



System Dynamics and Machine Learning Combined Approach to Simulate Sustainable Competitive Advantage in Banking Industry

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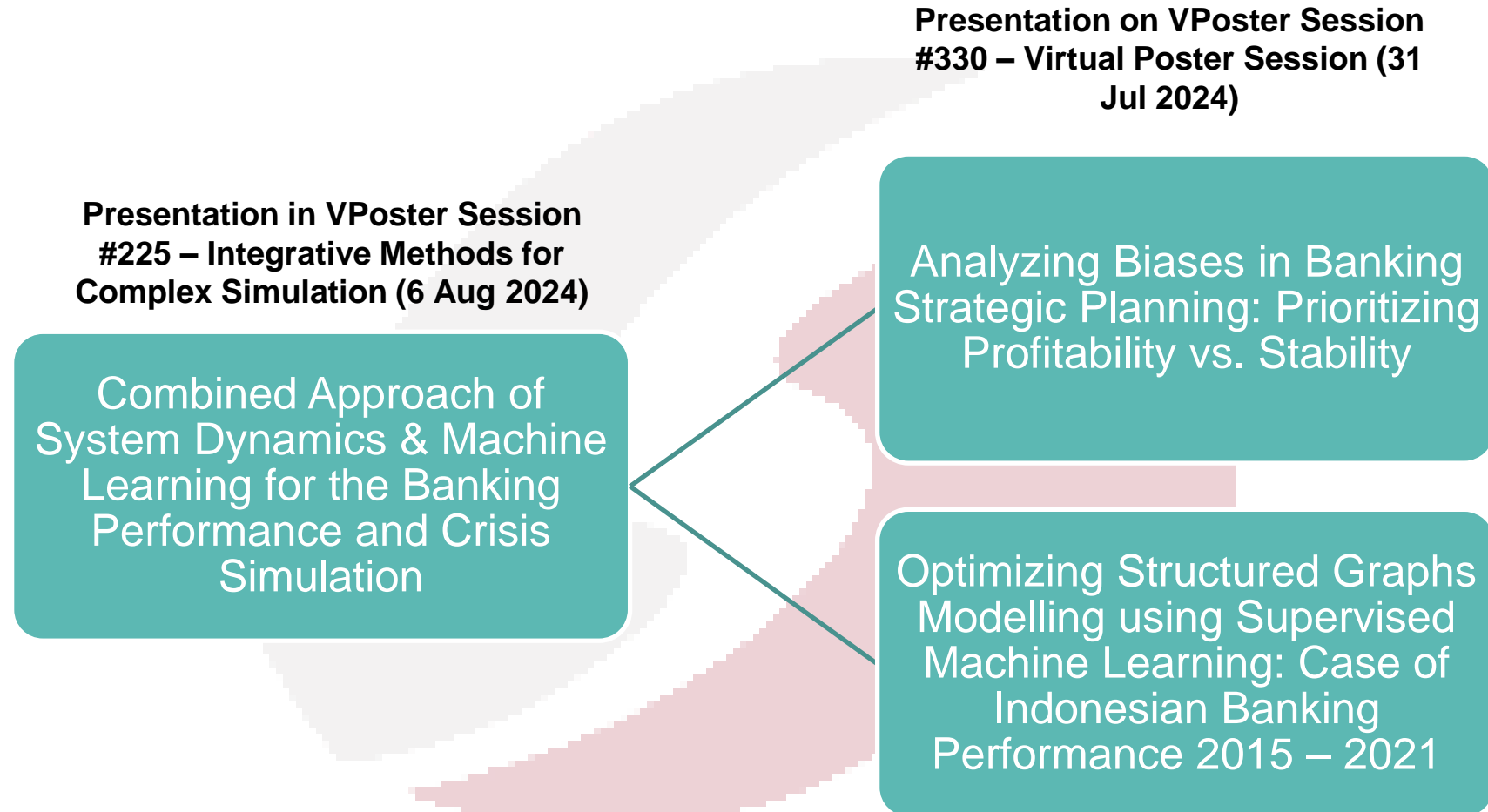
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Research Publication in ISDC 2024

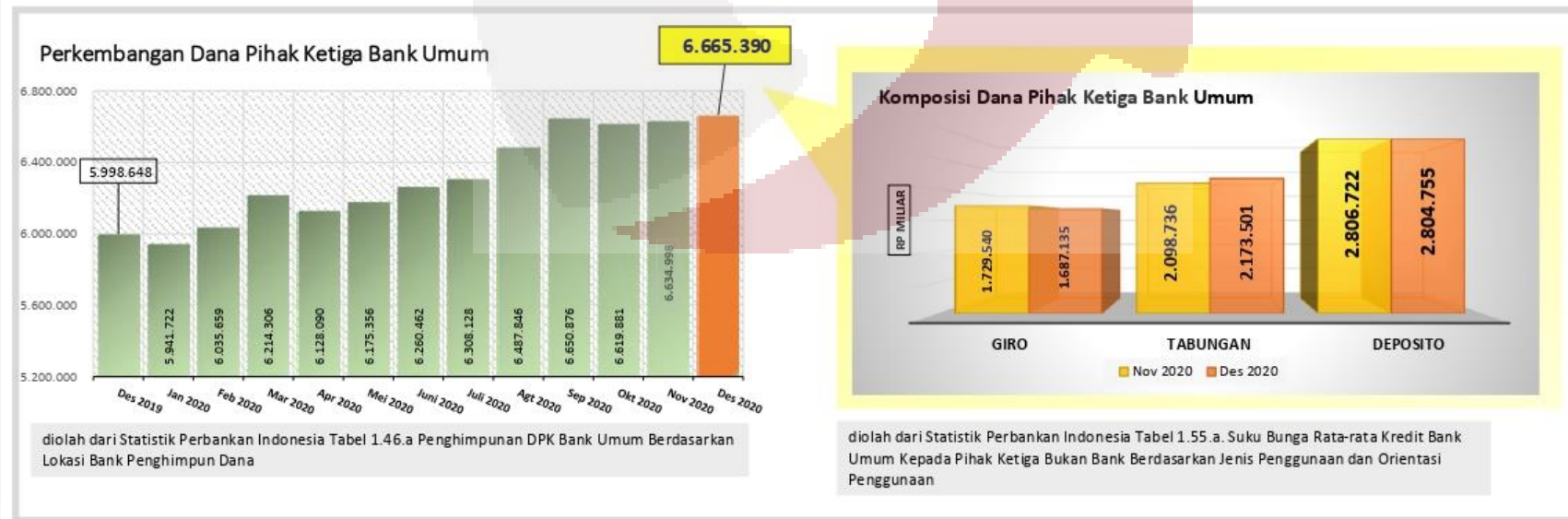
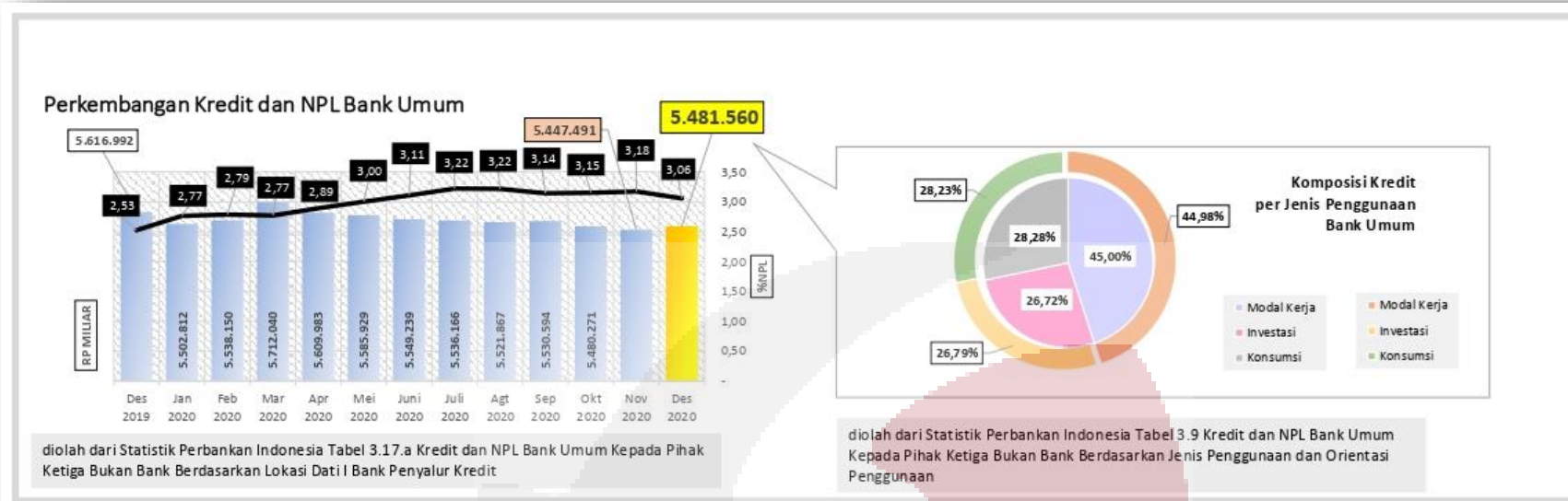




Backgrounds



Inverse Performance



- Highly competitive market with more than 100 Banks.
- Lending has increased, on the other hand, Non Performing Loan has also increased and the concentration is still on Working Capital Loan.
- The concentration of Third Party Fund is still in deposits.
- Several large Banks suffered underperformance before COVID19, contradicting to the overall banking industry performance.



