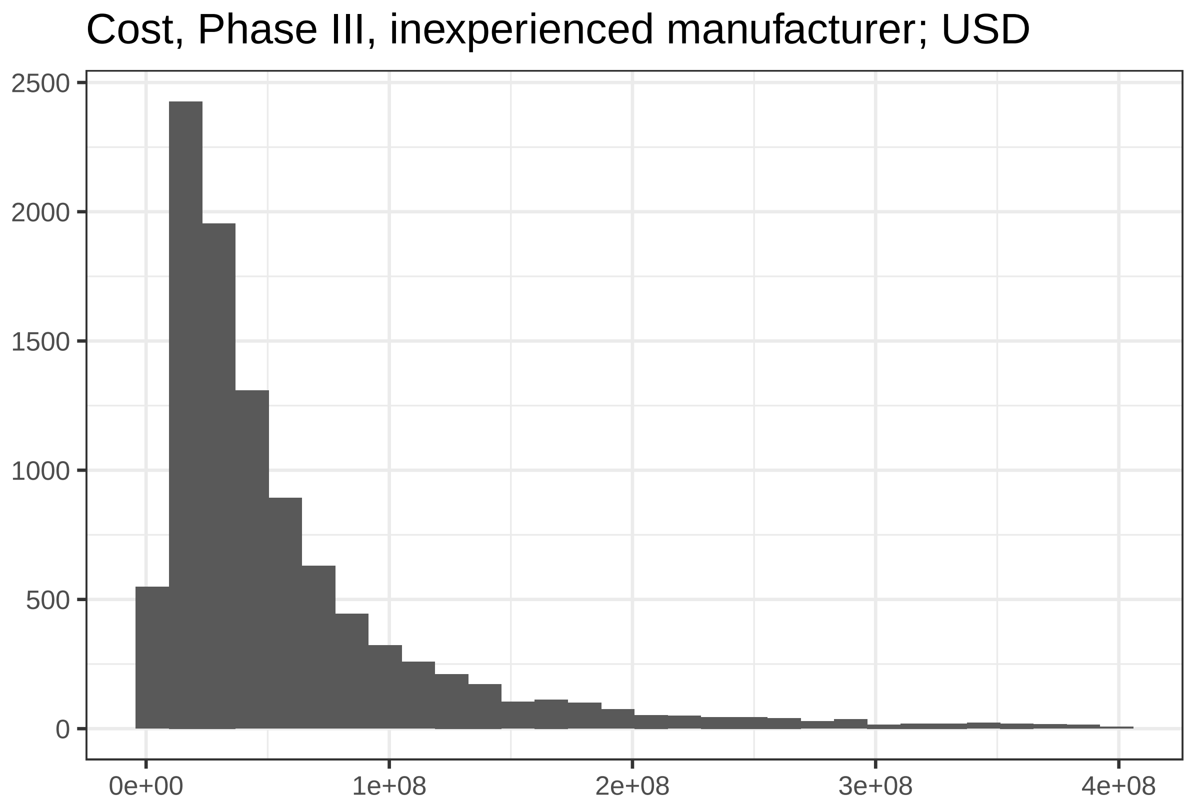

Cost, Phase II, experienced manufacturer; USD
1500
1000
500
0
0e+00
5e+07
1e+08



