A Mathematical Model for Dengue Fever Insurance

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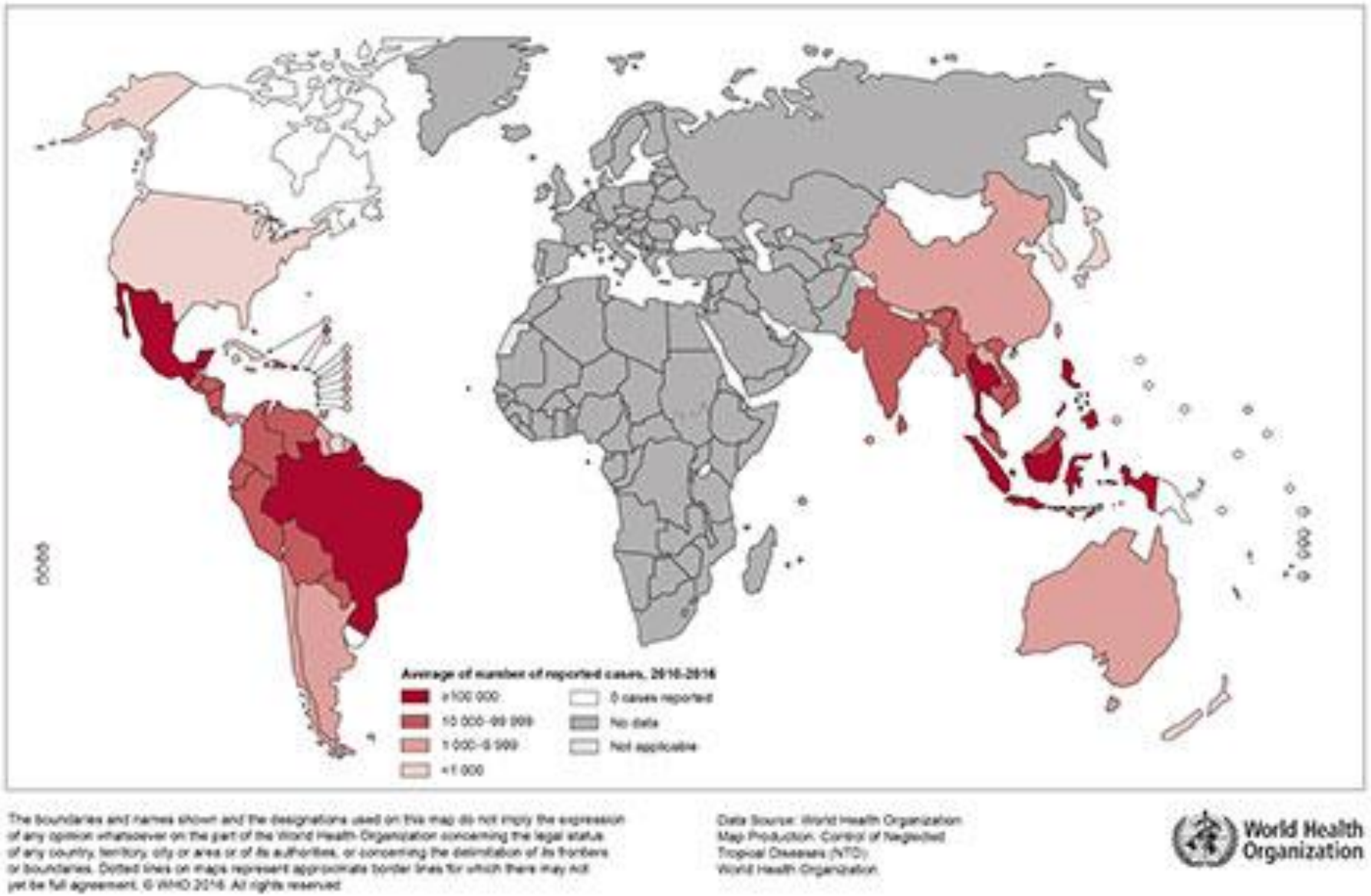

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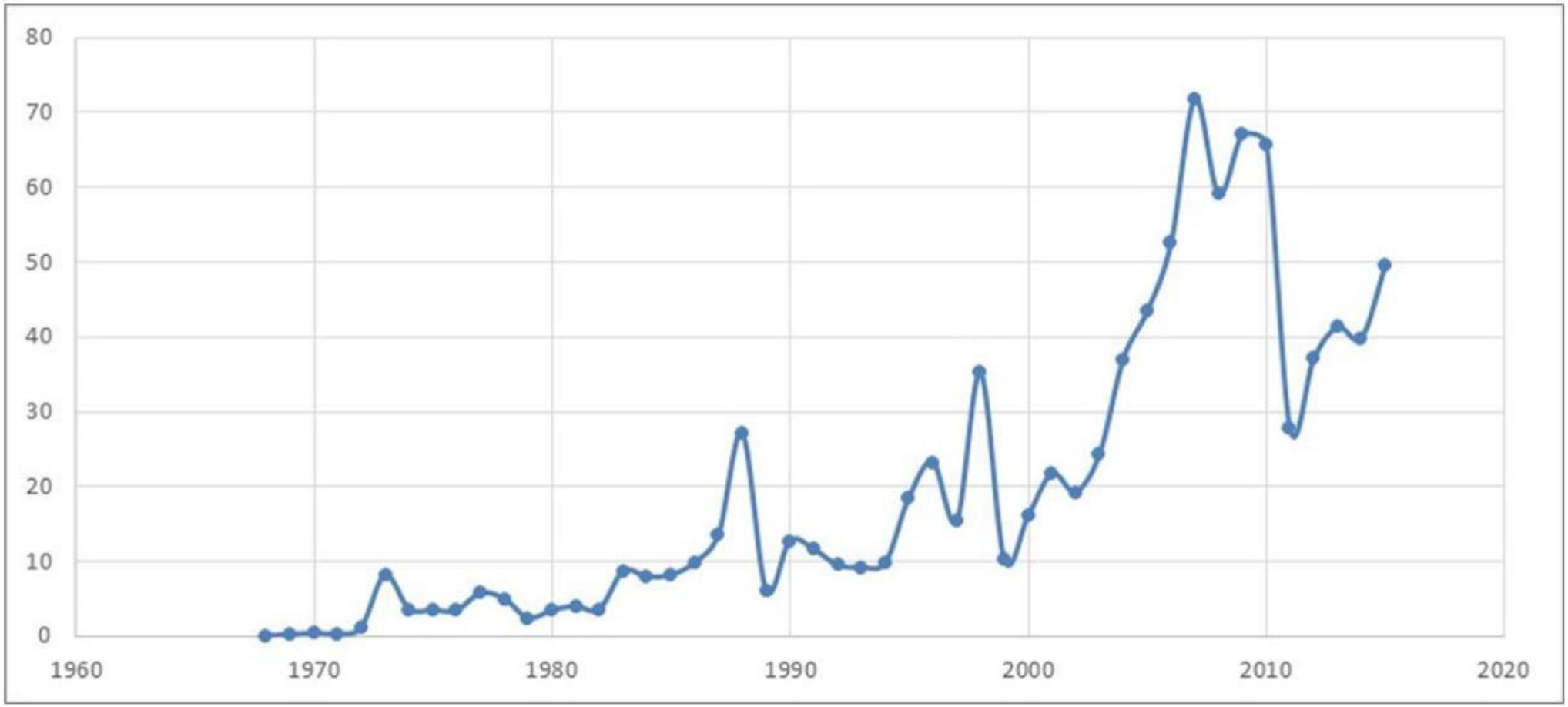


Figure 2.1: Dengue incidence rate per 100000 population in Indonesia, 1968-2015 (source: [2])

Facts on Dengue Desease

- The severity of dengue fever varies from mild to deadly symptoms (mild dengue fever - the life-threatening dengue haemorrhagic fever - dengue shock syndrome)
- Four serotypes of DENV exist (DENV1–4)
- Primary dengue infection only gives a partial immunity to the surviving person
- Subsequent infection by another serotype, termed secondary DV infection, is a risk factor for dengue hemorrhagic fever, which is associated with significant morbidity and occasionally death

Indonesian Dengue Data

Table 2.1: Clinical study data for DENV-1 and DENV-2. Source: [17], [10], [14], [9], [4], [11].