Profitability vs Financial Stability

WP/19/5

IMF Working Paper

Bank Profitability and Financial Stability

Xu, T., Hu, K., & Das, U. S. (2015). Bank Profitability and Financial Stability. International Monetary Fund (IMF), Working Paper No. 2019/005.

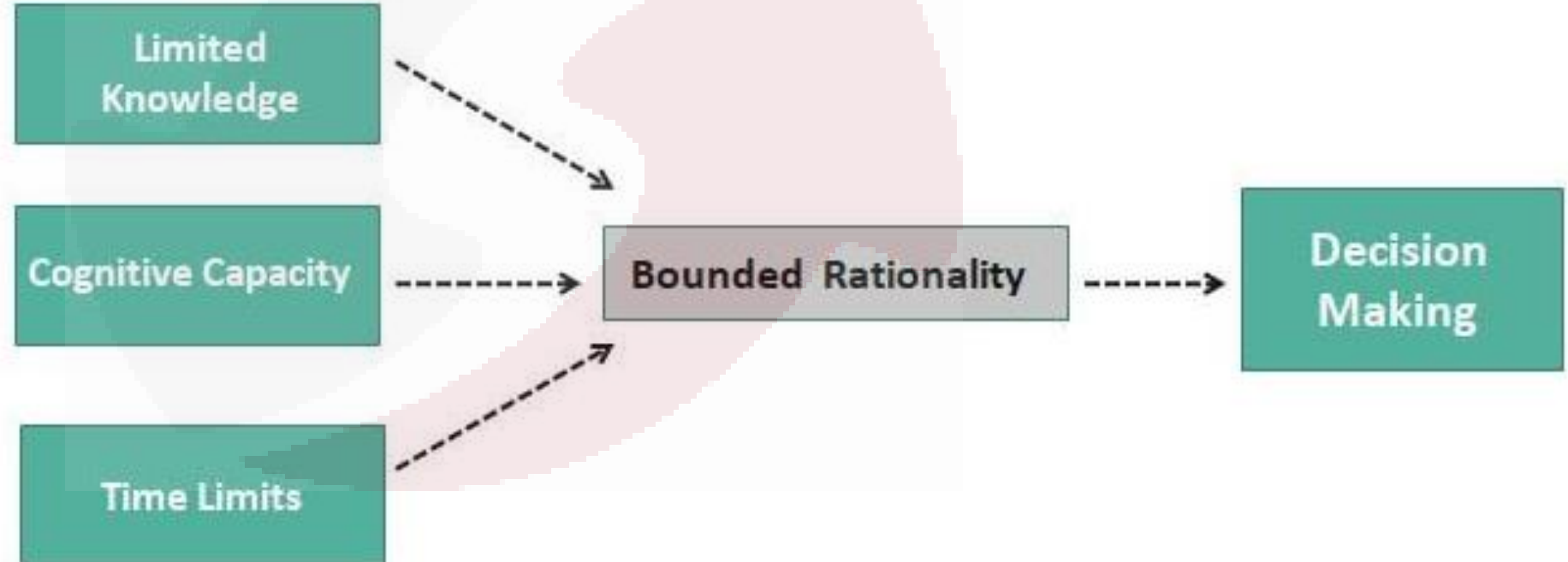
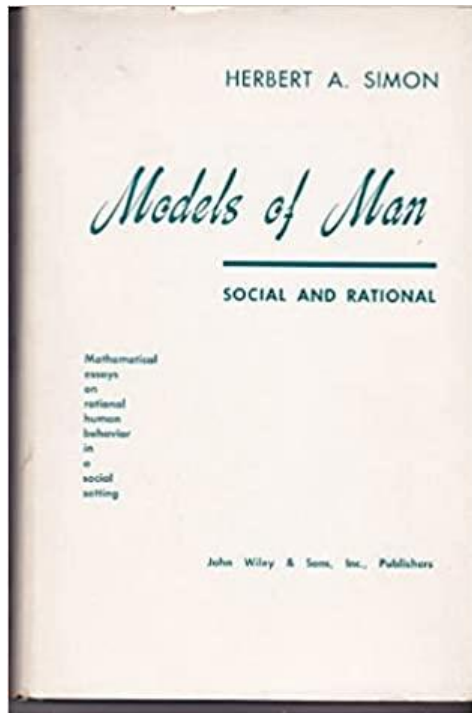
- From a financial stability policy viewpoint, the right balance between cost efficiency and a competitive and stable banking environment is an important consideration.
- These results highlight **the need to evaluate the sustainability of bank profitability.**
- **An over-reliance on leverage and wholesale funding are associated with higher idiosyncratic and contribution to systemic risks and thereby lower financial stability.**
- Policy makers and financial stability authorities should pay more attention to the source and the sustainability of bank profitability in the design and the calibration of macroprudential stress tests and systemic risk analysis.
- Banking system is the one of the most complex systems that several internal and external factors intertwined together in a dynamic environment creating a potential misjudgement in strategic planning process



Literature Review & Systematic Thinking



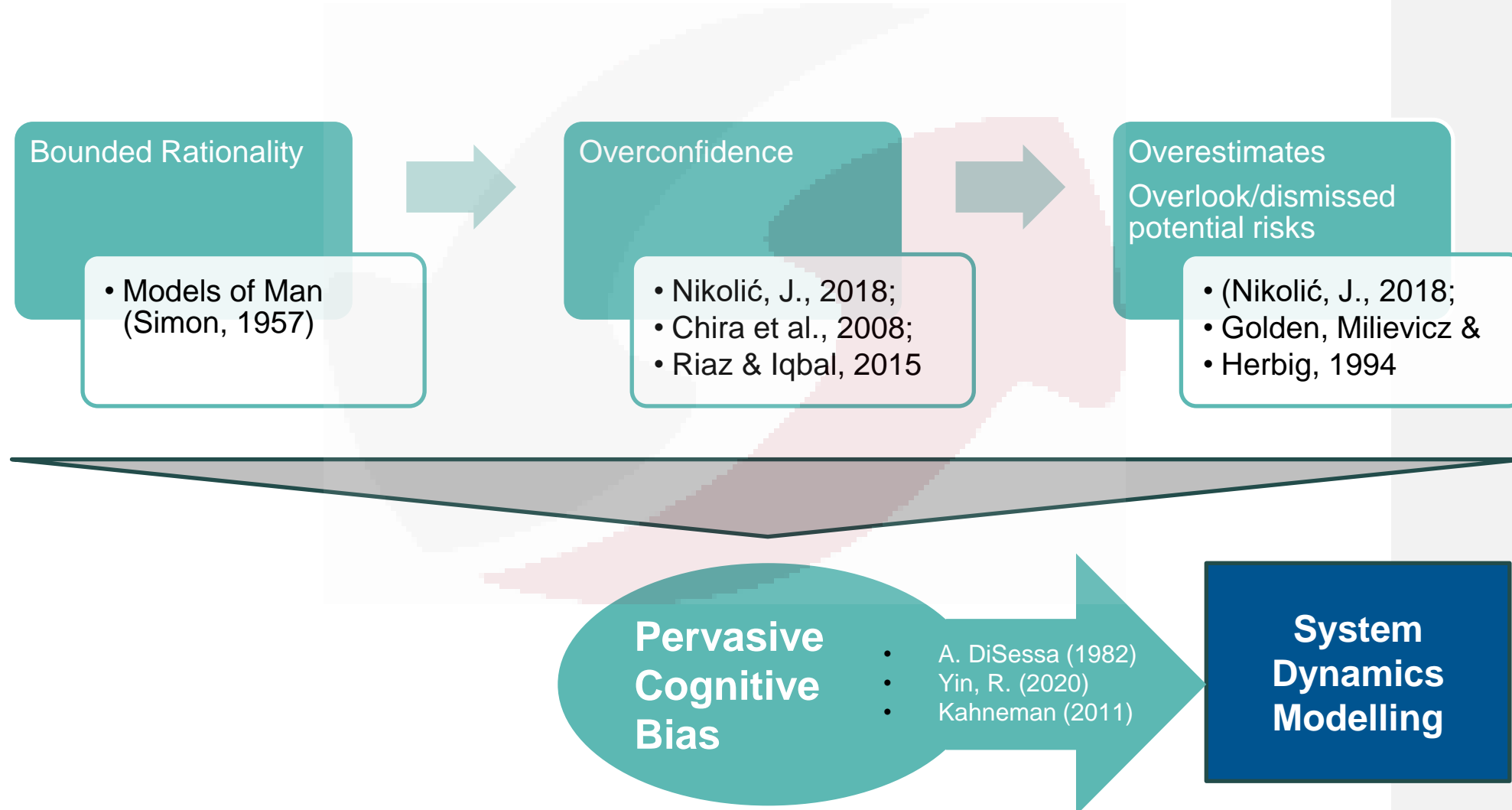
Insufficient Simulation to Support Bank Strategic Planning Process



Source: Bounded Rationality (Simon, 1957)

