Uso de modelos de simulação para estimar fator de recuperação

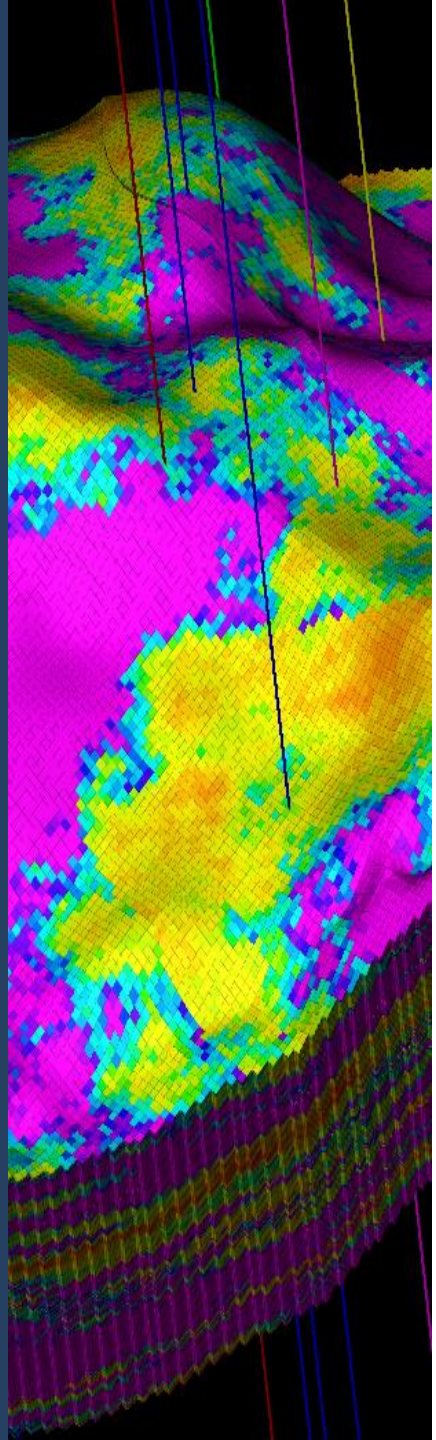
Use of reservoir simulation models to estimate recovery factor

Denis J. Schiozer

March – 2017

denis@unicamp.br

UNICAMP/CEPETRO/UNISIM



UNICAMP

ANO 50

CEPETRO

CENTRO DE ESTUDOS DE PETRÓLEO

ANO 30

UNISIM

ANO 20

Outline

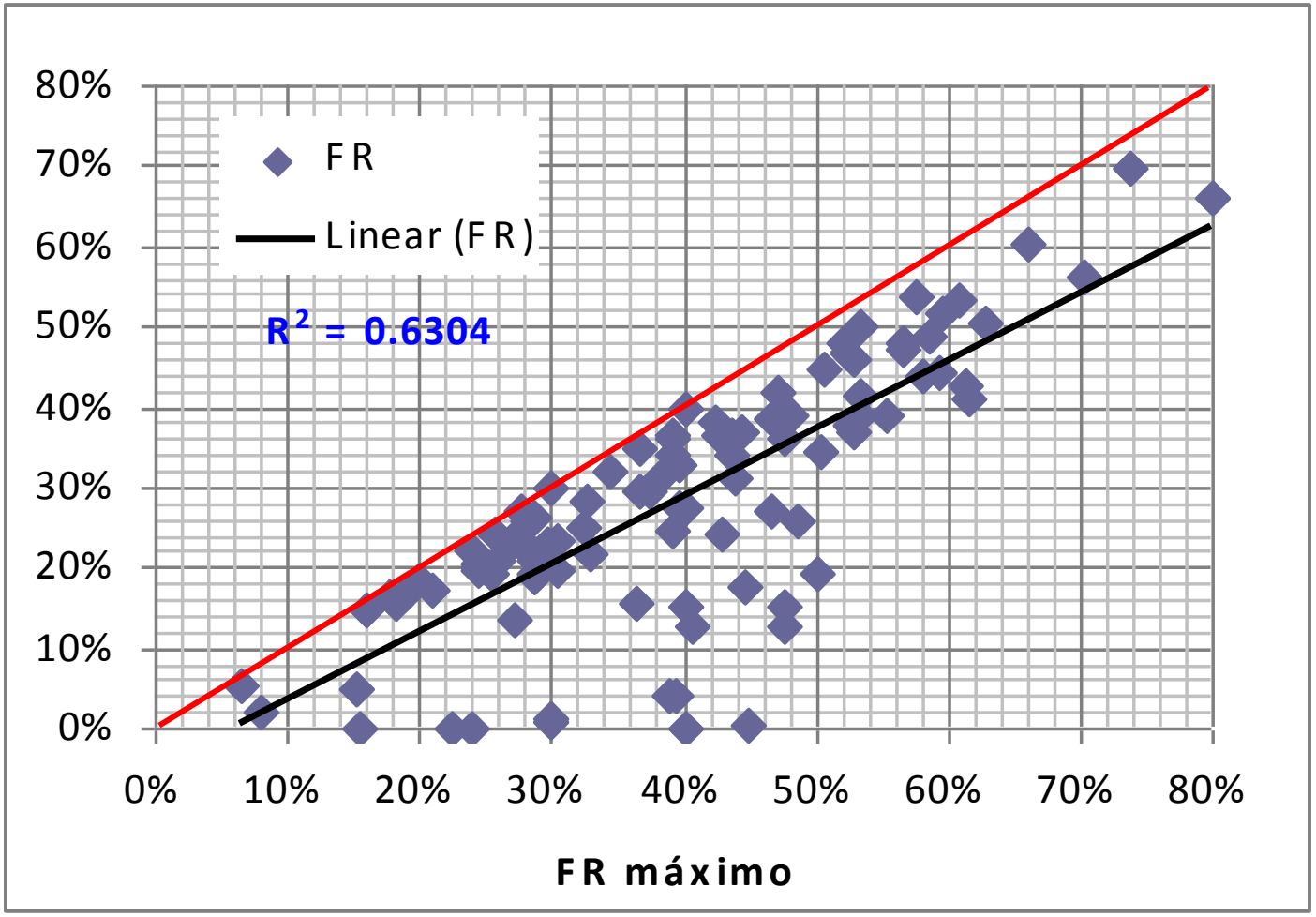
- 1) Recovery factor (RF) study
  - literature review
- 2) Model based decisions
  - Closed loop
  - NPV x RF (performance indicators)
- 3) Importance of R&D

Recovery factor study

- Based on study - literature review
- Hard to find reliable data
  - Partial description of reservoir characteristics (specific places/regional/ missing data)
- Definition RF
  - RF = Np / VOOIP
  - RF max = (Np + Expected production) / VOOIP