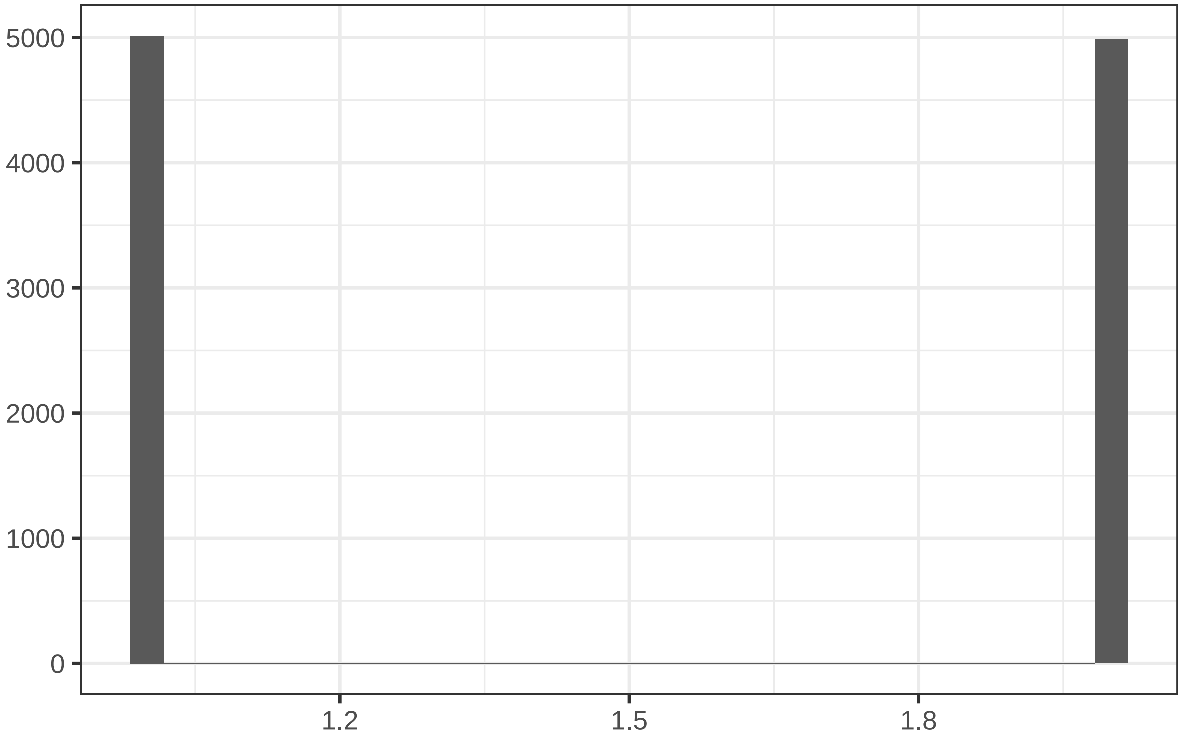
Cost, Phase II, inexperienced manufacturer; USD
1000
750
500
250
0
1e+07
2e+07
3e+07
4e+07
5e+07