No	Year of Observation	Location	Population	DENV-1			DENV-2		
				Total	Primary	Secondary	Total	Primary	Secondary
1	February - August 2012	Surabaya	79	73%	33.30%	66.70%	8%	16.70%	83.30%
2	2009 - 2015	Bali	154	28%	18.60%	81.40%	17%	11.50%	88.50%
3	May 2007 - August 2010	Makasar	126	41%	97.14%	2.86%	31%	88.46%	11.54%
4	2015	Purwokerto	47	23.40%	36.36%	63.64%	10.64%	60.00%	40.00%
5	December 2011 - July 2012	Semarang	31	35.50%	18.18%	81.82%	12.90%	25.00%	75.00%
6	2011-2012	Sukabumi	25	20%	n/a	n/a	64%	n/a	n/a

Table 2.2: Clinical study data for DENV-3 and DENV-4. Source: [17], [10], [14], [9], [4], [11].

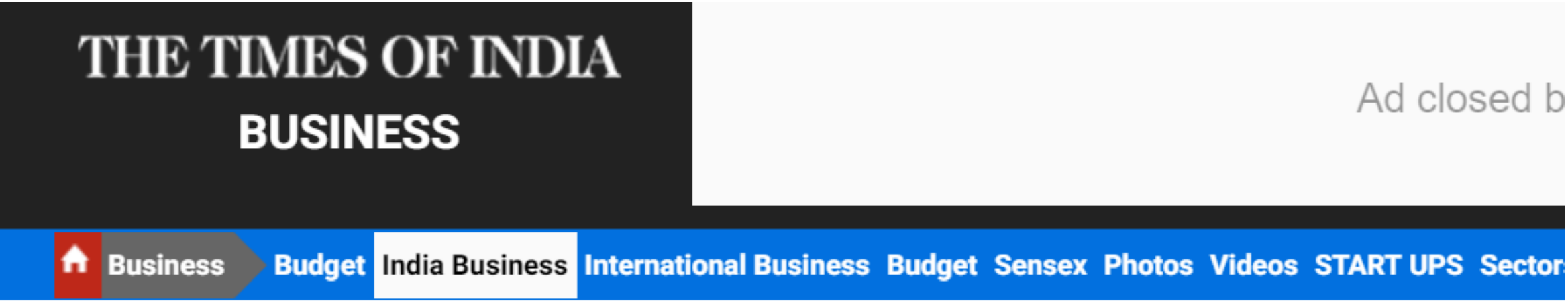
No	Year of Observation	Location	Population	DENV-3			DENV-4		
				Total	Primary	Secondary	Total	Primary	Secondary
1	February - August 2012	Surabaya	79	6%	0%	100%	8%	0%	100%
2	2009 - 2015	Bali	154	48%	17.60%	82.40%	4%	16.70%	83.30%
3	May 2007 - August 2010	Makasar	126	20%	76.92%	23.08%	7%	83.33%	16.67%
4	2015	Purwokerto	47	55.32%	46.15%	53.85%	10.64%	20.00%	80.00%
5	December 2011 - July 2012	Semarang	31	12.90%	25.00%	75.00%	9.70%	0.00%	100.00%
6	2011-2012	Sukabumi	25	0	n/a	n/a	16.00%	n/a	n/a

Indonesian Dengue Data (Mixed Infection)

Table 2.3: Clinical study data for mixed DENV zerotypes. Source: [17], [10], [14], [9], [4], [11].

No	Year of Observation	Location	Population	Mixed					
				DENV 1&2	DENV 1&3	DENV 1%4	Total Mix	Primary	Secondary
1	February - August 2012	Surabaya	79	1%	3%	1%	5%	50%	50%
2	2009 - 2015	Bali	154	0%	0%	-	3%	0%	100%
3	May 2007 - August 2010	Makasar	126	0%	0%	-	1%	n/a	n/a
4	2015	Purwokerto	47	0%	0%	0%	0%	n/a	n/a
5	December 2011 - July 2012	Semarang	31	0%	0%	0%	29.03%	22.22%	77.78%
6	2011-2012	Sukabumi	25	0%	0%	0%	0%	n/a	n/a

What is the potential impact of dengue on insurance industries?



News » BUSINESS NEWS » India Business News » Insurance claims for dengue on the rise