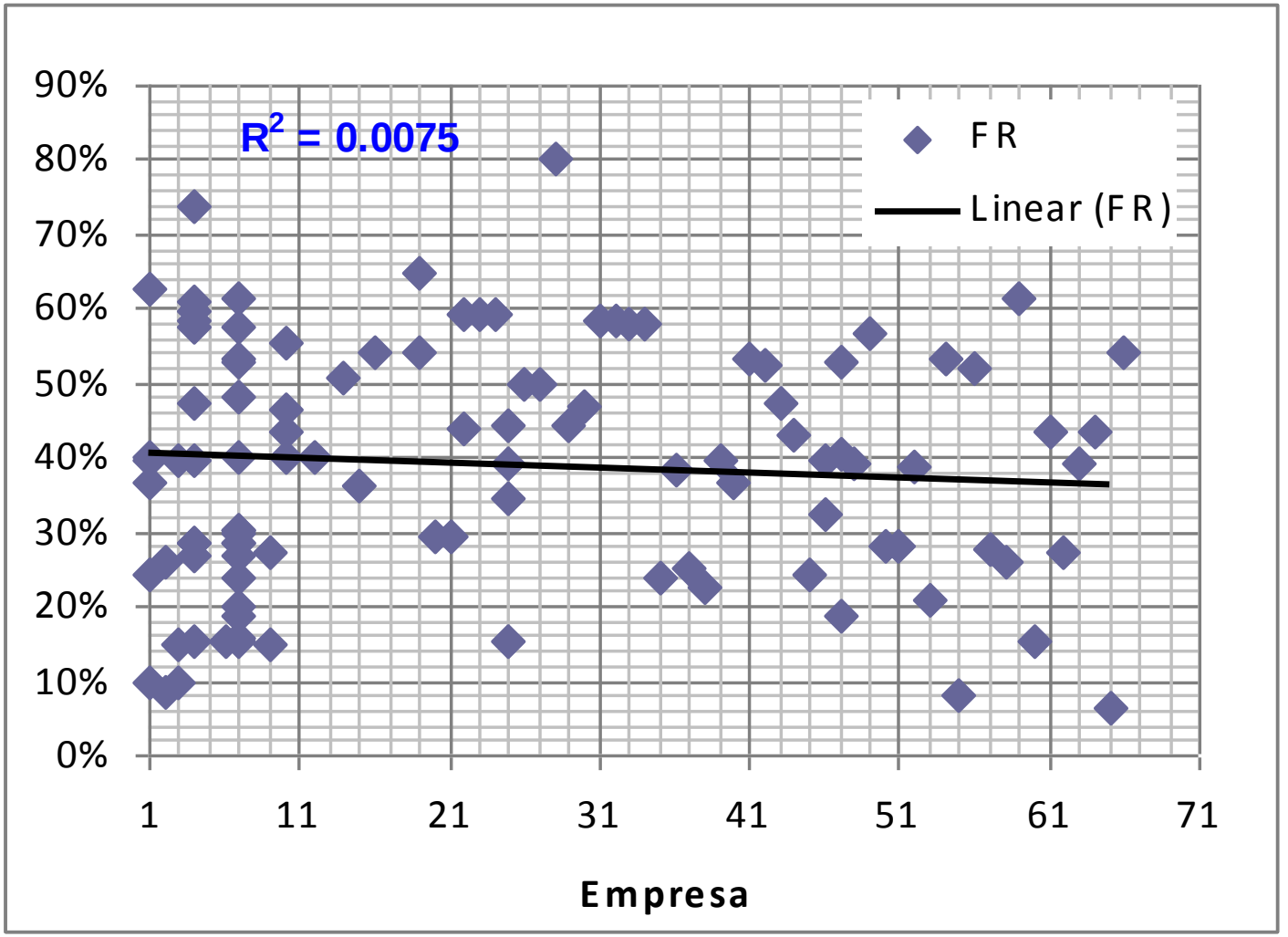
Recovery factor study

- Maximum reported FR



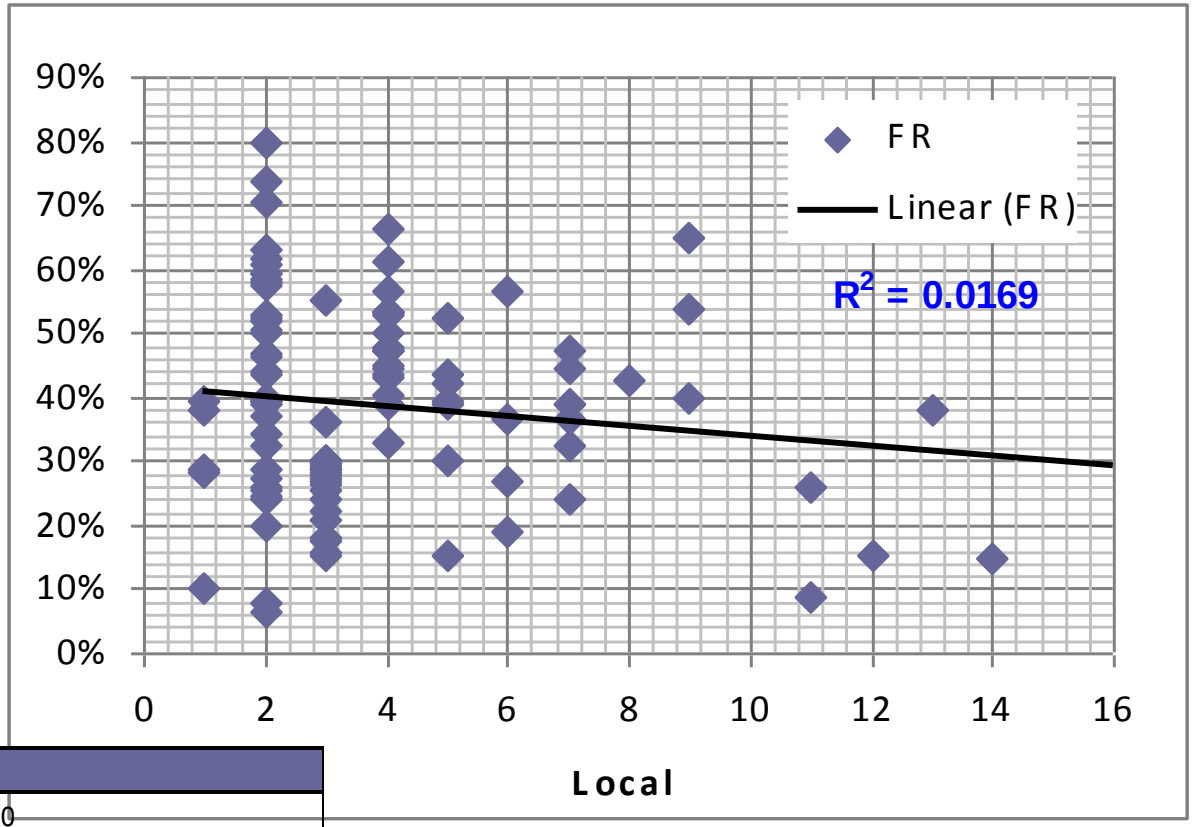
Recovery factor study

- 66 companies



Recovery factor study

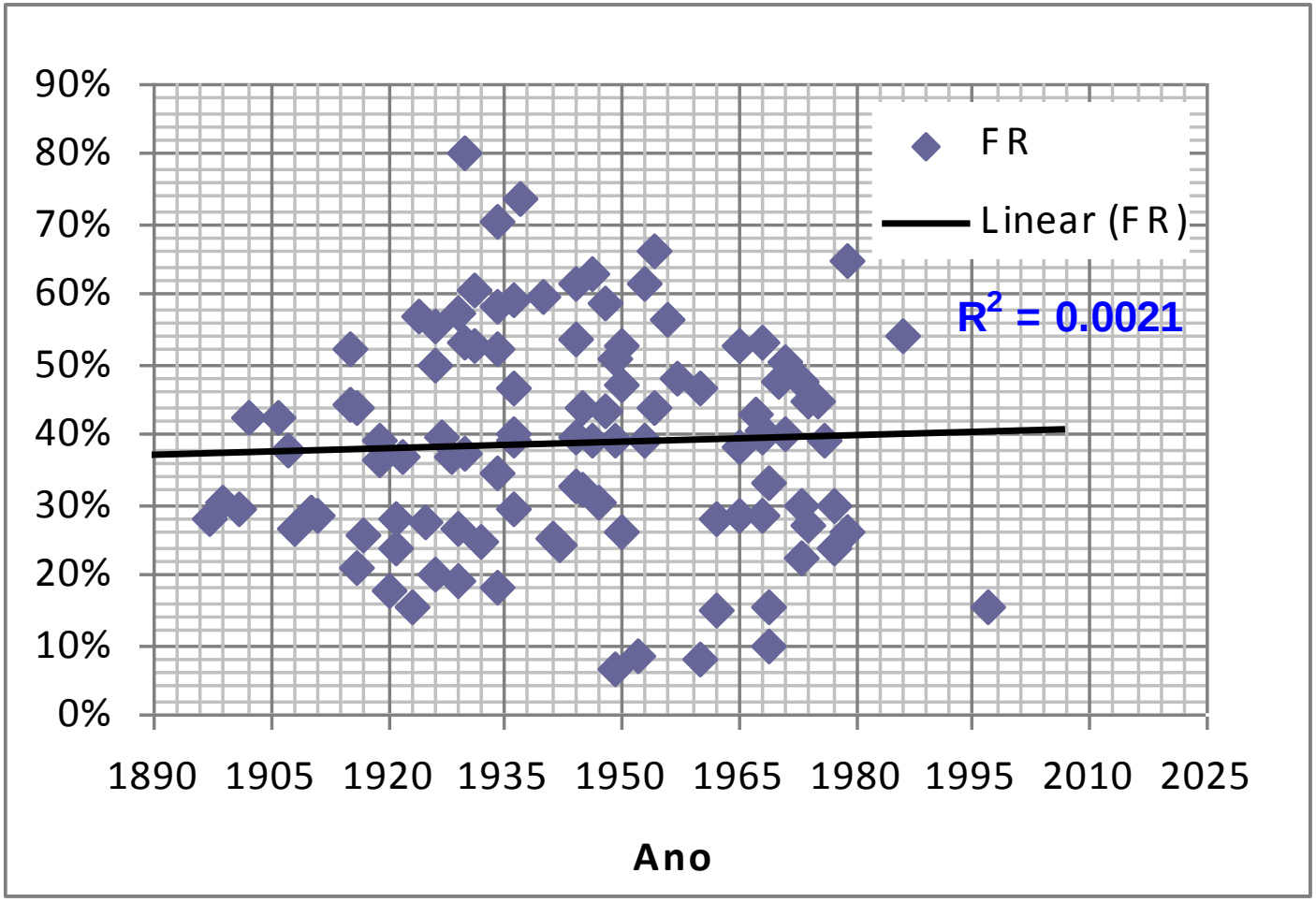
- Place



	Código Local(Região)		
1	Alaska	8	Colorado
2	Texas	9	Mar do Norte/Noruega
3	Califórnia	10	Golfo do México
4	Louisiana	11	México
5	Wyoming, Montana	12	Canadá
6	New México	13	Illinois
7	Arkansas	14	Argélia
7	Florida, Alabama, Kansas, Mississipi	15	Angola
7	Oklahoma	16	Nigéria