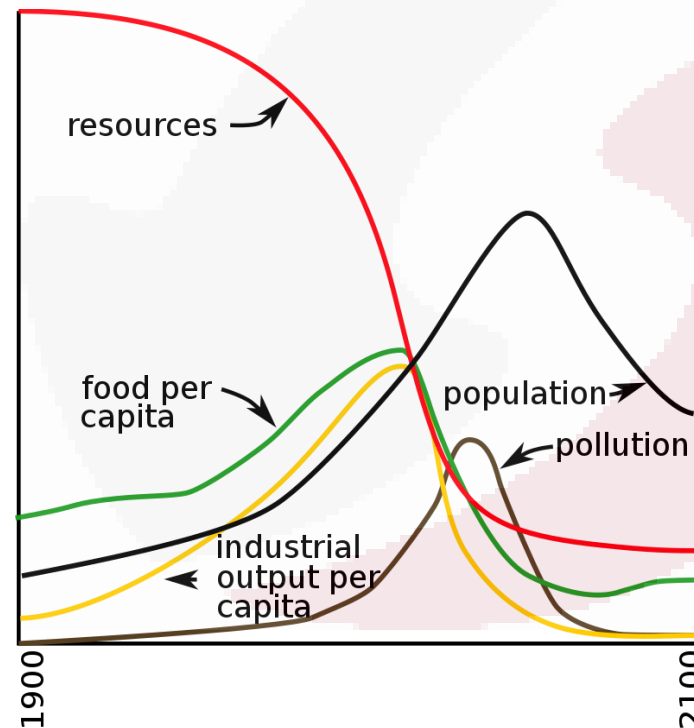
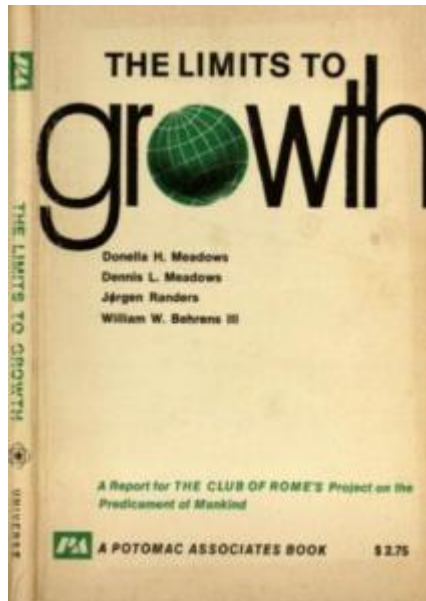


Systematic Thinking





Low Interest Rate Fund is the Limited Resource



Source: Limits to Growth (Meadows et. al., 1972)

Using the World3 Model derived from World Dynamics and Industrial Dynamics (Forrester, 1971)

Growth depends on the availability of resources. If there are still resources, they can continue to grow and support sustainability. However, bank management's social intervention (bounded rationality) causes losses due to the need to look for alternative funding resources.

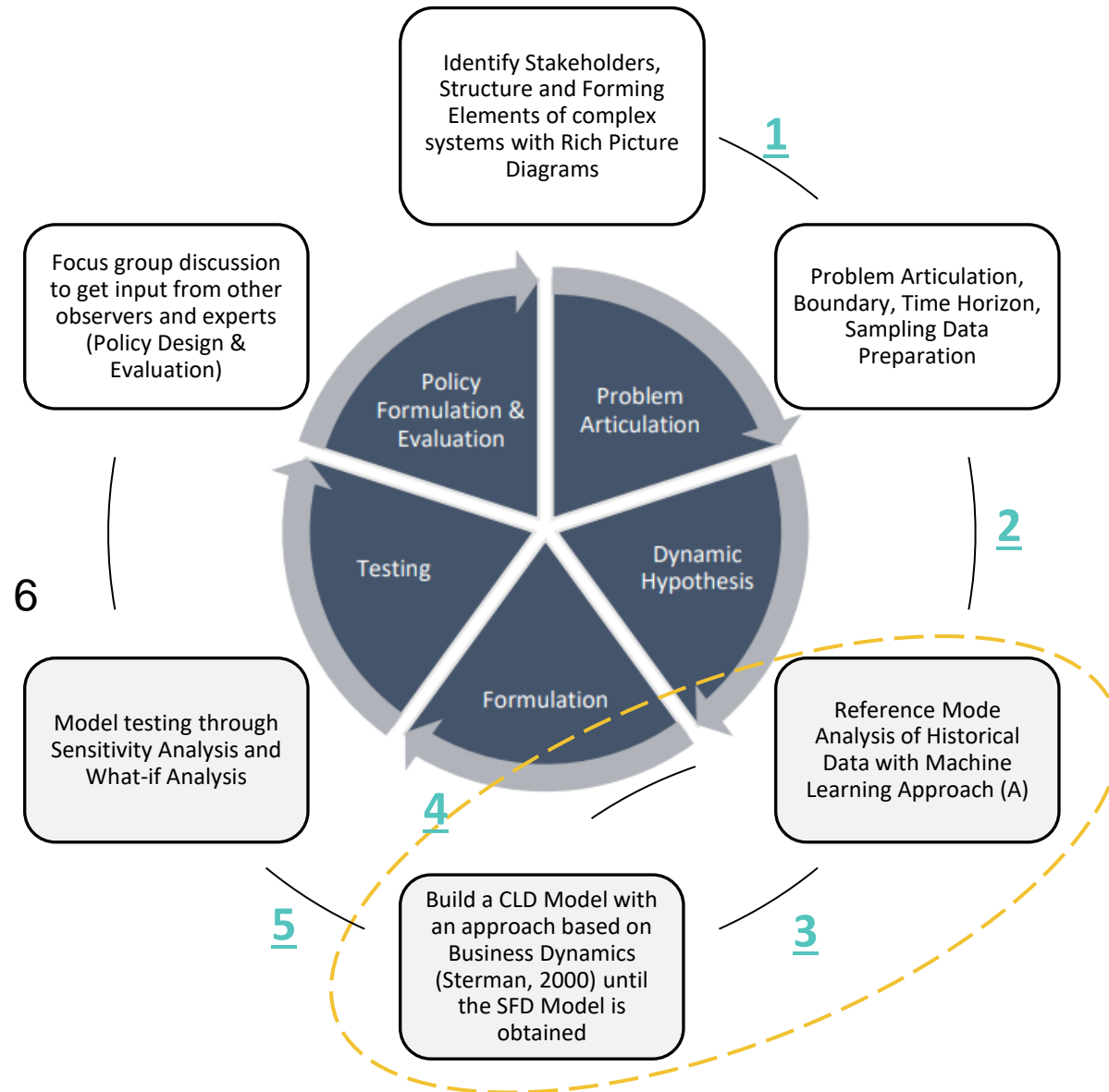
Alternative funding resources (high interest rate/rare):

1. Interbank Borrowing (high interest rate)
2. Government capital injection (rate)
3. Wholesale/corporate deposits (high interest rate)
4. Loans are given to existing debtors (low margin/non productive loan)