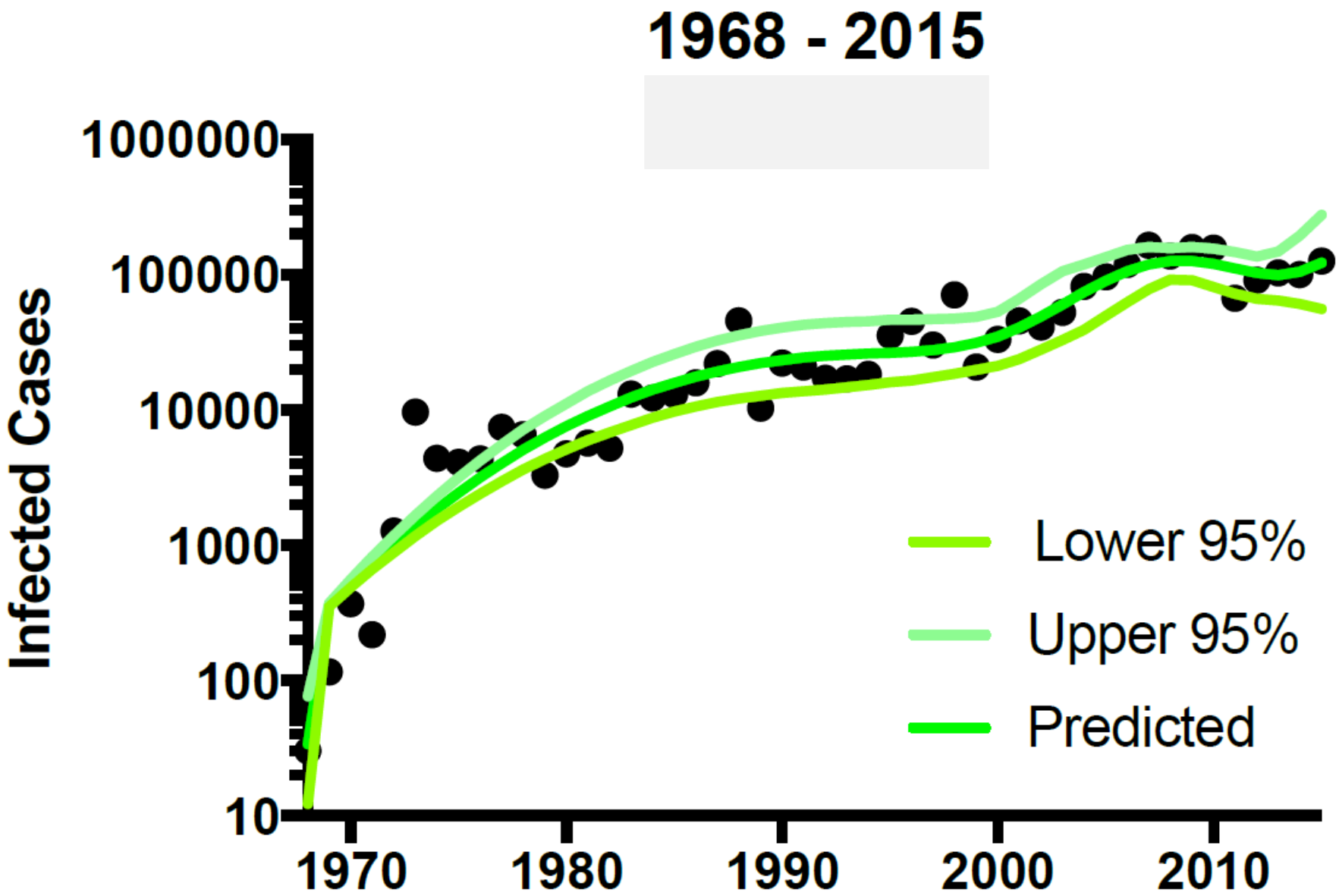
Insurance claims for dengue on the rise

Aparna Ramalingam and Ekatha Ann John| TNN | Updated: Dec 7, 2013, 12:23 IST

From Clinical Data to Insurance Products

- The increase of dengue cases as reported by WHO, implies that there are more people who are subjected to secondary infection, which is more severe and costly.
- Formulate a multiple state model that describes the infection, re-infection and survival probability of dengue in Indonesia.
- The model must be able to capture the increase of severity of illness in the case of re-infection.
- Because data on dengue primary and secondary infection were never measured completely in Indonesia, We need build a theoretical model for the re-infection case and reconstruct / predict the data.

Results from Dengue Epidemiological Model



Micro-Insurance Pricing for Primary and Secondary Dengue Infection Based on The SIRSEIR Epidemiological Model

- 1-year Term Insurance
- There are 3 conditions that are explored: (1) Underwriting the primary and secondary dengue infection; (2) Death Benefit; (3) Hospital Income or Hospital Reimbursement
- The premium calculation includes: (1) Loss Ratio; (2) Medical Inflation in Indonesia; (3) Public Awareness

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Product Descriptions

Product Code	Underwriting the state of susceptibility	Death Benefit	Hospital Income	Hospital Reimbursement
NU ND HI	-	-	Yes	-
U ND HI	Yes	-	Yes	-
U1/U2 ND HI	Yes	-	Yes	-
NU D HI	-	Yes	Yes	-
NU ND HRNL	-	-	-	No Limit
NU ND HRL	-	-	-	Limit

Note: Any other combination can be calculated using similar formulas

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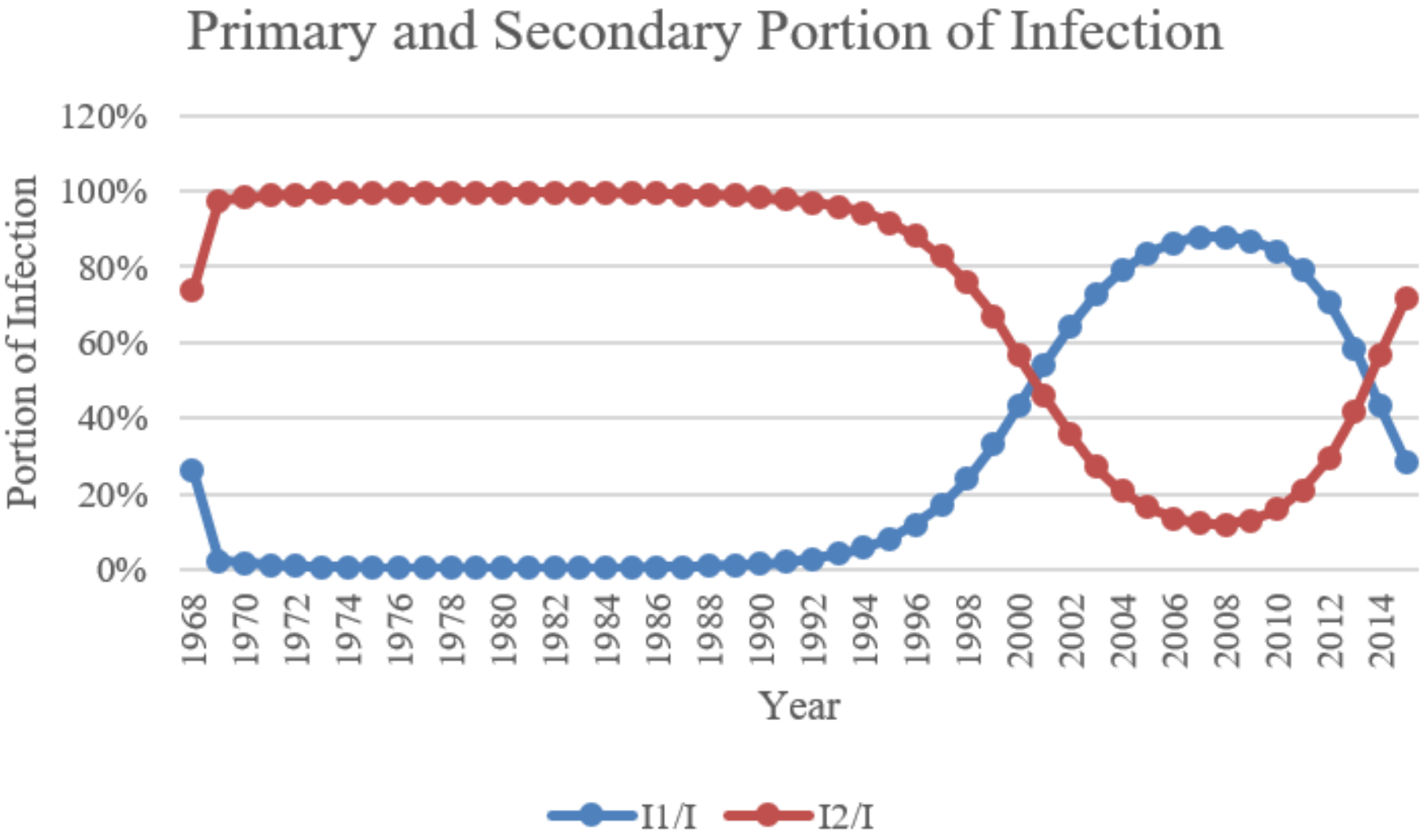