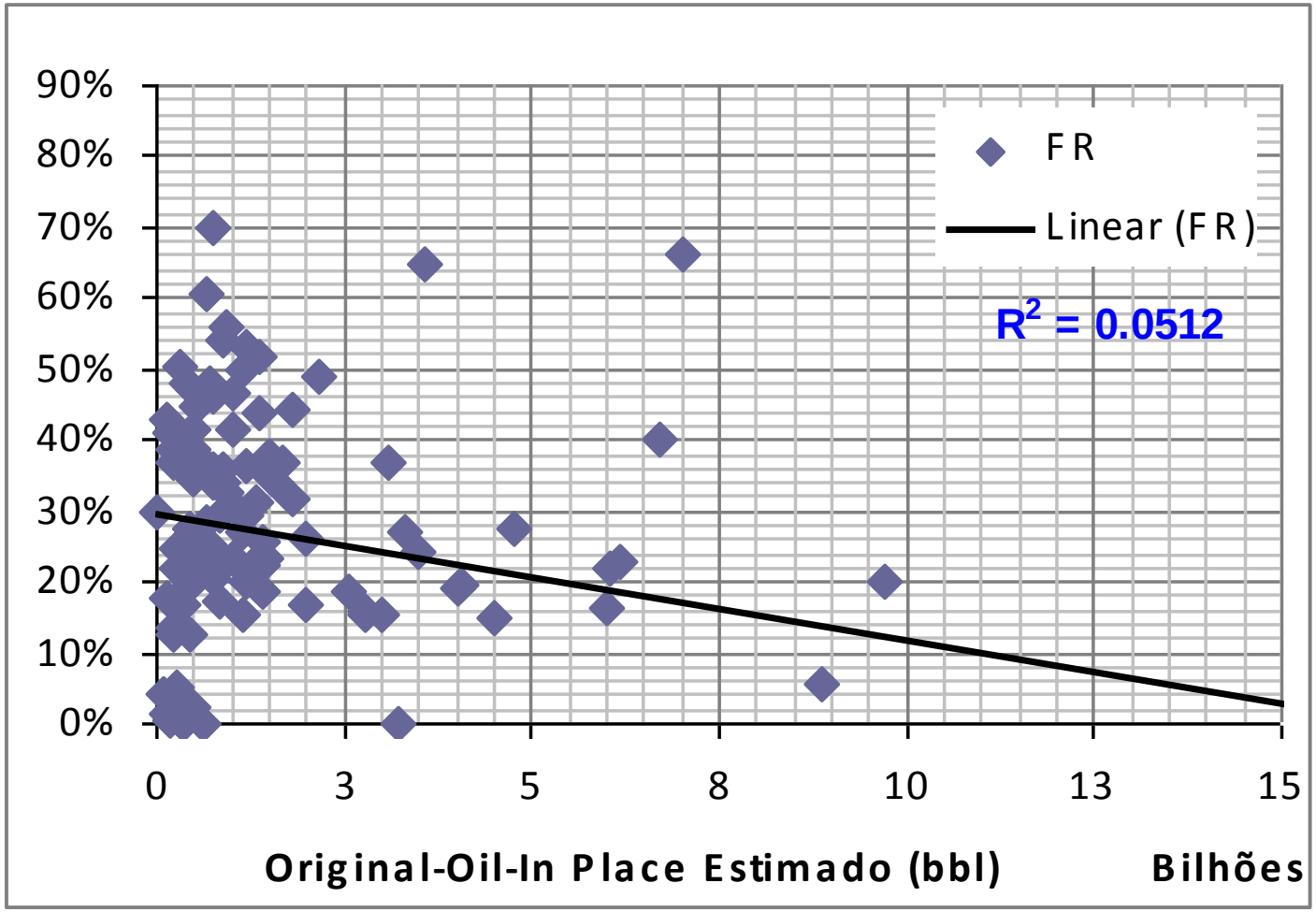
Recovery factor study

- Year of initial production



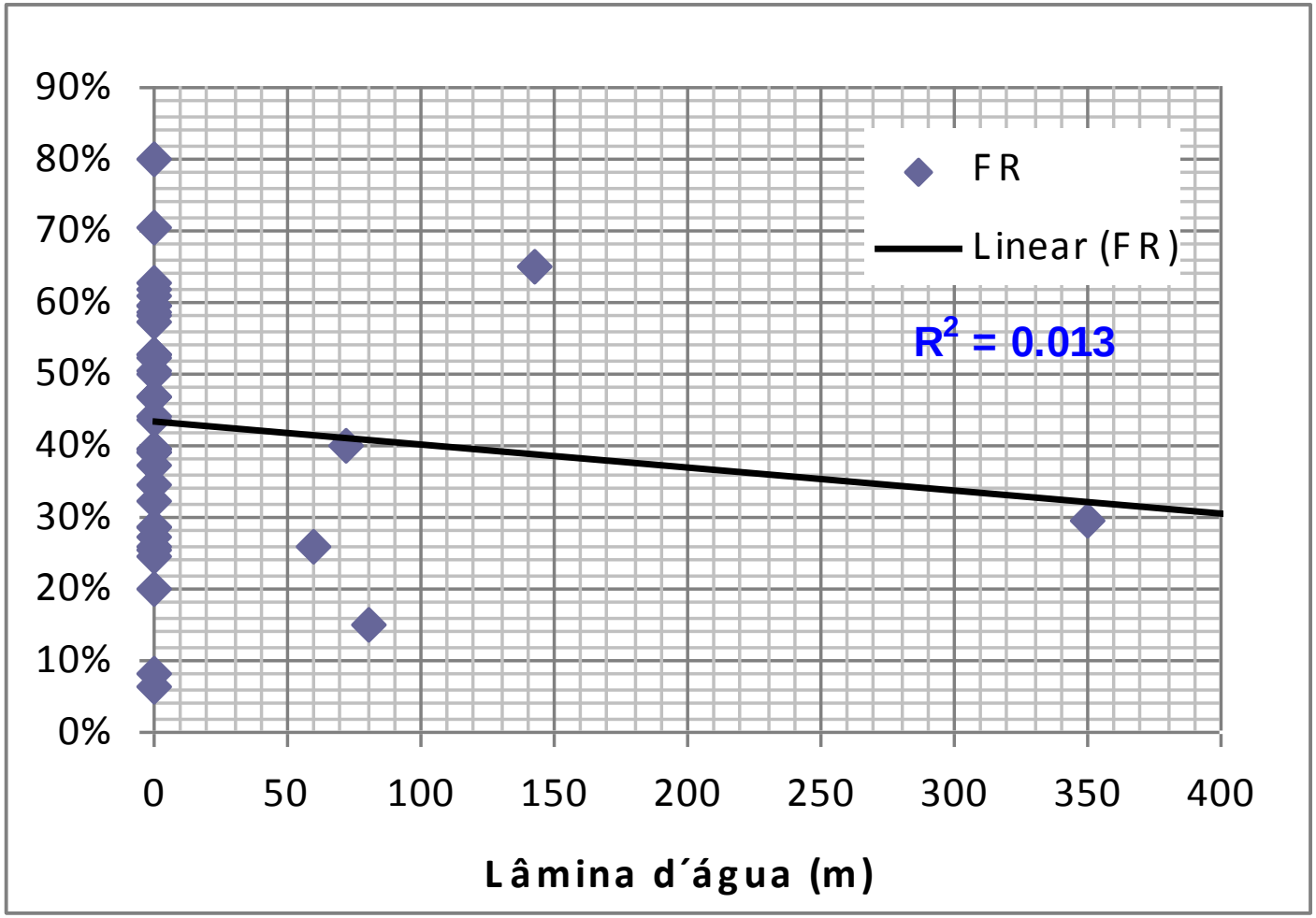
Recovery factor study

- Reported original oil in place



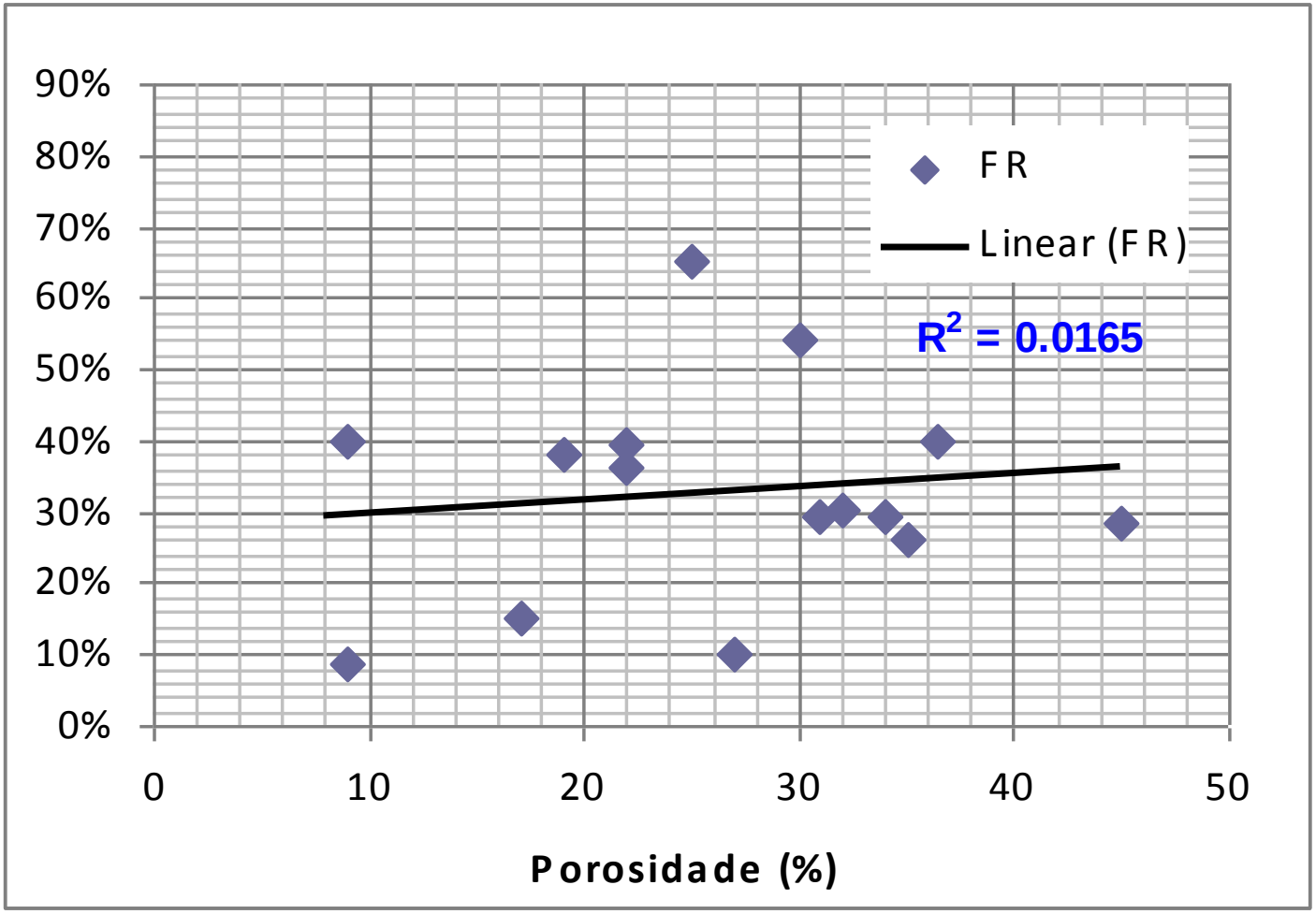
Recovery factor study

- Onshore / Offshore (water depth)