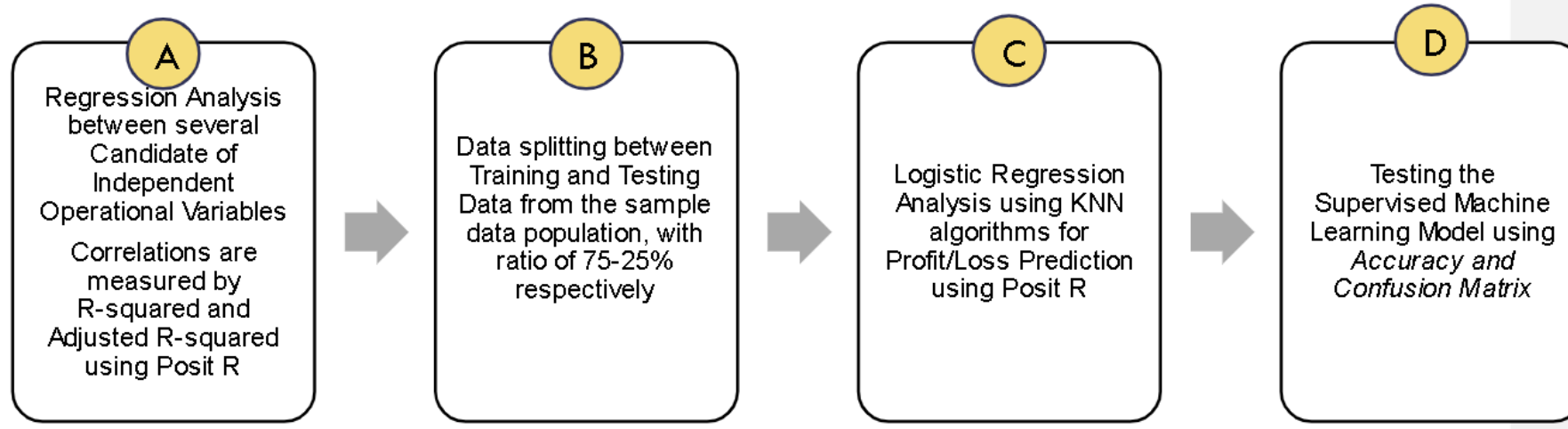
Research Methodology

Research Methodology

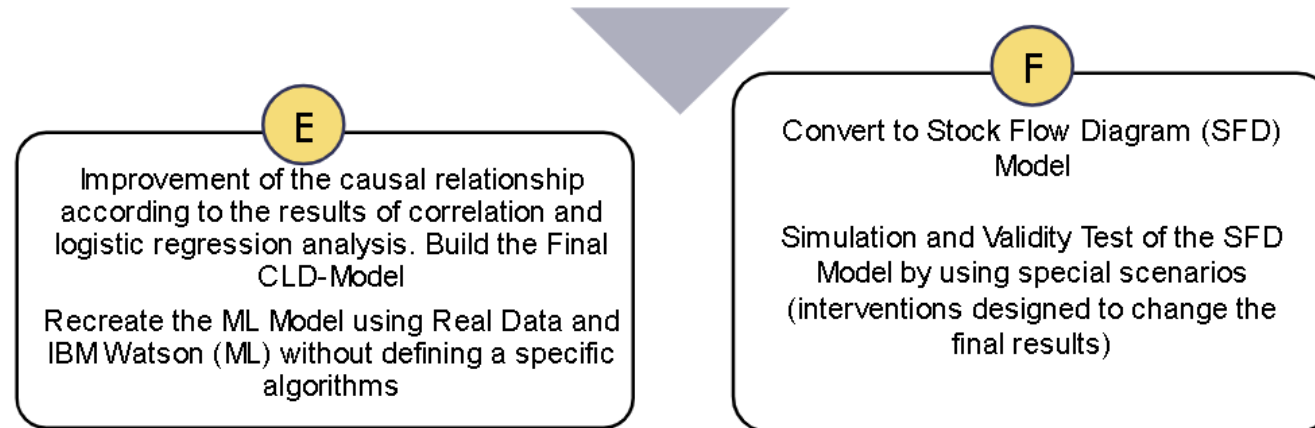


This research is basically carried out in the form of an iterative cycle to obtain model optimization using references from Business Dynamics (Sterman, 2000)

Research Methodology (steps 3-5)

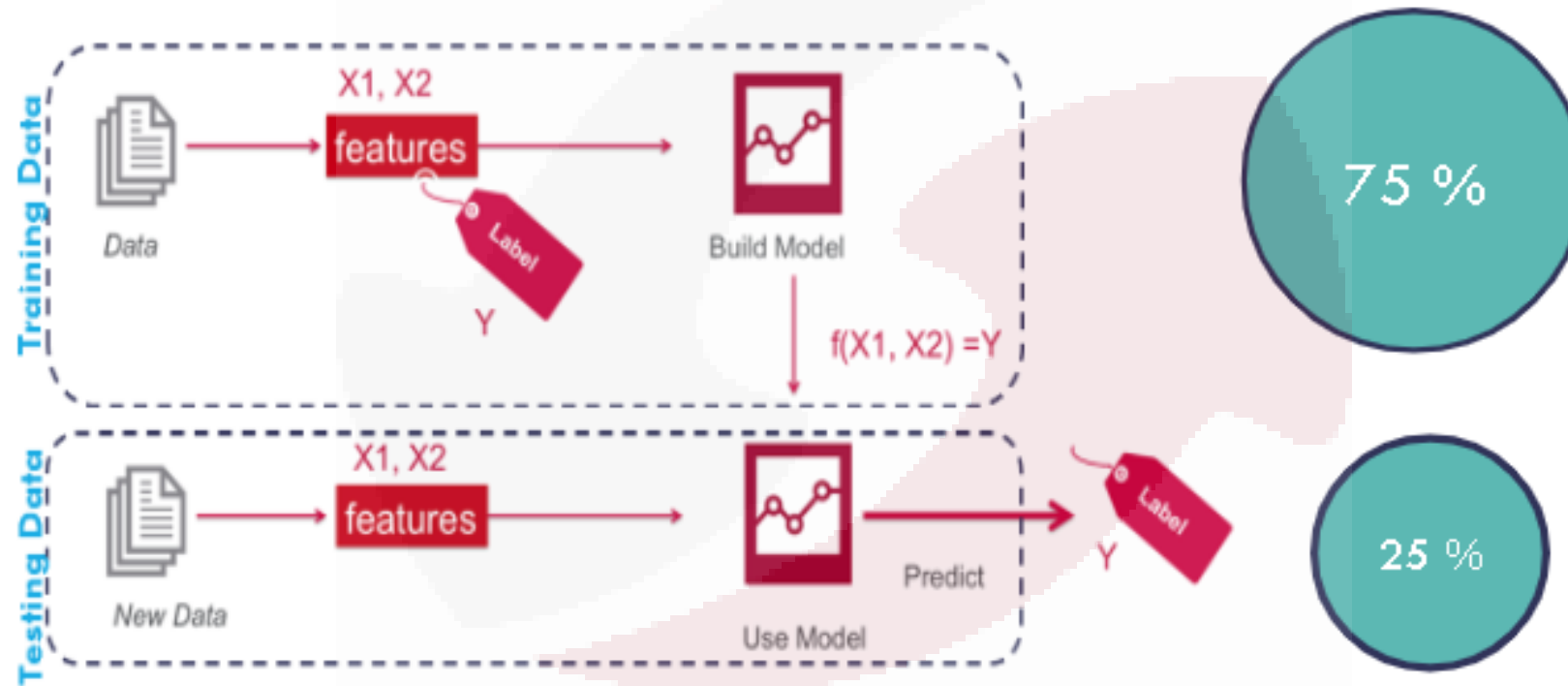


Machine Learning based Causal Loop Diagram (CLD)



Splitting Data Into Training and Testing

Splitting Data into 2 groups of Training Data to form a model according to the programmed algorithm.



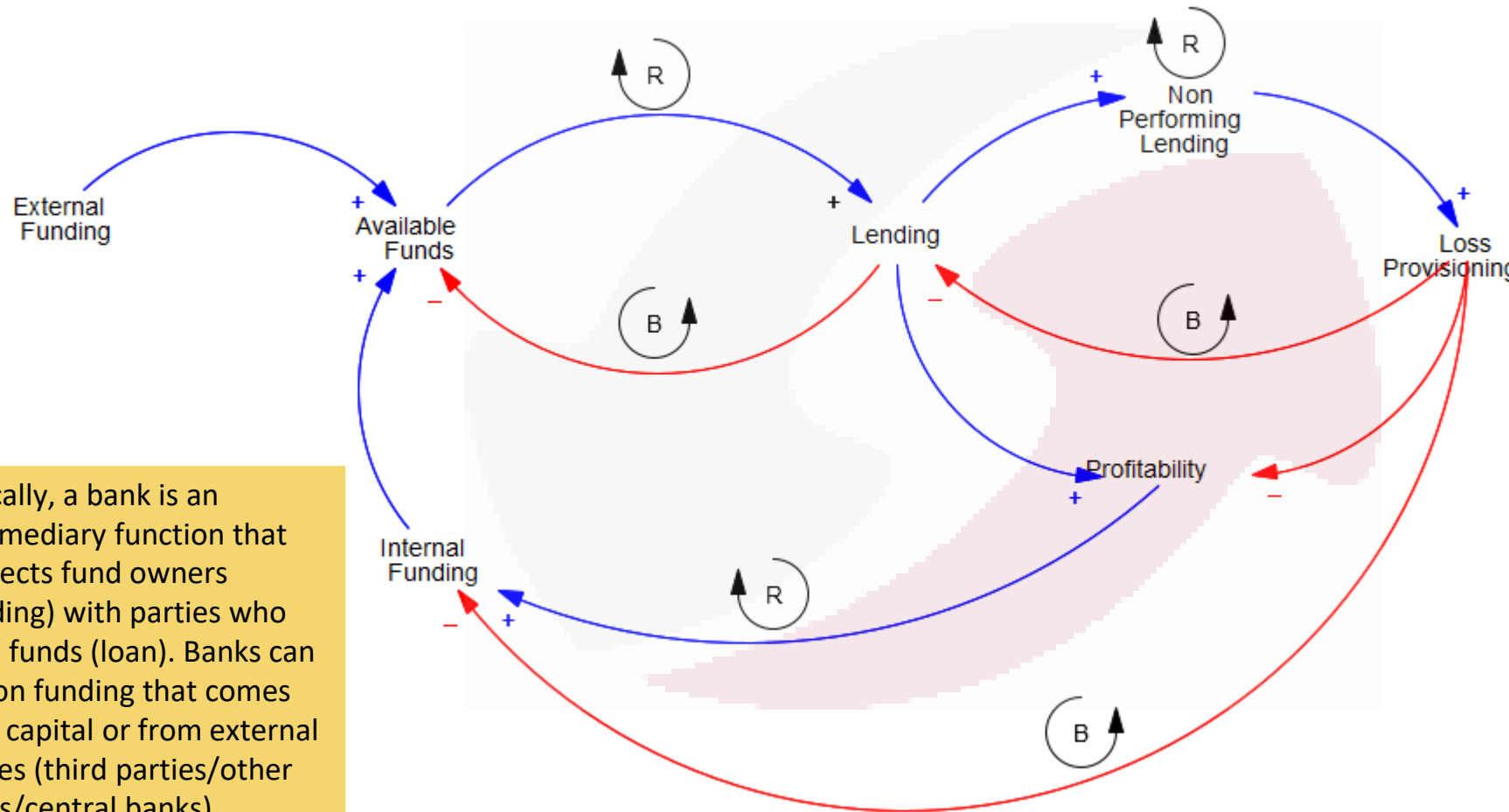
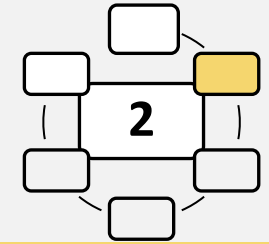
Testing is simultaneously carried out by the program in the Testing Data group, and displays the results in the Confusion Matrix



Results



Initial Causal Loop Diagram



Basically, a bank is an intermediary function that connects fund owners (funding) with parties who need funds (loan). Banks can rely on funding that comes from capital or from external parties (third parties/other banks/central banks)

Reinforcements and Balancings occurred in the performance system which is the core to create the system behaviors.