It can be shown that
The SIR model fits in the interval
1968-1990

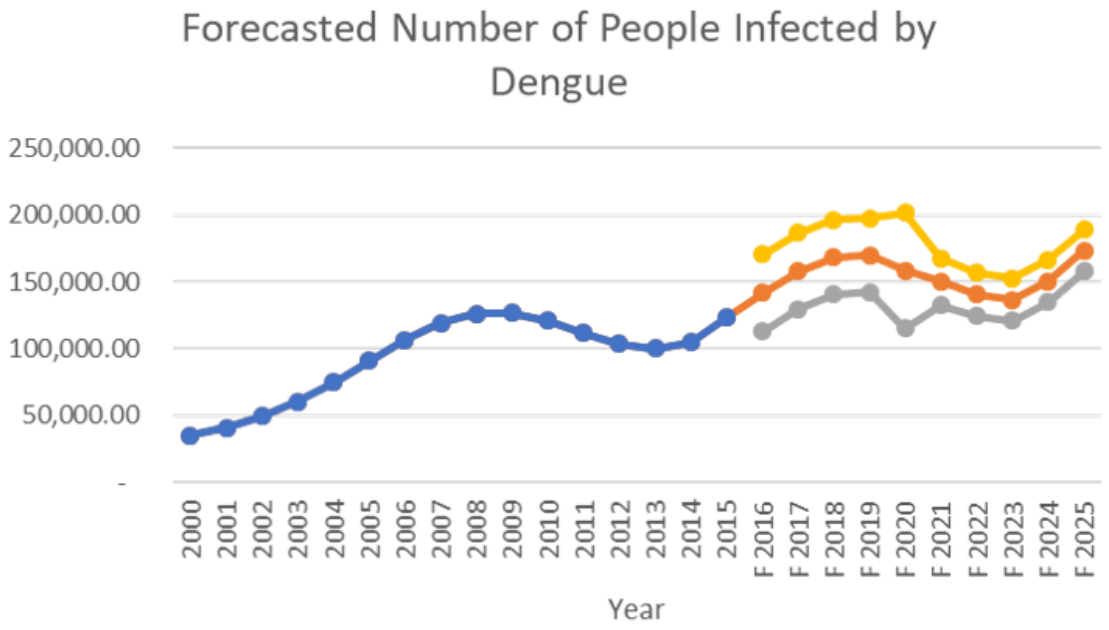
Insurance models starts
From year 2000

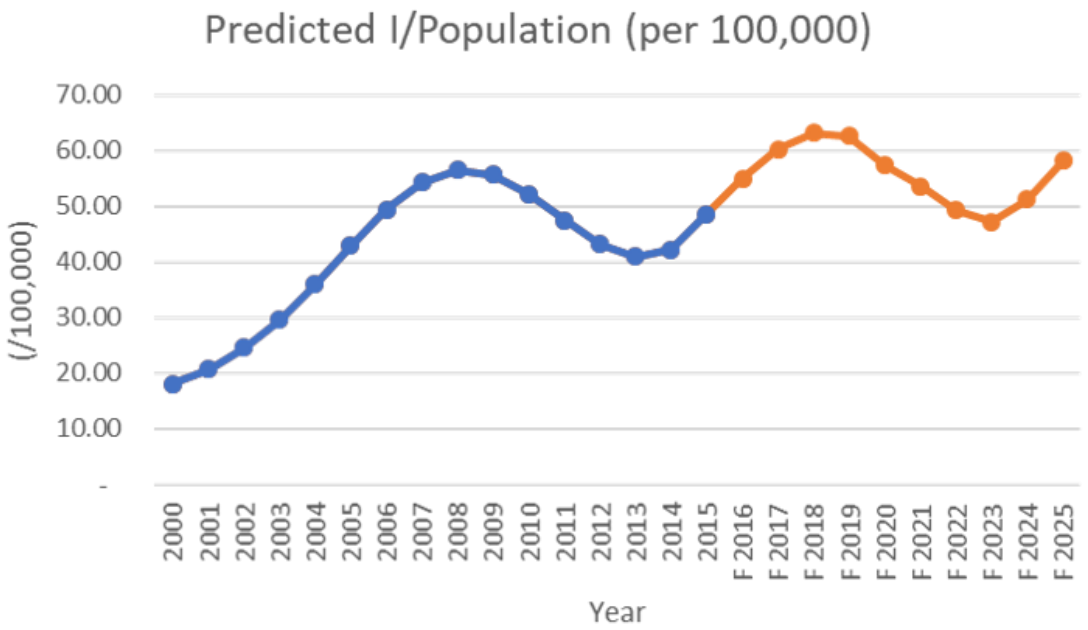
Year	General Inflation	Medical Inflation
2017	3.61%	15.00%
2016	3.02%	15.00%
2015	3.35%	9.30%
2014	8.36%	9.50%
2013	7.72%	
2012	4.30%	
2011	3.79%	
2010	6.96%	
2009	2.78%	
2008	10.23%	
2007	6.59%	
2006	6.60%	
2005	17.07%	
2004	6.47%	
2003	5.17%	
2002	9.92%	
2001	12.55%	
2000	9.35%	
Source:	inflation.eu [2]	Multiple Sources[3][4]

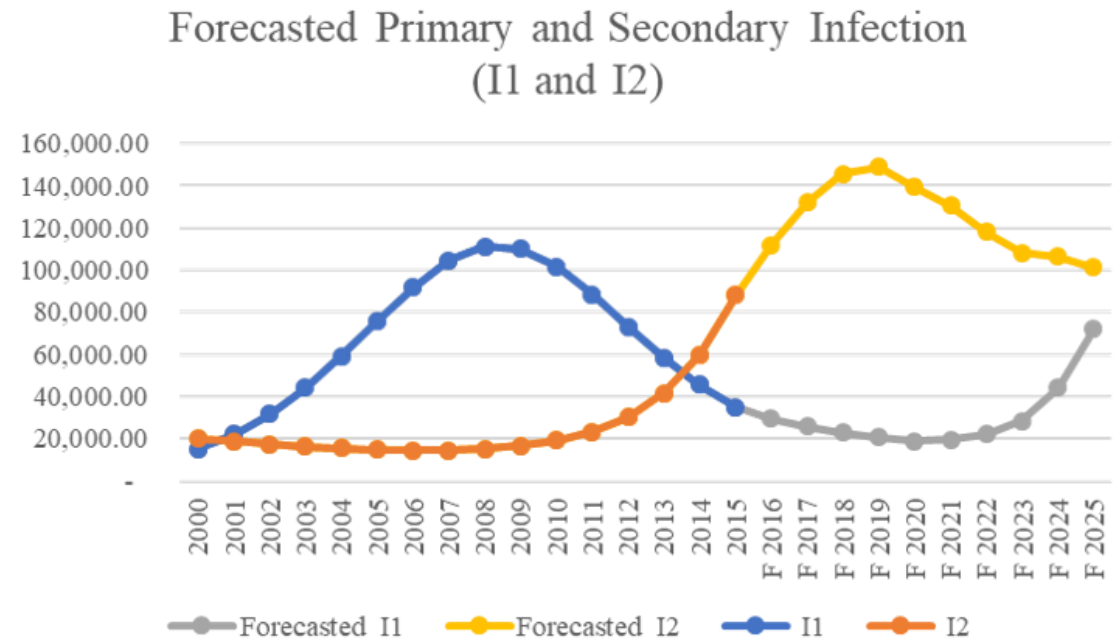
General and Medical Inflation in Indonesia