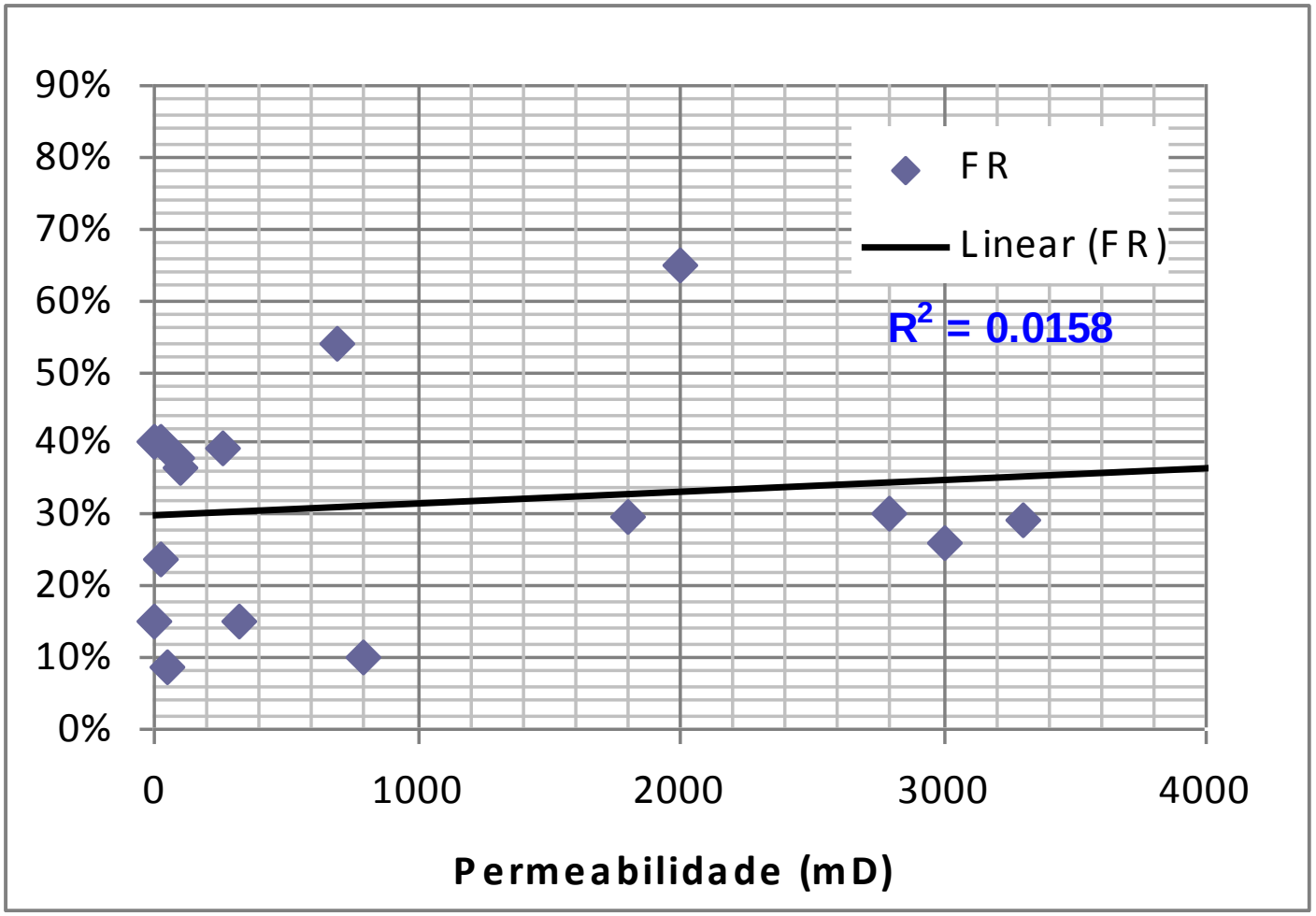
Recovery factor study

- Average porosity



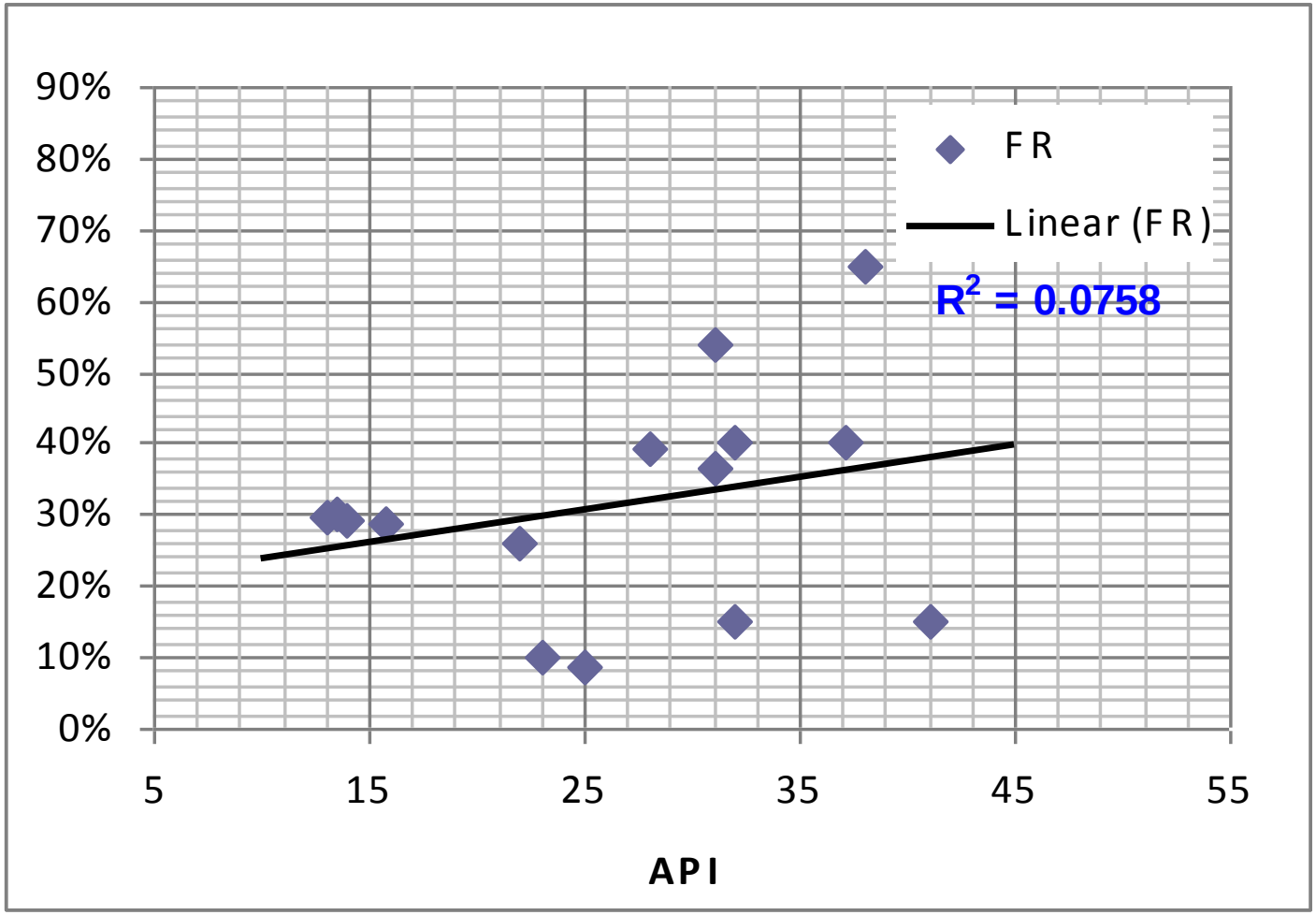
Recovery factor study

- Average permeability



Recovery factor study

- API gravity



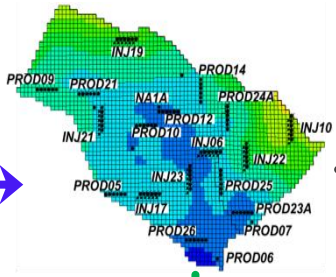
Remarks - Part 1

- Estimation of recovery factor is complex
  - Reservoir (rock/fluid) properties
  - Economic model
  - Tax regime
  - Investments / objective
- Literature examples:
  - high variability
  - hard to find strong correlations
- Important to consider particularities of each case

Part 2 – Model Based Decisions

Closed Loop Reservoir Management and Development (model based decisions)

UNICAMP



Operational Noise

Prod. Strategy

Production

Fluid Movement

Data measurement noise

Geology, seismic, well logs, well tests, fluid properties…