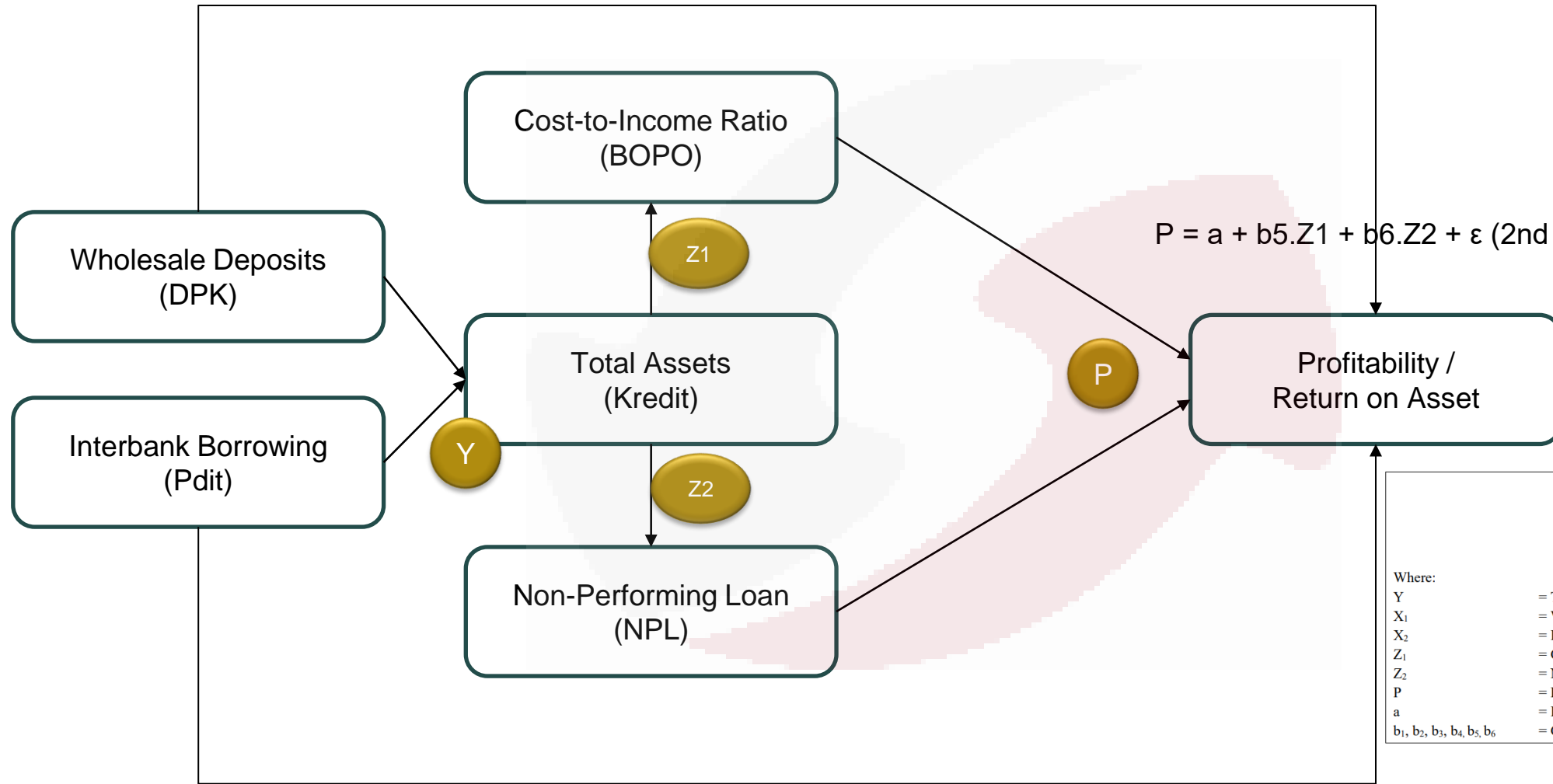
A good bank is able to create a control strategy that allows it to see not only reinforcement factors but also balancing factors.

The limits/restrictions that exist at each bank determine the strength of the balancing.



Interlinked Operational Variables as Dynamic Hypothesis

This interlinked variables structure represent the complexity of decision making in the Banking credit risk management



$$P = a + b_5.Z_1 + b_6.Z_2 + \epsilon \text{ (2nd Hypothesis)}$$

$$Y = a + b_1.X_1 + b_2.X_2 + \epsilon \text{ (1st Hypothesis)}$$

$$Z_1 = a + b_3.Y + \epsilon$$

$$Z_2 = a + b_4.Y + \epsilon$$

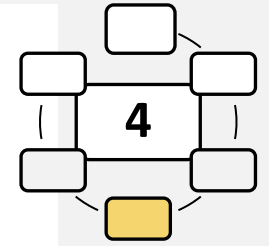
$$P = a + b_5.Z_1 + b_6.Z_2 + \epsilon \text{ (2nd Hypothesis)}$$

- Where:
- Y = Total Assets
 - X₁ = Wholesale Deposits
 - X₂ = Interbank Borrowings
 - Z₁ = Cost-to-Income Ratio
 - Z₂ = Non-Performing Loan
 - P = Profitability (Return-on-Asset)
 - a = Intercept
 - b₁, b₂, b₃, b₄, b₅, b₆ = Coefficients

Y $Y = a + b_1.X_1 + b_2.X_2 + \epsilon \text{ (1st Hypothesis)}$

Z1 $Z_1 = a + b_3.Y + \epsilon$

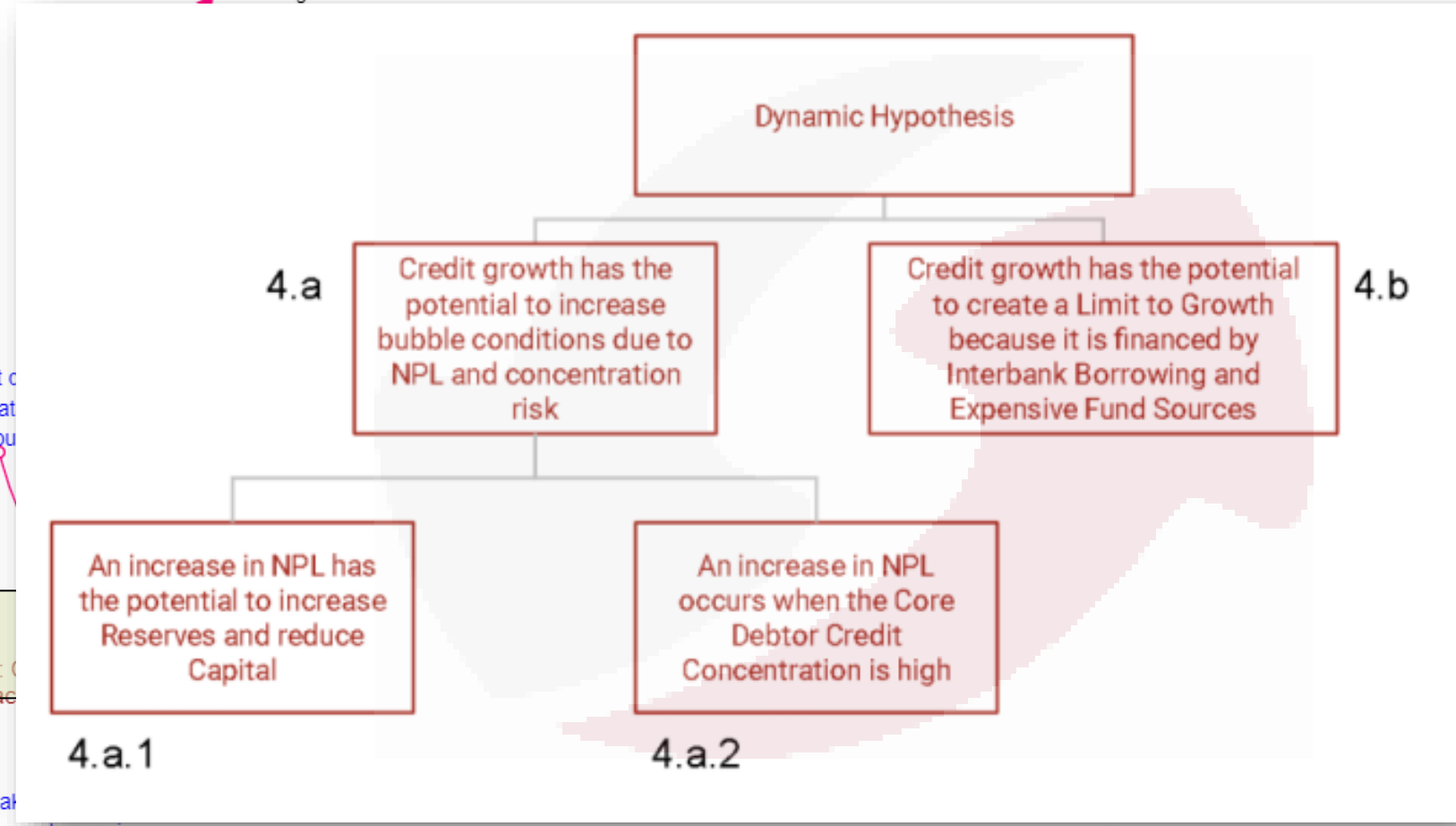
Z2 $Z_2 = a + b_4.Y + \epsilon$



Cek RBB dan atau Annual Report sbmlm ada ekspansi kredit
 Target growth ambisius dlm waktu singkat