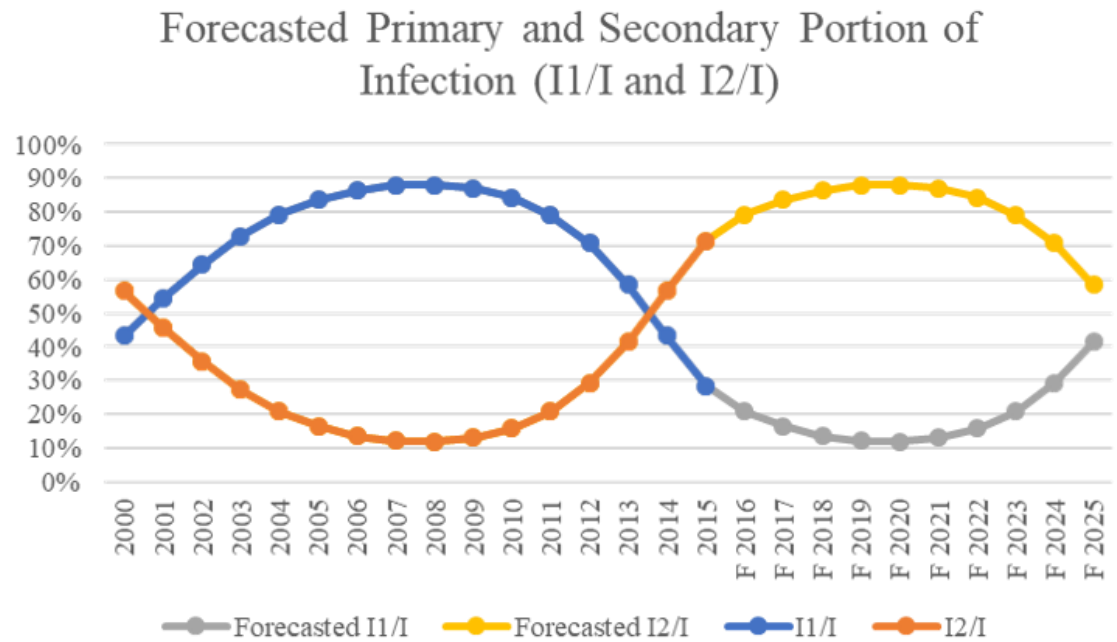
Medical inflation data only available from 2014.

Therefore for years before 2014, we will use general inflation instead of medical inflation

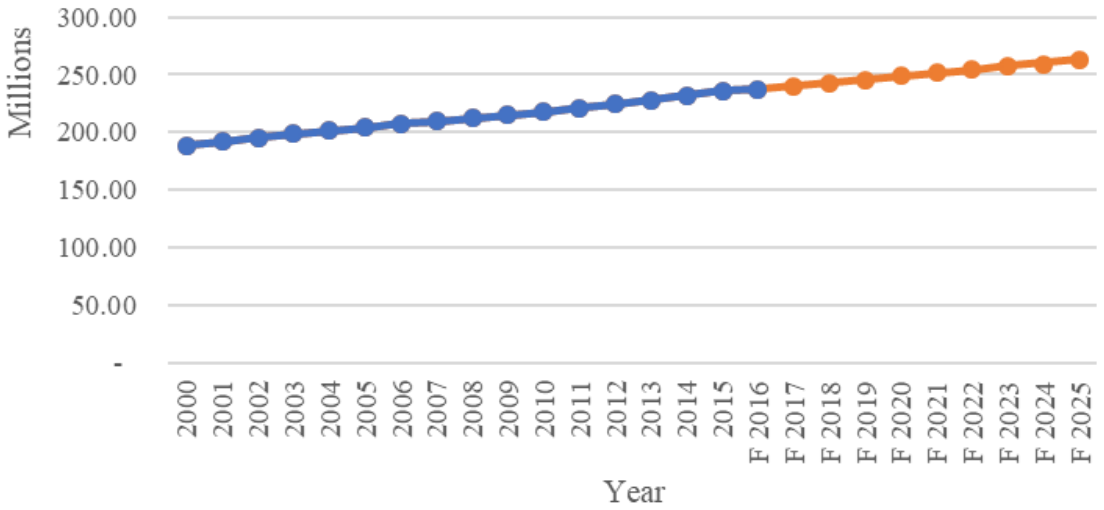

Forecasted Number of People Infected by Dengue
250,000.00
200,000.00
150,000.00
100,000.00
50,000.00
-
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 F 2016 F 2017 F 2018 F 2019 F 2020 F 2021 F 2022 F 2023 F 2024 F 2025
Year


Predicted I/Population (per 100,000)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
-
(/100,000)
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 F 2016 F 2017 F 2018 F 2019 F 2020 F 2021 F 2022 F 2023 F 2024 F 2025
Year

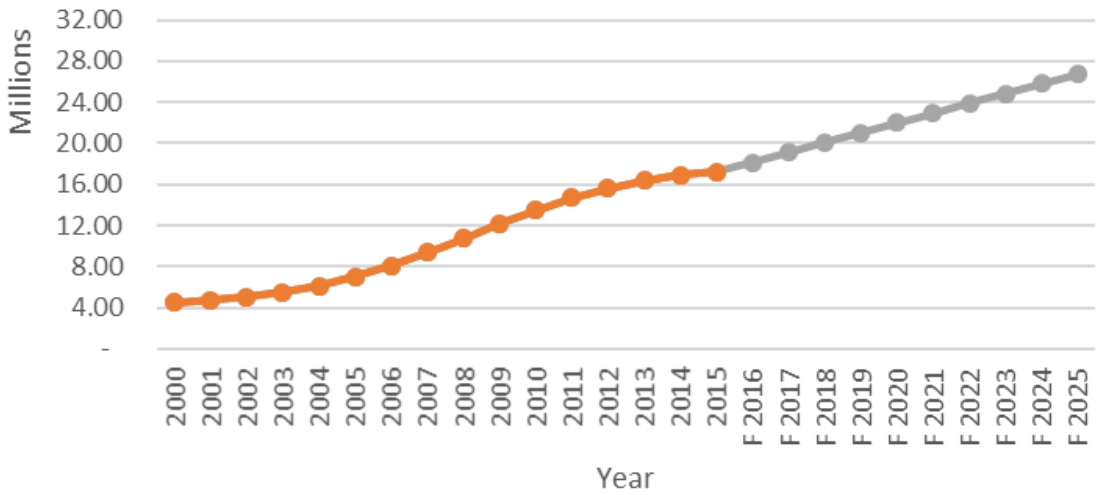

Forecasted Primary and Secondary Infection (I1 and I2)
160,000.00
140,000.00
120,000.00
100,000.00
80,000.00
60,000.00
40,000.00
20,000.00
-
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 F 2016 F 2017 F 2018 F 2019 F 2020 F 2021 F 2022 F 2023 F 2024 F 2025
Forecasted I1
Forecasted I2
I1
I2


Forecasted Primary and Secondary Portion of Infection (I1/I and I2/I)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 F 2016 F 2017 F 2018 F 2019 F 2020 F 2021 F 2022 F 2023 F 2024 F 2025
Forecasted I1/I
Forecasted I2/I
I1/I
I2/I

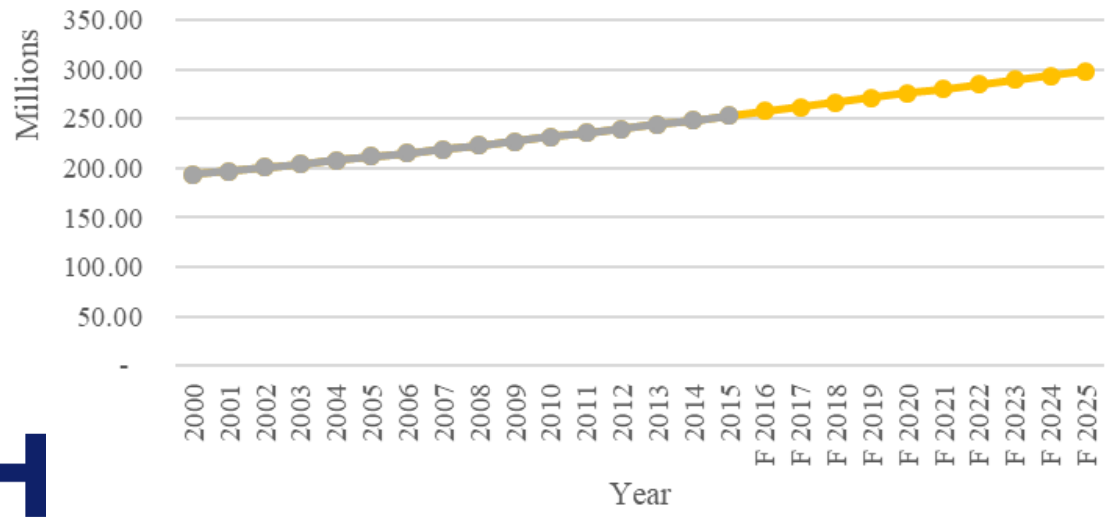
Predicted Number of People Susceptible to Primary Dengue (S1)