High fidelity models

Big loop

Measured output

Prod. Strat.

Simulation models

Data assimilation algorithms

Decision Analysis

Predicted output

Objective

Future

Past

Reservoir Development / Managment

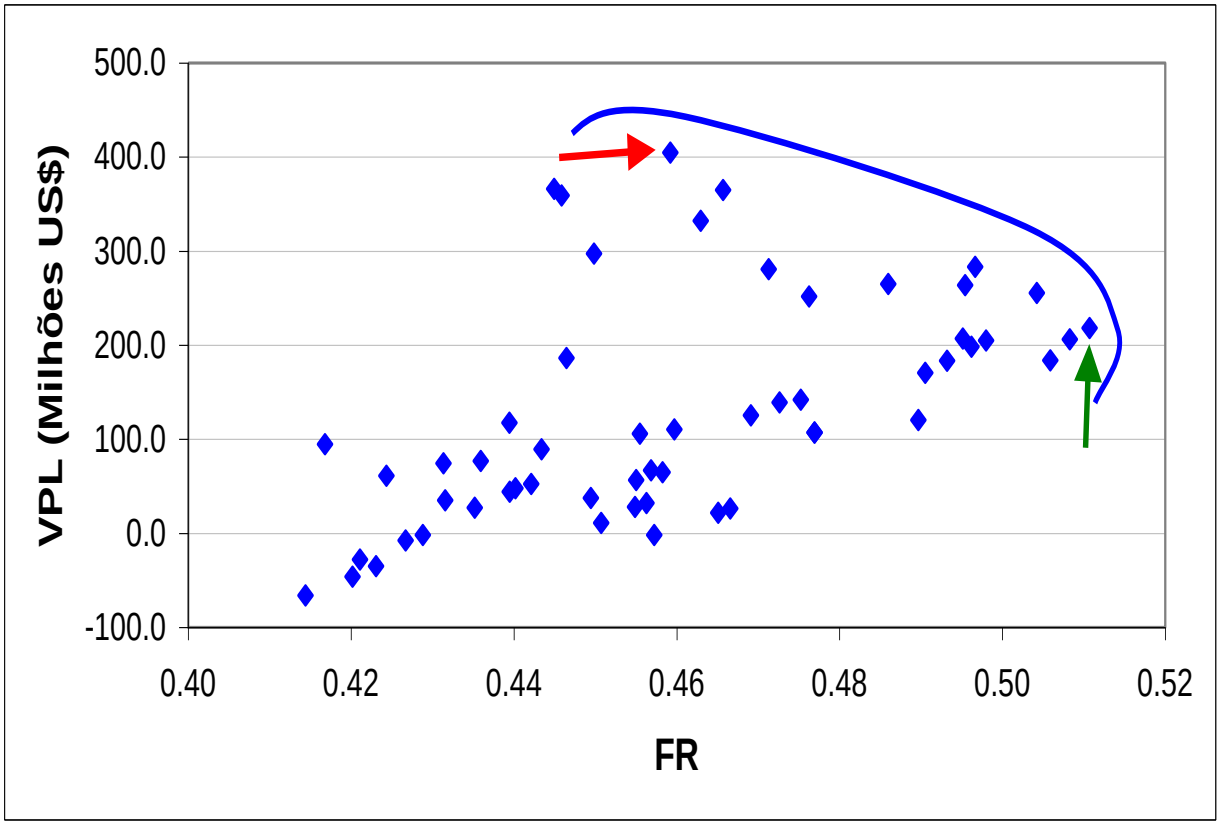
- Objective (Objective-function)
- Project variables (G1)
  - Production system (platform, wells, ...)
- Control variables (G2)
  - Field Operation
- Field revitalization variables (G3)
  - IOR/EOR
- It is important to
  - IOR/EOR in the development phase
  - consider uncertainties (rock/fluid/economic/operational …)
  - Integration with economic studies
  - Integration with production facilities (MIP)

Example 1 – NPV vs RF

NPV x RF – average economic model

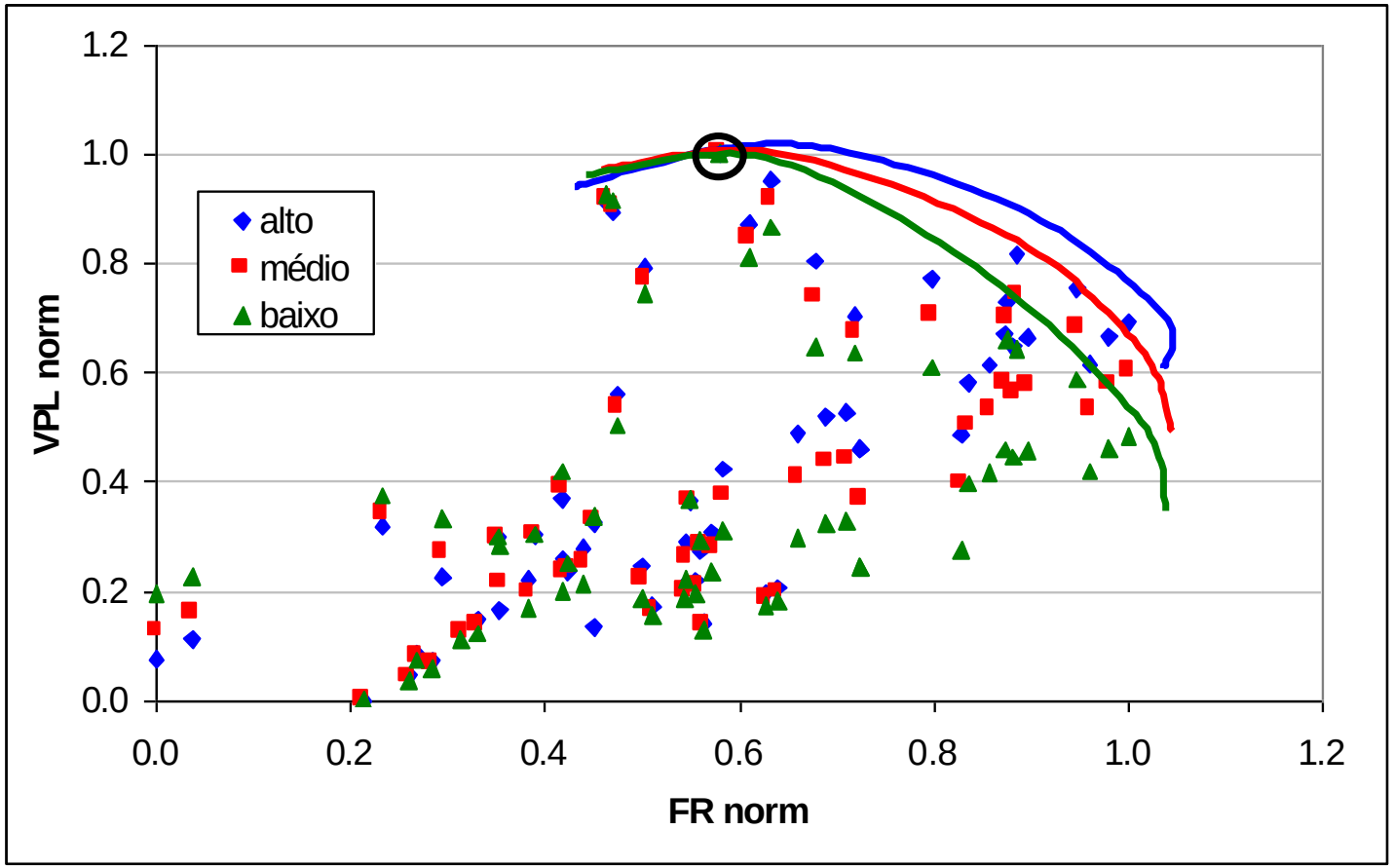
Best tested NPV strategy (14 wells)