Total Asset vs Total Kredit dalam 3 sd 5 tahun sebelum kerugian

- Reference mode:
- | | | | |
|---|--|---|---|
| 1 | Ekspansi kredit dalam 3 sd 5 tahun terakhir sbmlm kerugian | 1 | Total Asset dan Total Kredit meningkat |
| 2 | Peningkatan konsentrasi pada debitur inti sbmlm kerugian | 2 | Persentase Debitur Inti vs Total Kredit meningkat |
| 3 | Peningkatan pinjaman antar Bank sbmlm kerugian | 3 | BOPO meningkat |
| 4 | Peningkatan komposisi deposito dlm komposisi pendanaan | 4 | NIM menurun |



al yang ga/B17RR (a beli turun)

Pendanaan cepat Antar Bank dan at Korporasi berbu

Cluster: Adequate Buffer

Modal Bank tidak untuk mendukung ekspansi, shareholder tidak mau menambah modal

CAR Bank dalam 3 sd 5 tahun terakhir tidak terlalu besar (<20%)

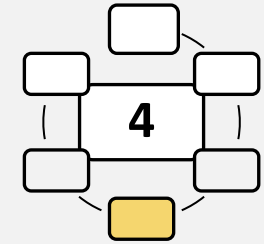
Kerugian Bank

Dynamic Hypothesis Causal Loop Diagram

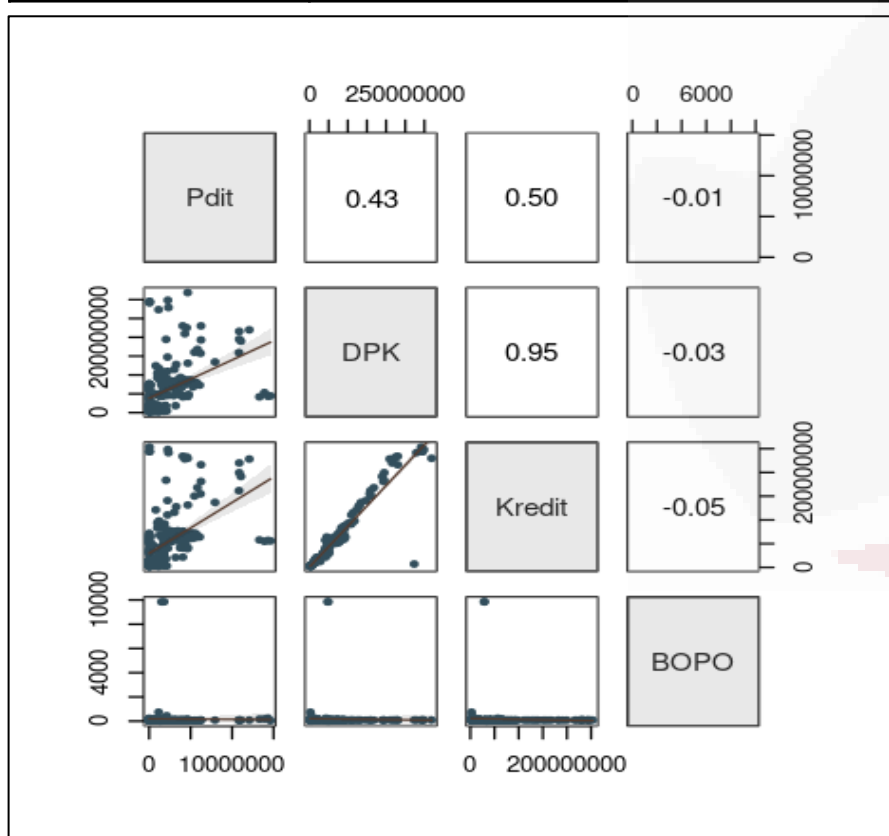
Reference Model Utama



Correlation Analysis



Cluster	Efficiency Factor
Independent Variable	BOPO_pos, Pdit_pos, DPK_pos, Kredit
Dependent Variable	Pdit_pos



Standard deviation of Pdit: 2,692,796.036

Standard deviation of residuals: 2,304,150.043 for 238 degrees of freedom
 95% range of residual variation: 9,078,266.052 = 2 * (1.970 * 2,304,150.043)

R-squared: 0.277 Adjusted R-squared: 0.268 PRESS R-squared: -0.036

Null hypothesis of all 0 population slope coefficients:
 F-statistic: 30.386 df: 3 and 238 p-value: 0.000

-- Analysis of Variance

	df	Sum Sq	Mean Sq	F-value	p-value
DPK	1	322695199590051.062	322695199590051.062	60.781	0.000
Kredit	1	160544845582534.625	160544845582534.625	30.240	0.000
BOPO	1	719656712537.802	719656712537.802	0.136	0.713
Model	3	483959701885123.500	161319900628374.500	30.386	0.000
Residuals	238	1263567566132339.250	5309107420724.114		
Pdit	241	1747527268017462.750	7251150489699.016		

-- Correlation Matrix

	Pdit	DPK	Kredit	BOPO
Pdit	1.00	0.43	0.50	-0.01
DPK	0.43	1.00	0.95	-0.03
Kredit	0.50	0.95	1.00	-0.05
BOPO	-0.01	-0.03	-0.05	1.00

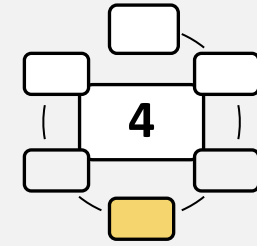
-- Collinearity

	Tolerance	VIF
DPK	0.094	10.602
Kredit	0.094	10.617
BOPO	0.995	1.005

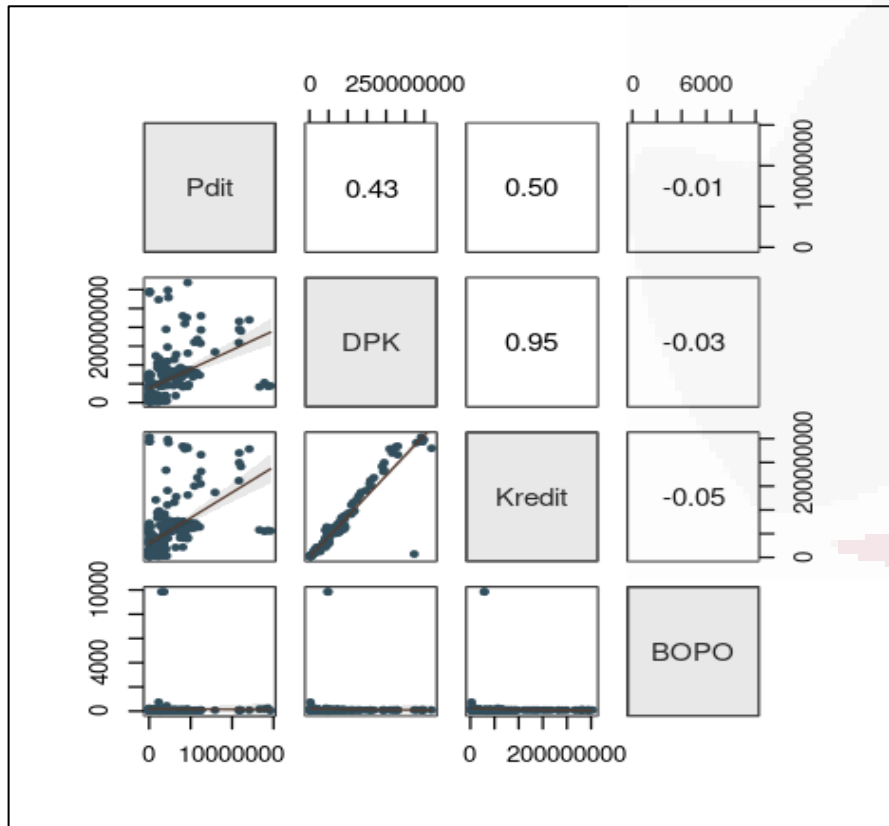
Causal-Loop: Third Party Fund (DPK) and Lon have a positive correlation with Interbank Borrowing (Pdit), meaning that Pdit increases along with an increase in Loan. This explains that during the Loan Growth, funding sources from DPK and also from Interbank Borrowing (Pdit) are required.