Cost, Phase III, experienced manufacturer; USD

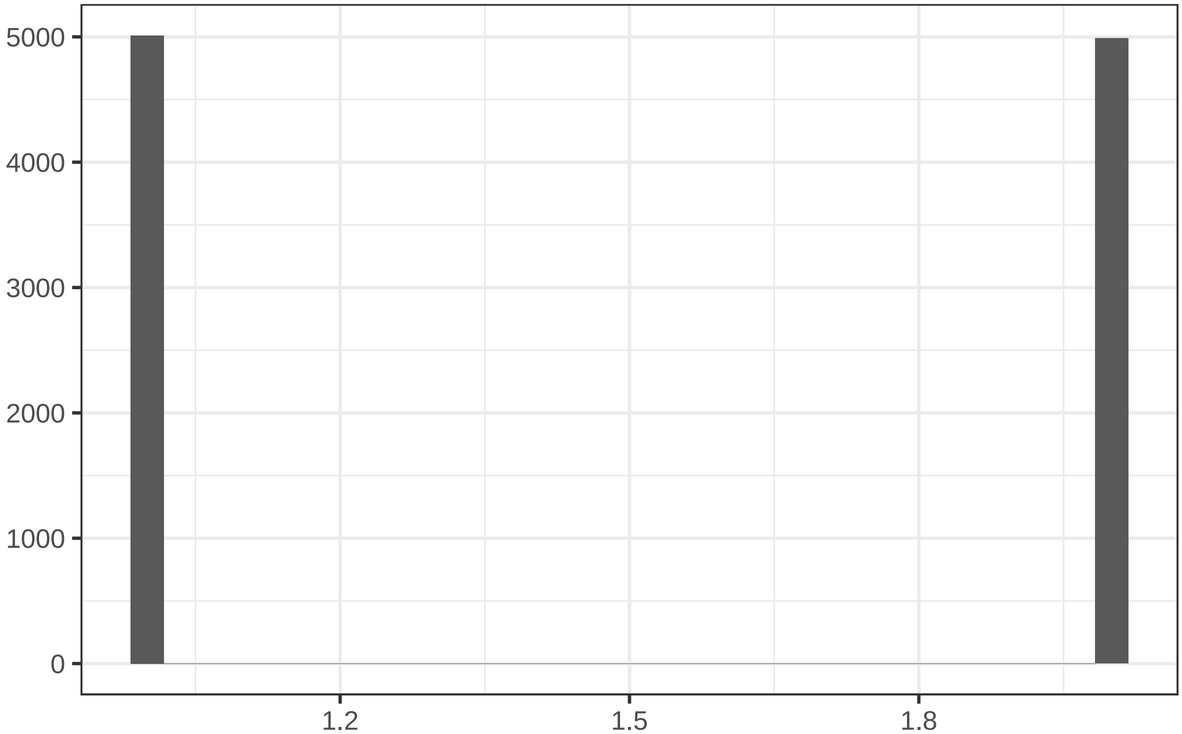



Cost, Phase III, inexperienced manufacturer; USD
2500
2000
1500
1000
500
0
0e+00
1e+08
2e+08
3e+08
4e+08

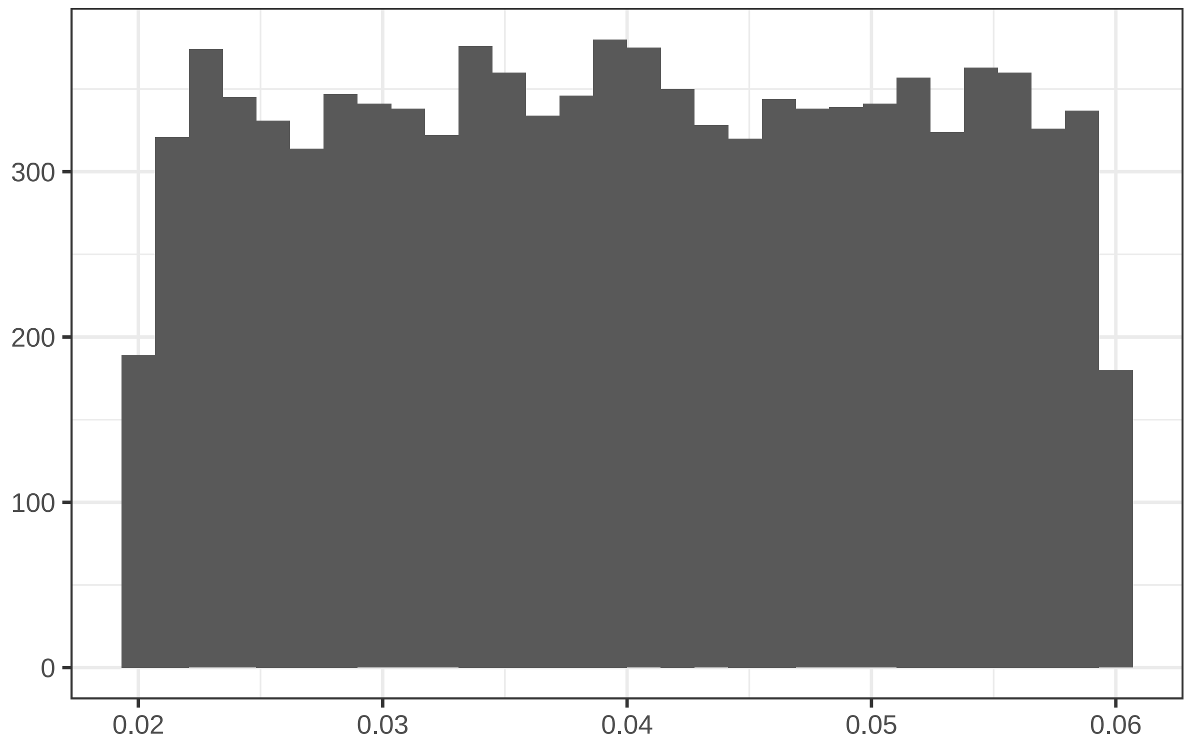
BPSV preclinical duration; years



BPSV Phase I duration; years



Discount rate



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