Best tested RF strategy (22 wells)



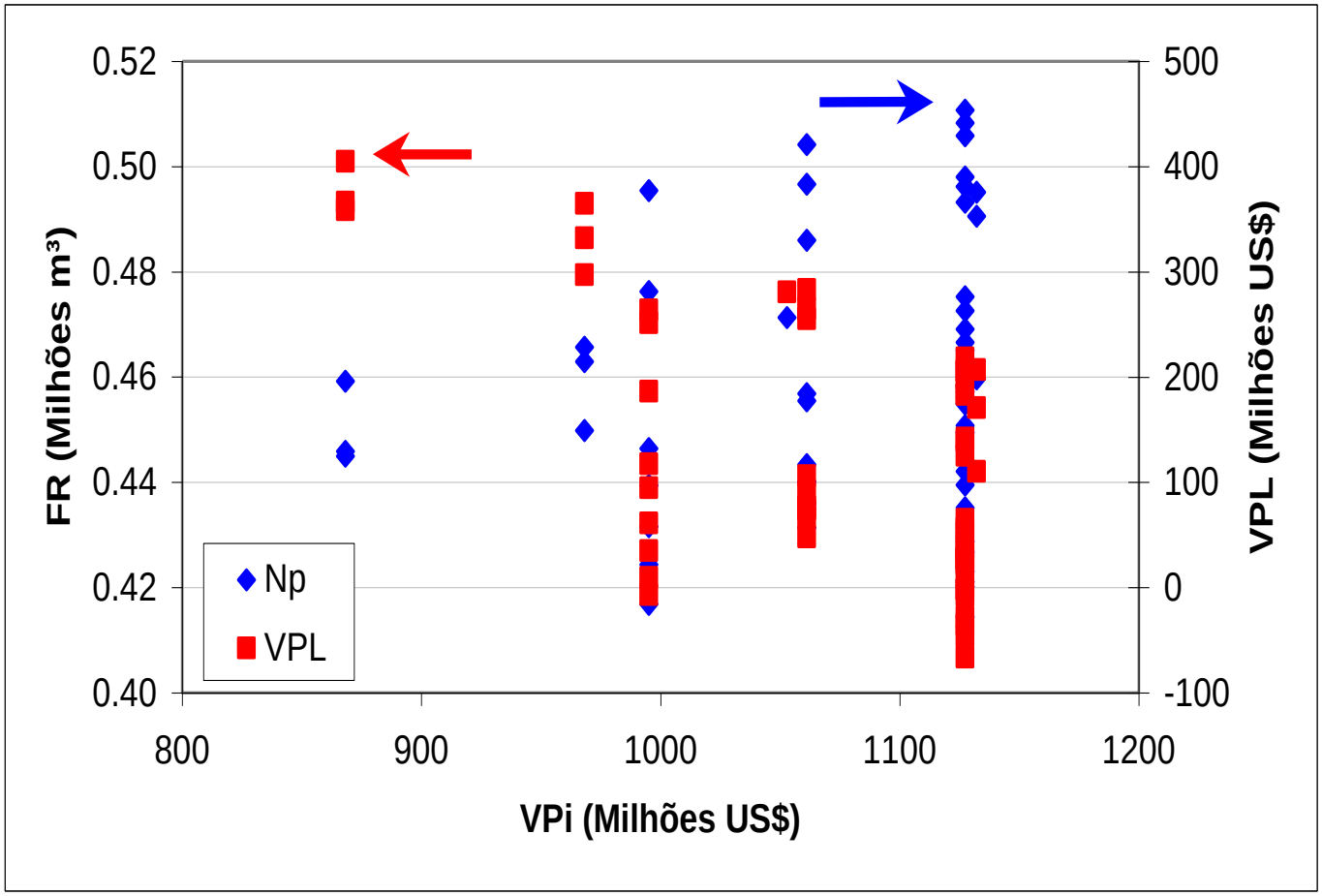
Example 1 – NPV vs RF

- 3 economic oil prices (normalized)



Example 1 – NPV vs RF

- Influence of Investment on NPV and RF



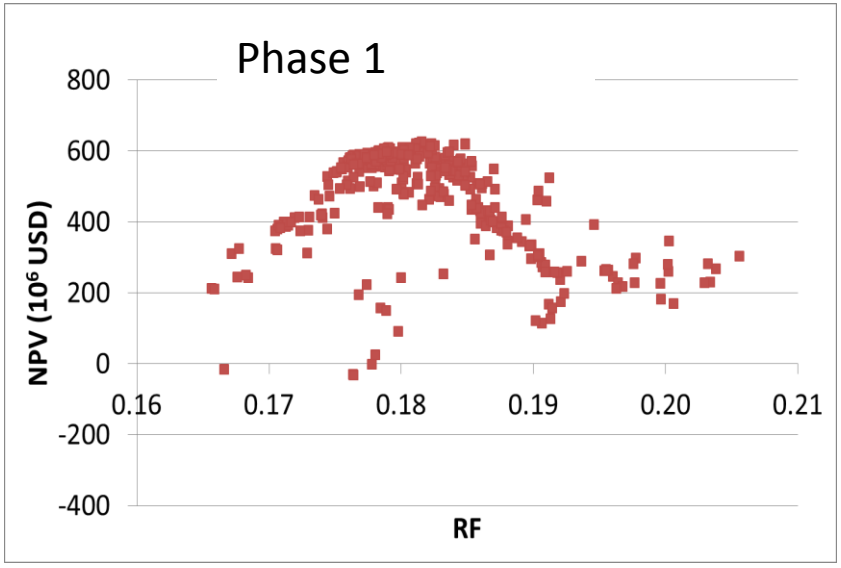
Example 2 – Polymer Flooding

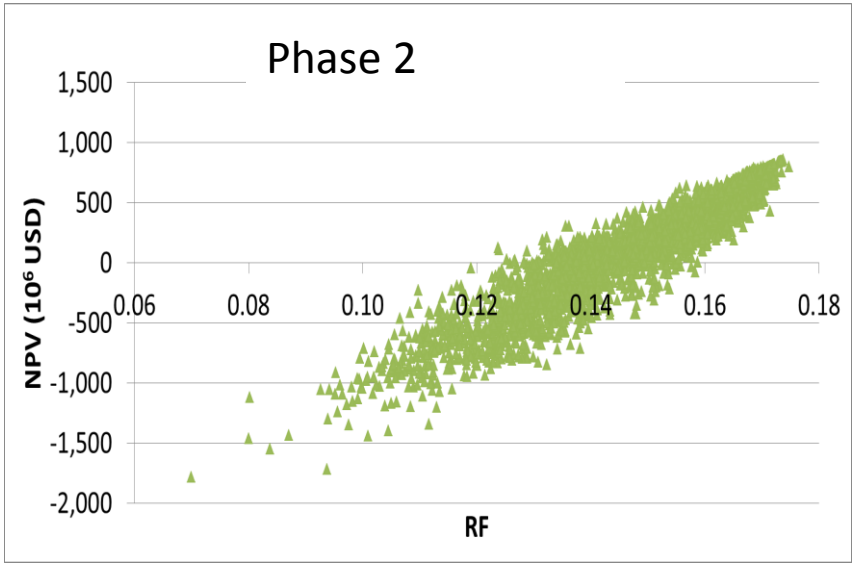
- Production strategy - polymer flooding
- Optimization considering 3 approaches
  A. Using NPV as objective-function;
  B. Using RF as objective-function;
  C. Using NPV as OF to select Investments and RF to optimize production
- Optimization process divided in 2 phases
  1. variables with influence in investment (project variables)
  2. variables without influence in investment (control variables)