Correlation Analysis



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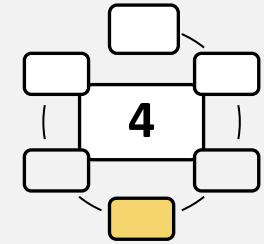
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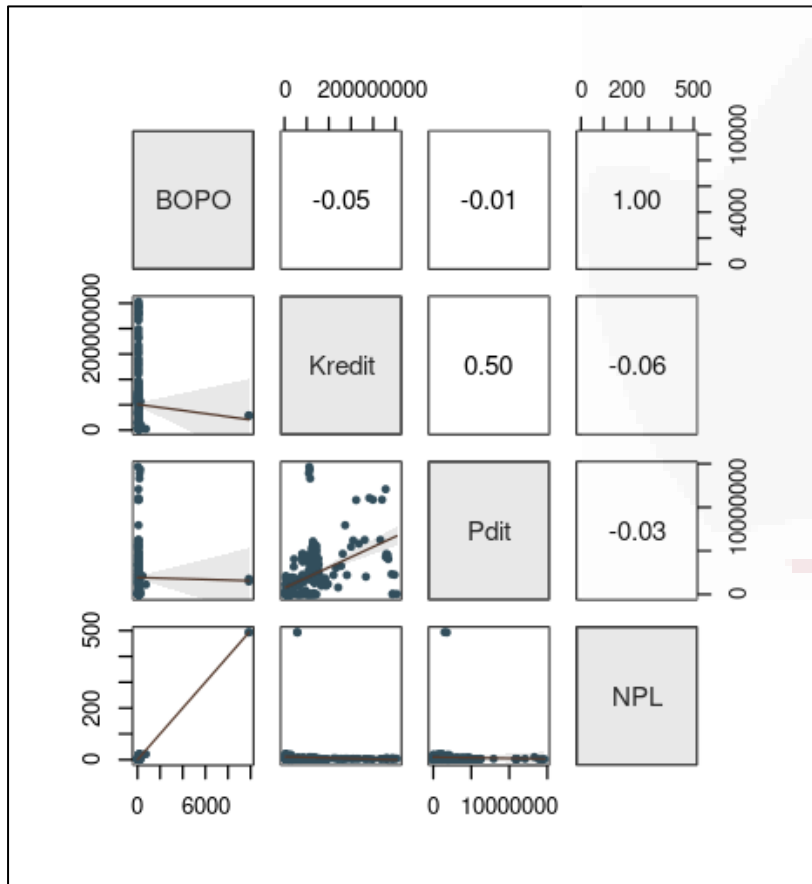
Causal-Loop: Meanwhile, on CIR, the influence of Pdit, DPK and Loan is small, so it is necessary to look for other intermediary variable(s). The R-Squared of this model is 0.277, and it can be seen that the correlation between CIR and 3 other variables is below 0.1. Apart from that, there is multicollinearity between DPK and Loan.



Correlation Analysis



Cluster	Efficiency Factor
Independent Variable	Kredit_pos, Pdit_pos, NPL
Dependent Variable	BOPO_pos



Standard deviation of BOPO: 764.758

Standard deviation of residuals: 67.642 for 238 degrees of freedom
 95% range of residual variation: 266.506 = 2 * (1.970 * 67.642)

R-squared: 0.994 Adjusted R-squared: 0.994 PRESS R-squared: 0.994

Null hypothesis of all 0 population slope coefficients:
 F-statistic: 13705.324 df: 3 and 238 p-value: 0.000

-- Analysis of Variance

	df	Sum Sq	Mean Sq	F-value	p-value
Kredit	1	419435.773	419435.773	91.672	0.000
Pdit	1	32984.210	32984.210	7.209	0.008
NPL	1	187669364.698	187669364.698	41017.091	0.000
Model	3	188121784.680	62707261.560	13705.324	0.000
Residuals	238	1088943.845	4575.394		
BOPO	241	189210728.525	785106.757		

-- Correlation Matrix

	BOPO	Kredit	Pdit	NPL
BOPO	1.00	-0.05	-0.01	1.00
Kredit	-0.05	1.00	0.50	-0.06
Pdit	-0.01	0.50	1.00	-0.03
NPL	1.00	-0.06	-0.03	1.00

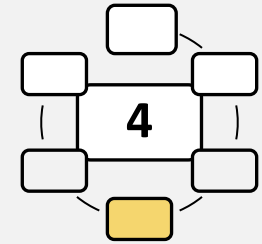
-- Collinearity

	Tolerance	VIF
Kredit	0.746	1.341
Pdit	0.748	1.337
NPL	0.996	1.004

Causal-Loop: NPL variable is added into the model. It can be seen that r-squared has increased to 0.994 because NPL affects CIR very significantly. This shows that in the causality model, the role of NPL is very high in influencing CIR. The interconnection between DPK, Loan, Pdit to CIR and then to Profit, is influenced by NPL.



Supervised Machine Learning KNN - Predicting Profit/Loss



Deskripsi	<ul style="list-style-type: none"> · Melakukan pemisahan data training dan data testing (split) · Melakukan klasifikasi dengan ROA positif dan negatif pada data training (positif/profit = 1, loss/negatif = 0) · Melakukan prediksi ROA pada data testing dengan model yang dibentuk dari data training menggunakan algoritma KNN/SVM
Label Kelas	ROA (positive class = kerugian (dikonversi menjadi 0))
Nearest Neighbors	BOPO, CAR, NPL
Hasil	Confusion Matrix dan Accuracy

```

dataworktest_target
m1      0      1
0 105      2
1      1     77