Predicted Number of People Recovered from Primary but Not Infected by Secondary (R1+S2+E2)



Predicted Population (S1+I1+R1+S2+E2+I2+R2)



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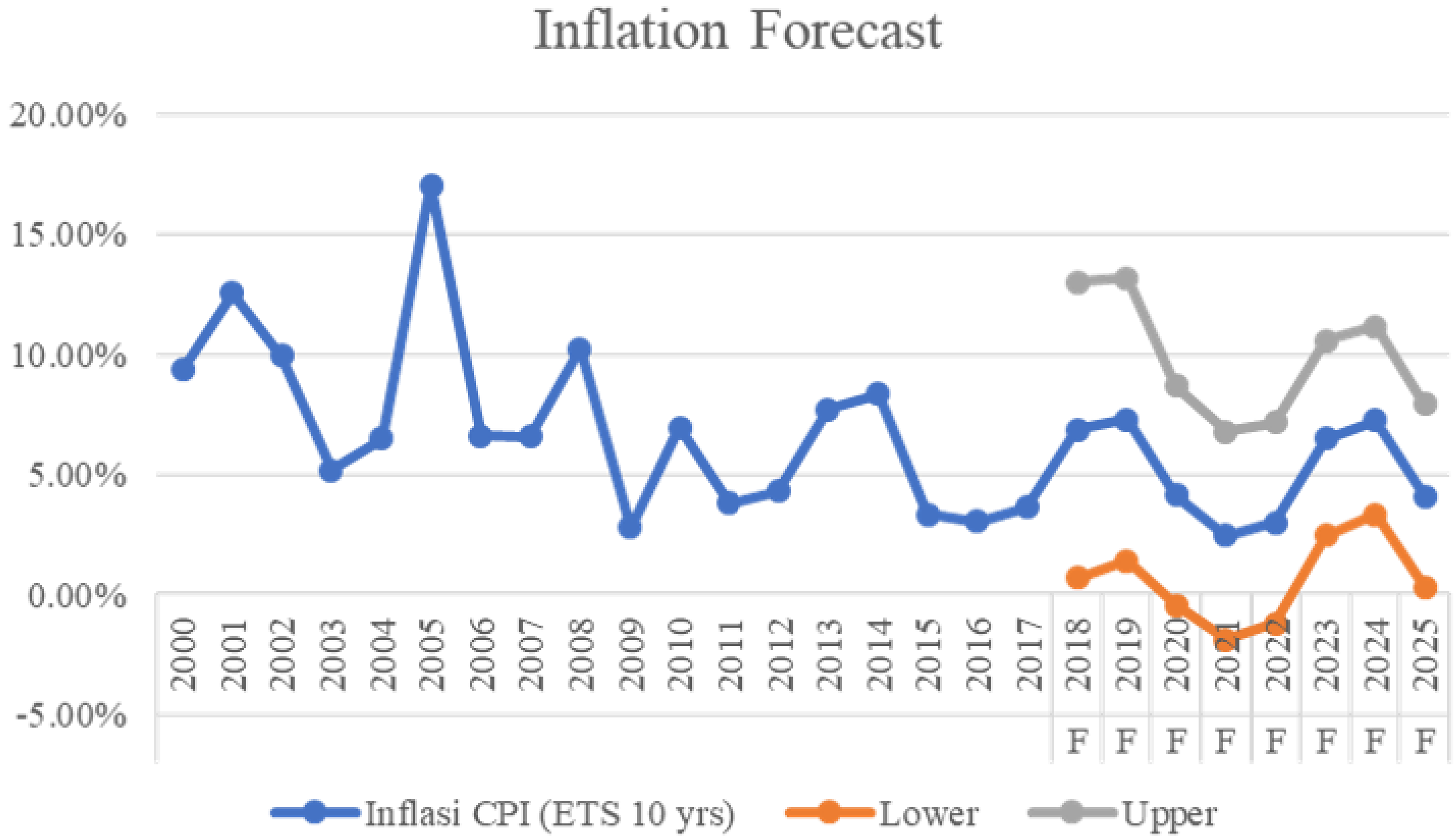

Inflation Forecast
20.00%
15.00%
10.00%
5.00%
0.00%
-5.00%
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018 F
2019 F
2020 F
2021 F
2022 F
2023 F
2024 F
2025 F
Inflasi CPI (ETS 10 yrs)
Lower
Upper

Values for sample product calculations

- Insurance awareness (a%) = 50%
- Loss Ratio (l%) = 60%
- HI benefit = Rp 3,021,400.00 (year 2015, source: BPJS Kesehatan First Class [8])
- U1/HI Benefit (k1) = 0.8
- U2/HI Benefit (k2) = 1.3
- HRNL Benefit = Rp 3,606,233.50 (year 2015, Dengue Cost Studies [5] [6])
- Std HRNL = Rp 1,000,000.00
- α for HRL = 25%
- Death Benefit (DB) = Rp. 150,000,000.00

Yearly Premium Calculations

- NU ND HI

$$\text{Expected Premium Income} = \text{Expected Benefit Payment}$$

$$(S_1 + R_1 + S_2 + E_2) \cdot P = (I_1 + I_2) \cdot BHI$$

$$a\% \cdot l\% \cdot (S_1 + R_1 + S_2 + E_2) \cdot P = (I_1 + I_2) \cdot BHI(t)$$

$$P = \frac{(I_1 + I_2) \cdot BHI(t)}{a\% \cdot l\% \cdot (S_1 + R_1 + S_2 + E_2)}$$

- U ND HI

$$a\% \cdot l\% \cdot (S_1 + R_1 + S_2 + E_2) \cdot P = [I_1 \cdot B_{HI,1}(t)] + [I_2 \cdot B_{HI,2}(t)]$$

$$a\% \cdot l\% \cdot (S_1 + R_1 + S_2 + E_2) \cdot P = [I_1 \cdot k1 \cdot BHI(t)] + [I_2 \cdot k2 \cdot BHI(t)]$$

$$P = \frac{[(I_1 \cdot k1) + (I_2 \cdot k2)] \cdot BHI(t)}{a\% \cdot l\% \cdot (S_1 + R_1 + S_2 + E_2)}$$