Study 2 – Polymer Flooding

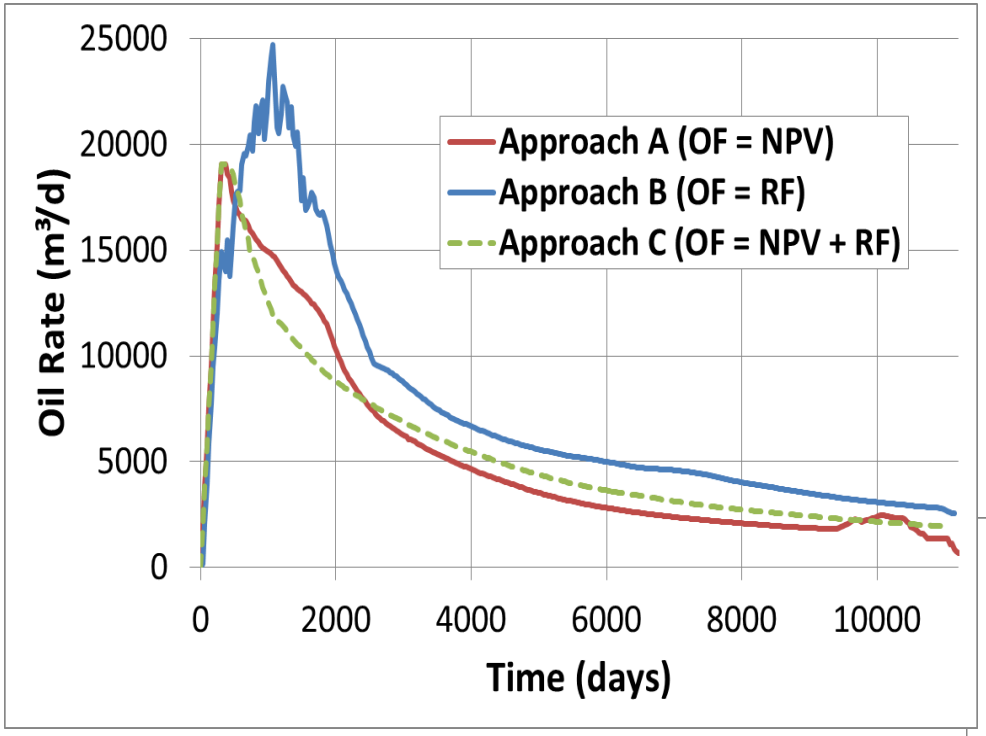
Approach	Objective Function	NPV (10^6 USD)	Np (10^6 m³)	Wp (10^6 m³)	RF	Winj (10^6 m³)	N_{Prod}	N_{Inj}	Total Investments (10^6 USD)
A	**NPV**	1456	58	59	0.19	77	11	4	2457
B	**RF**	-607	84	337	0.27	398	45	8	5322
C	**NPV+RF**	1275	60	97	0.20	112	11	4	2491