```

Confusion Matrix

```

Accuracy : 0.9838
95% CI : (0.9533, 0.9966)
No Information Rate : 0.573

Kappa : 0.9668

Sensitivity : 0.9906
Specificity : 0.9747
Pos Pred Value : 0.9813
Neg Pred Value : 0.9872
Prevalence : 0.5730
Detection Rate : 0.5676
Detection Prevalence : 0.5784
Balanced Accuracy : 0.9826

'Positive' Class : 0

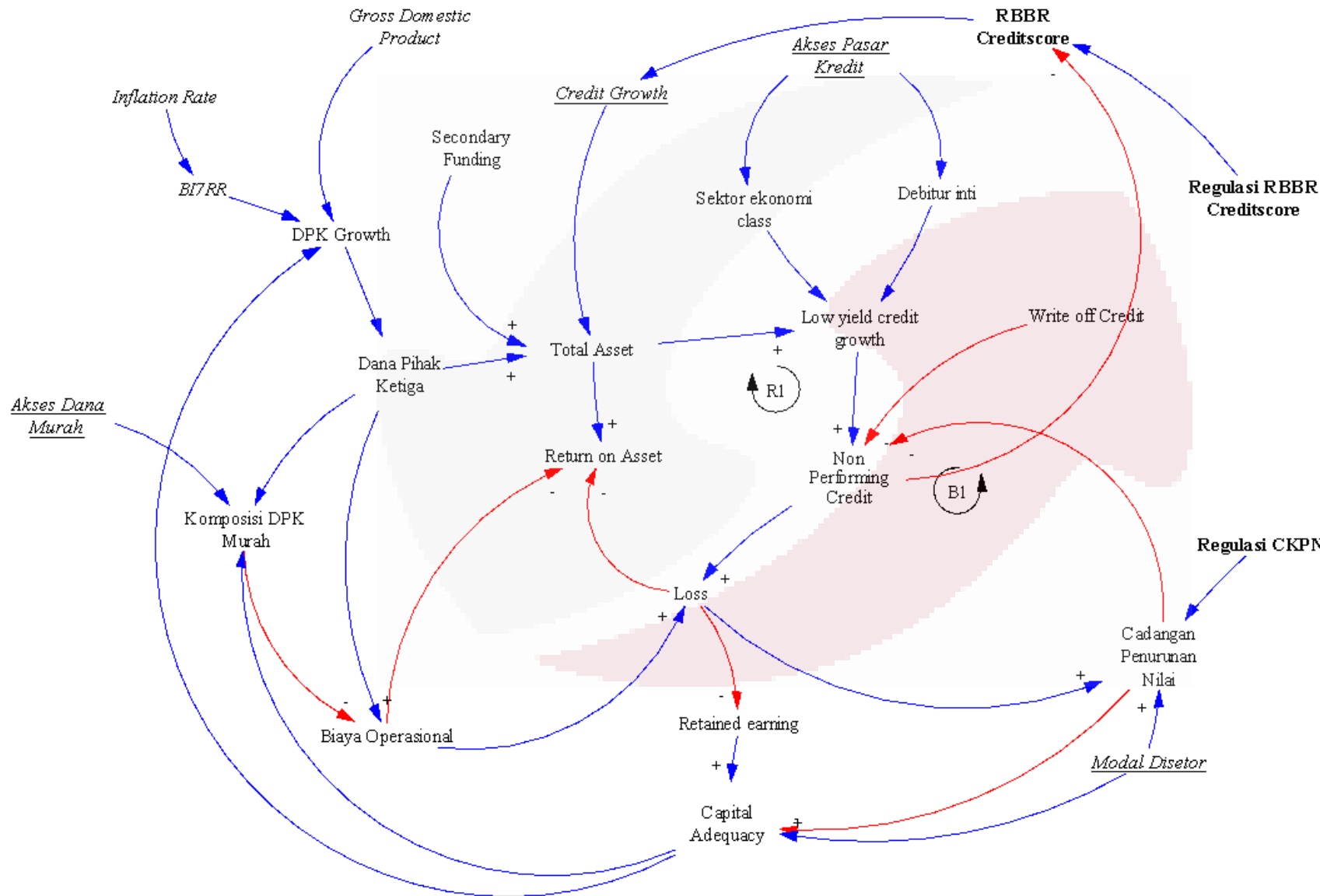
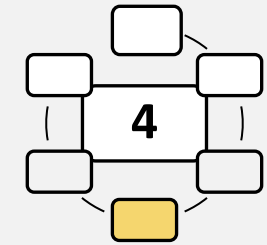
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Accuracy

Causal-Loop: ROA or Profitability can be predicted very well with an accuracy of 0.9838 using model generated from dataset in research samples. There were only 3 errors from testing from the testing dataset of 185 records, out of 738 total records in the sample.



Final Causal Loop Diagram



Revising the relationship between Non-Performing Credit/Loan (NPL) by adding a loop of influence from NPL can influence credit growth determined by bank management.

Added a relationship to Operational Costs

Added relationship with CKPN and Capital Adequacy



Decision Making Dynamic Model

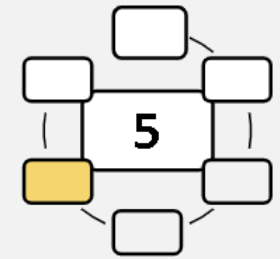
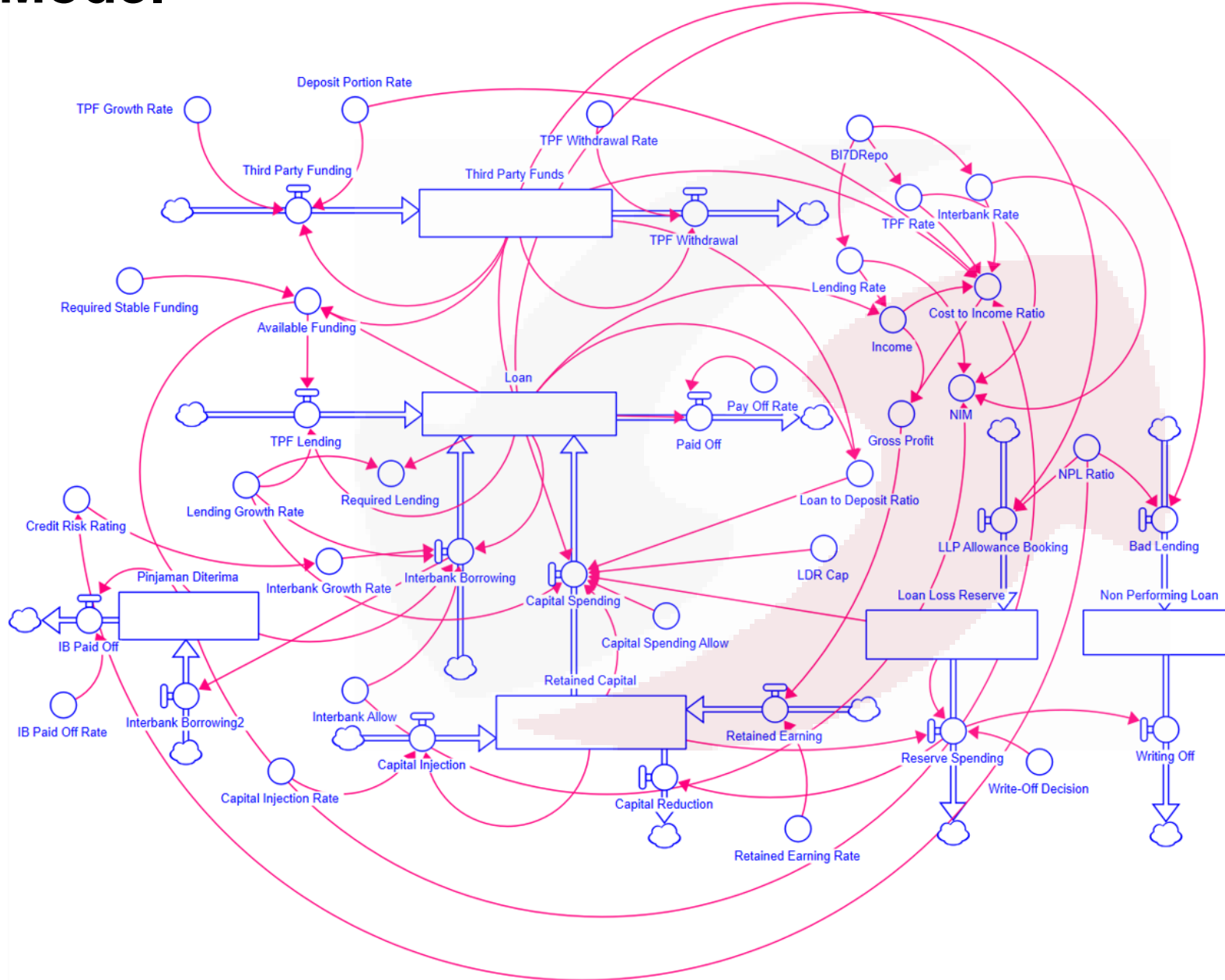
Variables	Description	Causal Loop Relationship	Supervised Machine Learning Regression - 1	R-Squared 1	R-Squared 1 (add)	Supervised Machine Learning Regression - 1	R-Squared 2	R-Squared 2 (add)
Kredit	Credit/Loan	Initial	Independent	0.822	0.916	Dependent	0.277	0.994
DPK	Third-party funds	Initial	Dependent			Dependent		
Pdit	Interbank Borrowing	Additional	Dependent	n/a		Dependent		
BOPO	Cost to Income Ratio	Initial	n/a	n/a	n/a	Independent		
NPL	Non-performing Loan	Additional	n/a	n/a	n/a	Dependent	n/a	

Fig 5. Gradual Cause-Effect Relationships Enhancement using MRA and SVM

At the end, it is confirmed that banks whose credit risk management are not able to control the NPL will end up with underperformance situation more deepened than banks with ability to manage credit risk properly and manage to have the low-interest rate source of funding. Applying this result to the System Dynamics modelling after gradual enhancements of cause effect relationships using Supervised Machine Learning will create a robust model for simulating the behavior planning or strategic decision



SFD Model



This model was built with the Stella Professional tool which is able to describe dynamic structures with components (primitives) in the form of stock-flow, variables and flow/links which describe the relationships between them.



System Dynamic Model Simulation Summary

No.	Scenario #	Parameters	Result	Limit to Growth
1.	High/Rapid Growth, High NPL	Credit Growth >50%, NPL >3%	High-profitability for the first 2-3 years but quickly reduced due high Cost to Income Ratio	Yes
2.	Moderate Growth, High NPL (>3%)	Credit Growth 10-15%, NPL >3%	Positive growth and profitability for more than 3 years but in the long run will be creating stress to Loan to Deposit Ratio	Yes
3.	High/Rapid Growth (>50%), Low NPL (<3%)	Credit Growth >50%, NPL <3%	Fluctuated profitability in Banks with Limit to Growth of low-interest funding and fund the growth using Interbank Borrowing/Commercial Loan	Yes
4.	Controlled Growth (Floating scenario according to the 2 nd Scenario)	Credit Growth 1-2 times higher than Funding Growth (esp. for low-interest rate)	Sustainable growth and sustainable profitability. However, the credit risk management is still another key driven factor.	Yes (2 times for Retail Deposits and Retained Earning)



Conclusion




- 1) The structure of the banking performance system is a complex and dynamic structure, so that determining a strategy can have different impacts between one bank entity and another bank.
- 2) In this dynamic banking performance system, there are phenomena that follow the nature of the Limits to Growth archetype because banks have limited cheap funds so that their ability to reinforce loan expansion is also limited (balancing).
- 3) To overcome this reinforcing factor, several banks often carry out aggressive loan expansion strategies by looking for alternative funding (externally through inter-bank borrowings and/or issuing new shares-right issues).
- 4) Banks should change their strategy by carrying out a gradual expansion/growth while observing the limits of their credit risk management and limit of their low-interest fundings. Banks need to improve credit risk management to reduce the NPL ratio and maintain efficiency (Cost to Income Ratio), as well as maintaining adequate reserves for potential losses using a forward looking approach. This is the proper growth policy that Financial Authority should create for sustainable growth.
- 5) The dynamic model of the performance system structure has been tested and can be used as a simulation tool and early warning system so that it can be used as a dynamic capability in strategic planning that supports the achievement of sustainable competitive advantage for as long as possible.

5:30-7:00

THANK YOU



5:30-7:00

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 #isdc2024

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Bergen, Norway and Virtually