Yearly Premium Calculations

- U1/U2 ND HI

  For Primary: $S_1 \cdot P_1 = I_1 \cdot B_{HI,1}$

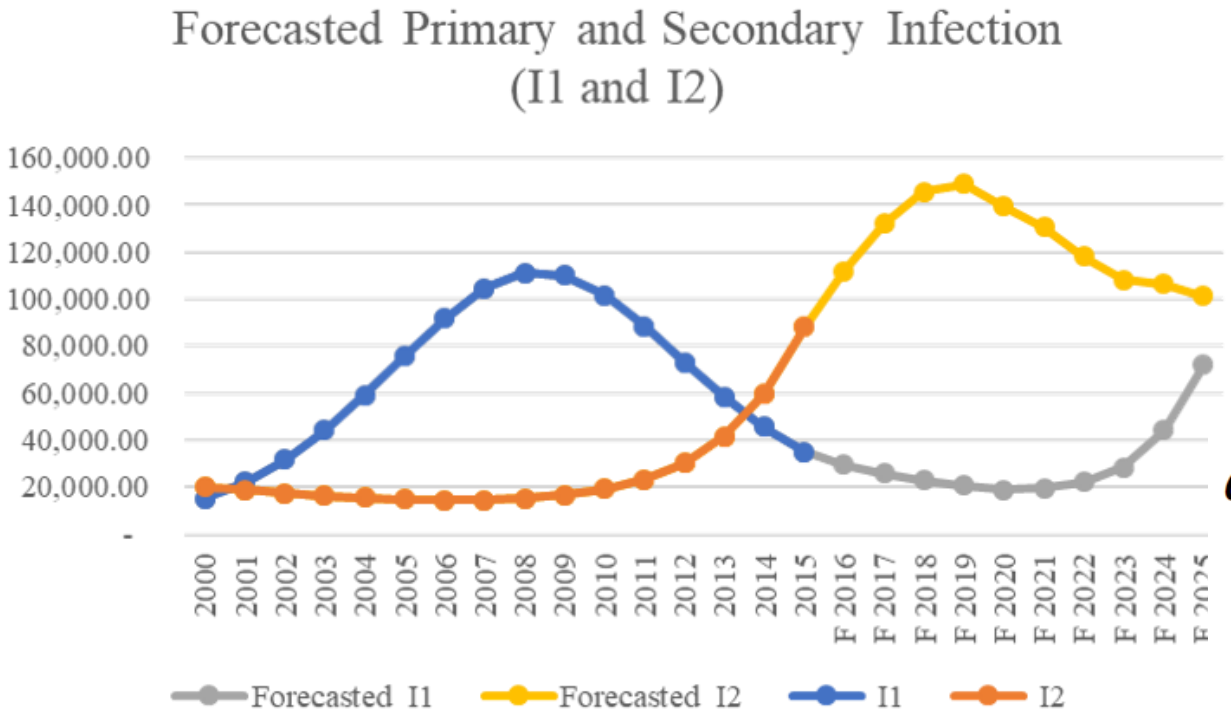
  For Secondary: $(R_1 + S_2 + E_2) \cdot P_2 = I_2 \cdot B_{HI,2}$

  The result of this may be very different since S_1 is vastly larger than $R_1+S_2+E_2$ combined.

  To solve this problem, we will transfer some of the primary susceptible to help support the secondary.

  We will need a constant s%, which is the portion of S_1 accommodating the primary, therefore leaving $S_1(1\text{-}s\%)$ to help the secondary.

  The equation becomes:



$$a\% \cdot l\% \cdot (S_1 \cdot s\%) \cdot P_1 = I_1 \cdot B_{HI,1}(t)$$

$$P_1 = \frac{I_1 \cdot B_{HI,1}(t)}{a\% \cdot l\% \cdot S_1 \cdot s\%}$$

$$a\% \cdot l\% \cdot (S_1(1 - s\%) + R_1 + S_2 + E_2) \cdot P_2 = I_2 \cdot B_{HI,2}(t)$$

$$P_2 = \frac{I_2 \cdot B_{HI,2}(t)}{a\% \cdot l\% \cdot [S_1(1 - s\%) + R_1 + S_2 + E_2]}$$

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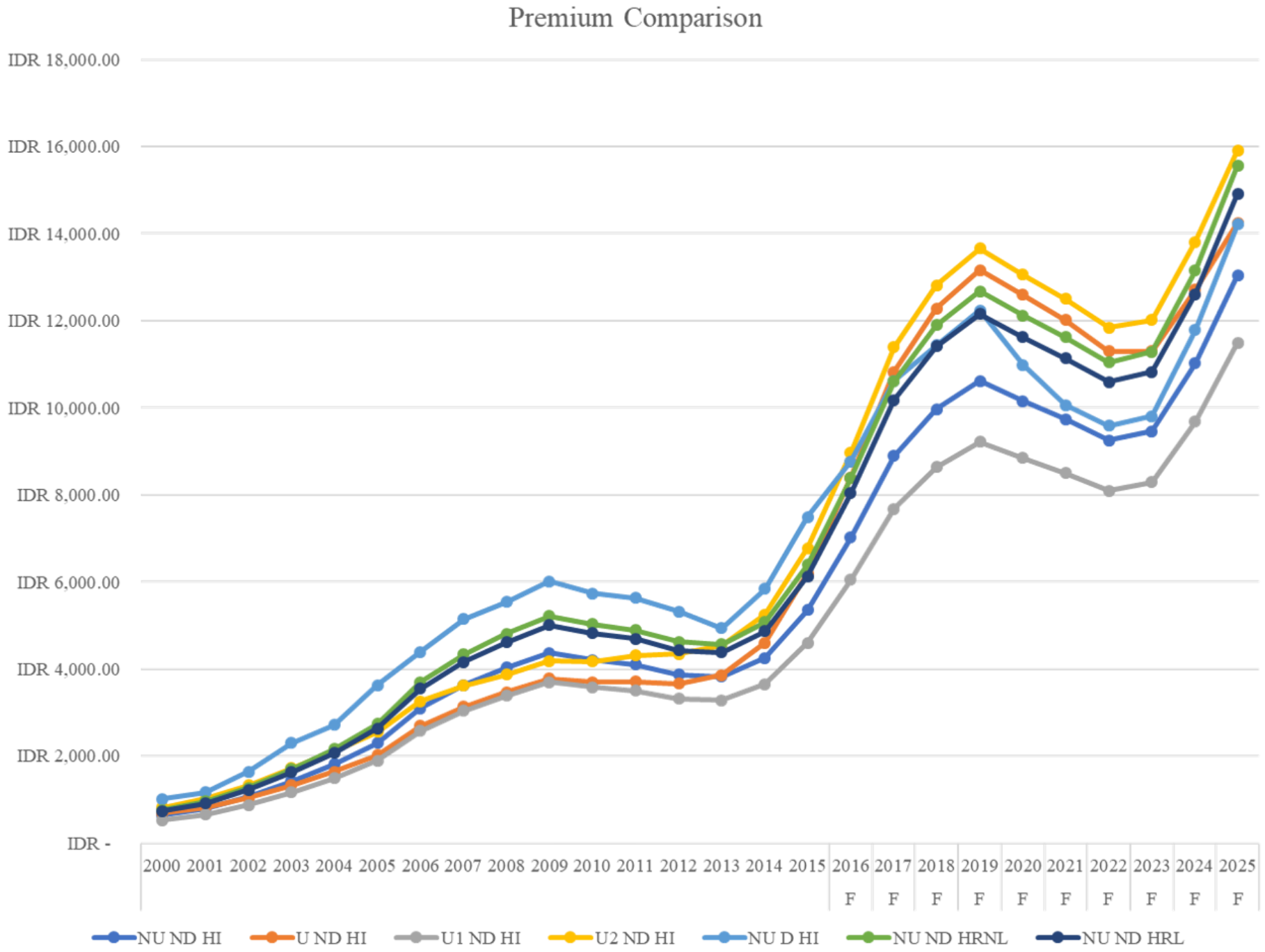
Premium Comparison
IDR 18,000.00
IDR 16,000.00
IDR 14,000.00
IDR 12,000.00
IDR 10,000.00
IDR 8,000.00
IDR 6,000.00
IDR 4,000.00
IDR 2,000.00
IDR -
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 F 2017 F 2018 F 2019 F 2020 F 2021 F 2022 F 2023 F 2024 F 2025 F
NU ND HI
U ND HI
U1 ND HI
U2 ND HI
NU D HI
NU ND HRNL
NU ND HRL

	NU ND HI	U ND HI	U1 ND HI	U2 ND HI	NU D HI	NU ND HRNL	NU ND HRL
Year	Non-Underwritten	Same Premium, Diff Benefit	Primary Protection	Secondary Protection	Death Benefit	Hosp. Reimbursement With No Limit	Hosp. Reimbursement With Limit
2000	IDR 642.79	IDR 696.35	IDR 526.49	IDR 821.02	IDR 1,016.54	IDR 767.22	IDR 735.66
2001	IDR 803.12	IDR 826.49	IDR 658.24	IDR 1,015.35	IDR 1,170.03	IDR 958.58	IDR 919.15
2002	IDR 1,069.24	IDR 1,046.25	IDR 877.39	IDR 1,329.95	IDR 1,646.53	IDR 1,276.20	IDR 1,223.72
2003	IDR 1,420.46	IDR 1,329.89	IDR 1,167.78	IDR 1,722.84	IDR 2,305.37	IDR 1,695.41	IDR 1,625.68
2004	IDR 1,811.00	IDR 1,637.58	IDR 1,492.92	IDR 2,116.78	IDR 2,713.56	IDR 2,161.54	IDR 2,072.64
2005	IDR 2,299.03	IDR 2,027.83	IDR 1,902.22	IDR 2,557.28	IDR 3,635.79	IDR 2,744.04	IDR 2,631.19
2006	IDR 3,101.93	IDR 2,692.77	IDR 2,578.40	IDR 3,256.62	IDR 4,390.21	IDR 3,702.35	IDR 3,550.08
2007	IDR 3,635.24	IDR 3,129.84	IDR 3,037.95	IDR 3,614.27	IDR 5,145.03	IDR 4,338.90	IDR 4,160.45
2008	IDR 4,032.14	IDR 3,467.40	IDR 3,389.09	IDR 3,871.59	IDR 5,539.29	IDR 4,812.61	IDR 4,614.68
2009	IDR 4,373.66	IDR 3,784.90	IDR 3,697.08	IDR 4,192.23	IDR 6,008.47	IDR 5,220.24	IDR 5,005.55
2010	IDR 4,214.84	IDR 3,705.28	IDR 3,581.11	IDR 4,179.83	IDR 5,737.77	IDR 5,030.68	IDR 4,823.78
2011	IDR 4,101.26	IDR 3,709.98	IDR 3,499.26	IDR 4,314.41	IDR 5,634.26	IDR 4,895.12	IDR 4,693.80
2012	IDR 3,872.54	IDR 3,665.46	IDR 3,314.33	IDR 4,349.53	IDR 5,320.03	IDR 4,622.12	IDR 4,432.02
2013	IDR 3,828.97	IDR 3,858.46	IDR 3,283.56	IDR 4,548.08	IDR 4,942.14	IDR 4,570.12	IDR 4,382.17
2014	IDR 4,254.23	IDR 4,607.64	IDR 3,651.87	IDR 5,256.41	IDR 5,844.41	IDR 5,077.70	IDR 4,868.87
2015	IDR 5,359.28	IDR 6,204.25	IDR 4,601.17	IDR 6,783.01	IDR 7,499.75	IDR 6,396.65	IDR 6,133.57
F 2016	IDR 7,022.06	IDR 8,396.66	IDR 6,047.32	IDR 8,960.97	IDR 8,764.31	IDR 8,381.28	IDR 8,036.58
F 2017	IDR 8,889.25	IDR 10,826.76	IDR 7,678.72	IDR 11,390.83	IDR 10,611.38	IDR 10,609.88	IDR 10,173.53
F 2018	IDR 9,972.61	IDR 12,285.30	IDR 8,638.40	IDR 12,810.01	IDR 11,437.92	IDR 11,902.95	IDR 11,413.41
F 2019	IDR 10,618.23	IDR 13,156.30	IDR 9,222.20	IDR 13,654.10	IDR 12,238.22	IDR 12,673.54	IDR 12,152.31
F 2020	IDR 10,158.74	IDR 12,597.42	IDR 8,846.50	IDR 13,061.65	IDR 10,986.94	IDR 12,125.10	IDR 11,626.43
F 2021	IDR 9,735.29	IDR 12,019.33	IDR 8,499.00	IDR 12,498.62	IDR 10,066.39	IDR 11,619.69	IDR 11,141.80
F 2022	IDR 9,256.85	IDR 11,301.66	IDR 8,100.99	IDR 11,842.82	IDR 9,591.31	IDR 11,048.64	IDR 10,594.24
F 2023	IDR 9,454.82	IDR 11,302.34	IDR 8,293.87	IDR 12,011.60	IDR 9,806.75	IDR 11,284.93	IDR 10,820.81
F 2024	IDR 11,016.75	IDR 12,707.53	IDR 9,685.78	IDR 13,806.31	IDR 11,788.45	IDR 13,149.20	IDR 12,608.41
F 2025	IDR 13,040.82	IDR 14,244.49	IDR 11,490.48	IDR 15,912.17	IDR 14,208.23	IDR 15,565.05	IDR 14,924.90

Conclusions

- In this study, we have created and priced sample micro-insurance products, based on data of primary and secondary dengue using an epidemiological model.
- We use three general features in all of our sample products, which are loss ratio, inflation, and insurance awareness. Loss ratio is the comparison between expected benefit payment and expected premium income. This functions to cushion the insurer from unexpected losses. Inflation, is the rate at which prices rise. Inflation is always a significant factor for everything finance-related, and adding this to our calculation will produce a more accurate price. Lastly, insurance awareness is our expected portion of eligible people who will buy the insurance, which function is also to cushion insurer's losses.
- There are three conditions we use to create six basic products. It is basic because some of the methods in creating these products can be combined to create a more advanced product. The three conditions are underwriting, death benefit, and hospital income/reimbursement. %Underwriting allows us to assess an individual's risk and price their premium accordingly. This results to different prices for people in different states, such as primary susceptible or secondary susceptible.
- Death benefit is an add-on, in which the insurer gives a benefit in case the insured dies because of dengue. This may be attractive to the beneficiaries, but it does increase the premium.

Conclusions

- For payment method, the two most common are hospital income and hospital reimbursement. Hospital income pays a fixed amount (per a certain length of time or per claim), while hospital reimbursement pays the exact amount of the insured's hospital billing (usually with a maximum limit). The latter is more complicated to calculate and needs more information which are not currently available.
- The formula we use is the basic principle of actuarial science: which is expected benefit and expected income, but modified to incorporate loss ratio, inflation, and insurance awareness. For underwriting, we use a mutual-cooperation system, in which the primary susceptibles help cover the secondary's load. This way, the premium for secondary protection is consistently higher than primary, but not too expensive either.

- For death benefit, we use the same formula. The difference is that the expected benefit payment is not for infection benefit only, but added with the expected death benefit payment too. This expected death benefit payment uses case fatality rate and a sample death benefit as its variable.

THE END

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