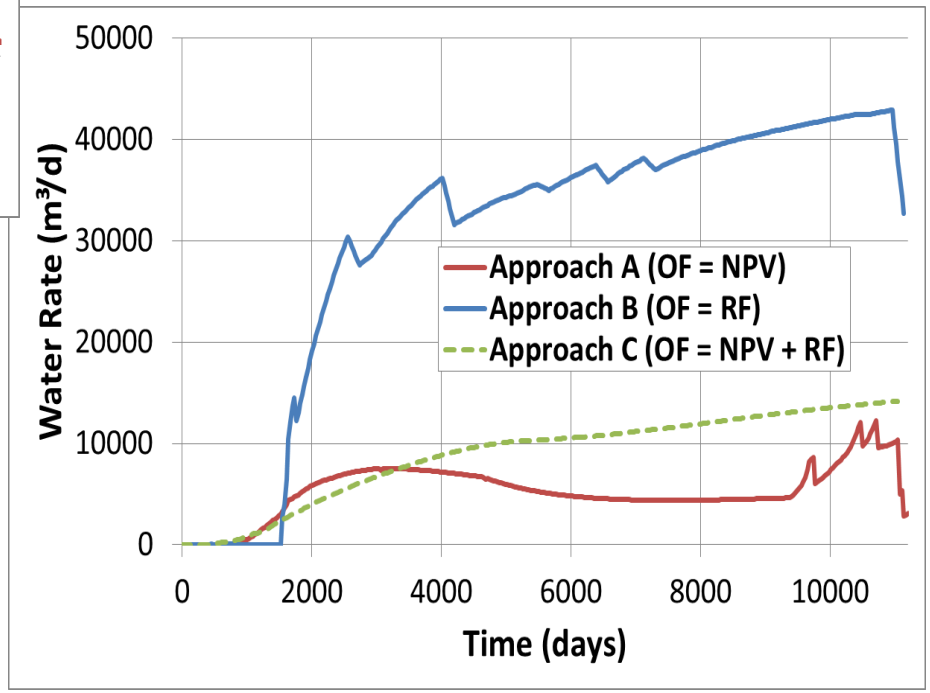
Approach A



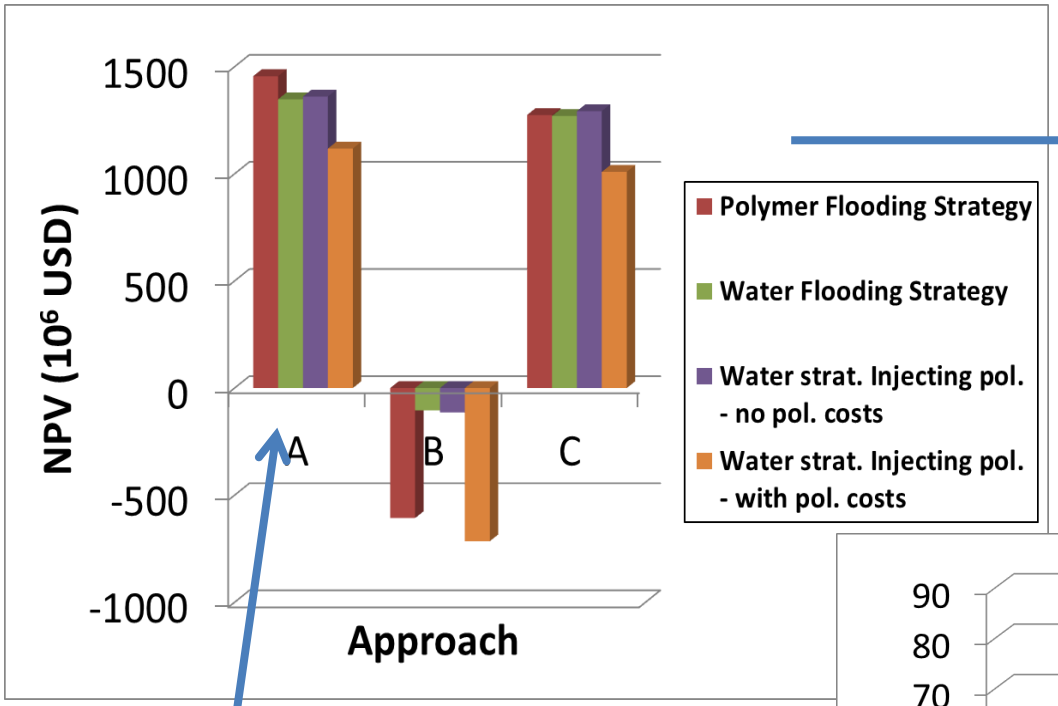


Study 2 – Polymer Flooding

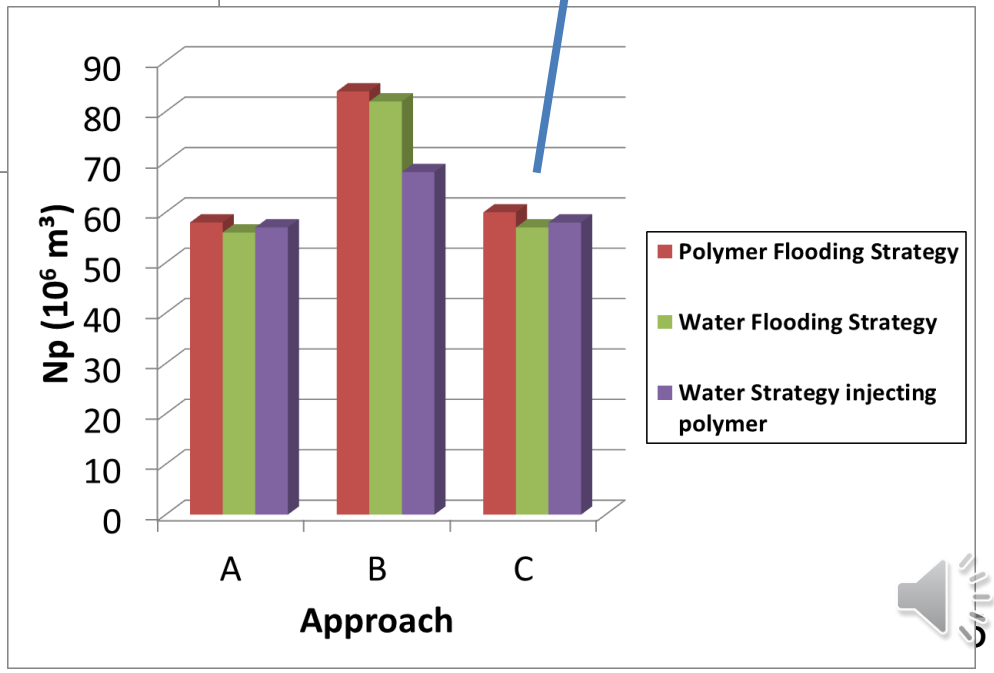




Study 2 – Polymer Flooding

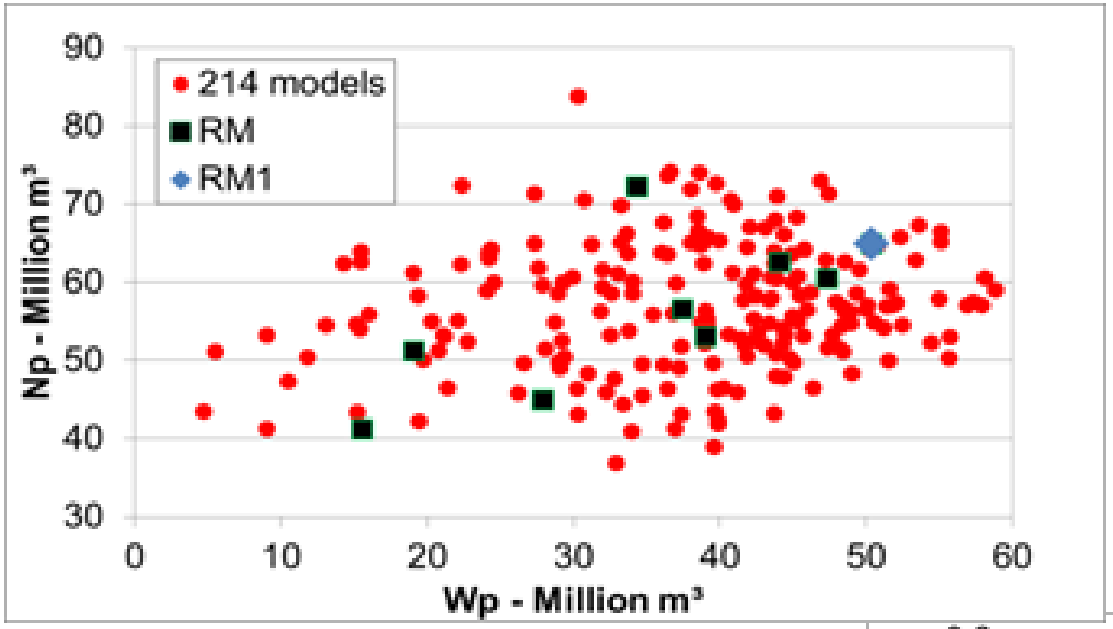


Very different solutions



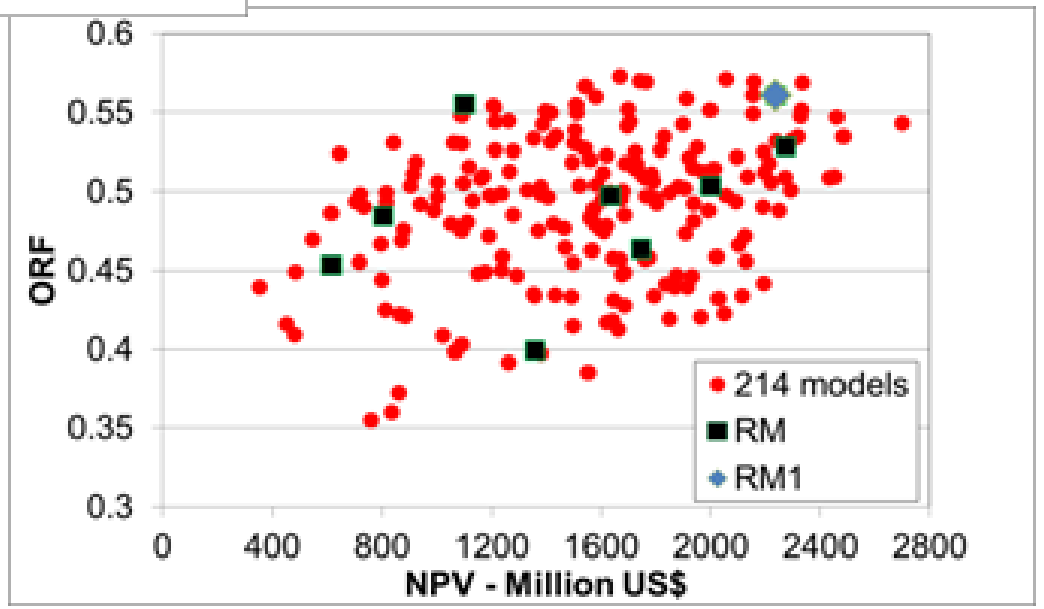
Additional information
EOR planned since the beginning yields much better results

Example 3 - Uncertanties



Uncertainties 214 scenarios:
- Rock / fluid
- Economic
- Operational

Red – 214 possible scenarios
Blue – best strategy for base case
Black – representative models



Example 3 - Uncertanties

- 9 representative models (possible scenarios)
- 9 different strategies

	NPV (billions)								
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**
RM1	2.24	1.91	0.79	1.33	1.42	0.96	1.48	1.32	1.72
RM2	1.64	2.30	0.78	1.84	2.01	0.87	1.54	1.77	1.67
RM3	0.80	1.04	1.64	0.97	0.65	1.14	1.06	1.05	0.57
RM4	2.00	1.61	1.10	2.50	1.99	1.24	1.18	2.19	2.01
RM5	1.36	1.70	0.82	1.68	2.41	0.87	1.31	1.55	1.72
RM6	1.10	1.07	0.9.3	0.51	0.39	1.91	0.91	0.71	1.04
RM7	0.62	0.74	0.26	0.62	0.60	0.53	1.48	0.54	0.40
RM8	1.75	1.82	1.25	1.82	1.95	1.23	1.25	2.51	1.69
RM9	2.27	2.18	1.08	1.67	2.07	1.56	1.24	2.13	2.97
EMV	**1.54**	**1.56**	**0.97**	**1.52**	**1.53**	**1.14**	**1.27**	**1.47**	**1.60**

Example 3 - Uncertanties

- 9 representative models (possible scenarios)
- 9 different strategies

	NPV (billions)								
	E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**
RM1	2.24	1.91	0.79	1.33	1.42	0.96	1.48	1.32	1.72
RM2	1.64	2.30	0.78	1.84	2.01	0.87	1.54	1.77	1.67
RM3	0.80	1.04	1.64	0.97	0.65	1.14	1.06	1.05	0.57
RM4	2.00	1.61	1.10	2.50	1.99	1.24	1.18	2.19	2.01
RM5	1.36	1.70	0.82	1.68	2.41	0.87	1.31	1.55	1.72
RM6	1.10	1.07	0.9.3	0.51	0.39	1.91	0.91	0.71	1.04
RM7	0.62	0.74	0.26	0.62	0.60	0.53	1.48	0.54	0.40
RM8	1.75	1.82	1.25	1.82	1.95	1.23	1.25	2.51	1.69
RM9	2.27	2.18	1.08	1.67	2.07	1.56	1.24	2.13	2.97
EMV	**1.54**	**1.56**	**0.97**	**1.52**	**1.53**	**1.14**	**1.27**	**1.47**	**1.60**

Example 3

- Uncertainties
  - Need to change production strategy (IOR)
  - Control variables (G2)
  - Revitalization variables (G3)
  - Concept of risk must be considered
- Robustness (ex. G3 in advance)
- Flexibility (ex. ICV)
- Information (ex. 4DS)
- MIP (integration with production facilities)

Remarks - Part 2

- Different objectives: company – agency
- Many solutions in-between
  - Companies
    - Additional investments
      - IOR/EOR
      - Flexibilities (ICV, development in stages, ...)
      - Information (4DS, ...)
    - Additional production time
  - ANP
    - Tax relief / other benefits

Part 3 – R&D - Universities

- Field development and management is a very complex process
  - People
    - PRH / research projects
  - Technology
    - R&D → Innovation
    - Cooperation Companies/Universities
  - Investments
    - Information (4DS), flexibility (ICV), laboratory experiments, R&D
- Long term projects
- Investment in people and research is one way to increase the recovery factor of fields

Acknowledgments

- UNICAMP
- ANP
- PETROBRAS
- BG/SHELL
- FCMG
- STATOIL
- FAPESP/CAPES/CNPq

Uso de modelos de simulação para estimar fator de recuperação

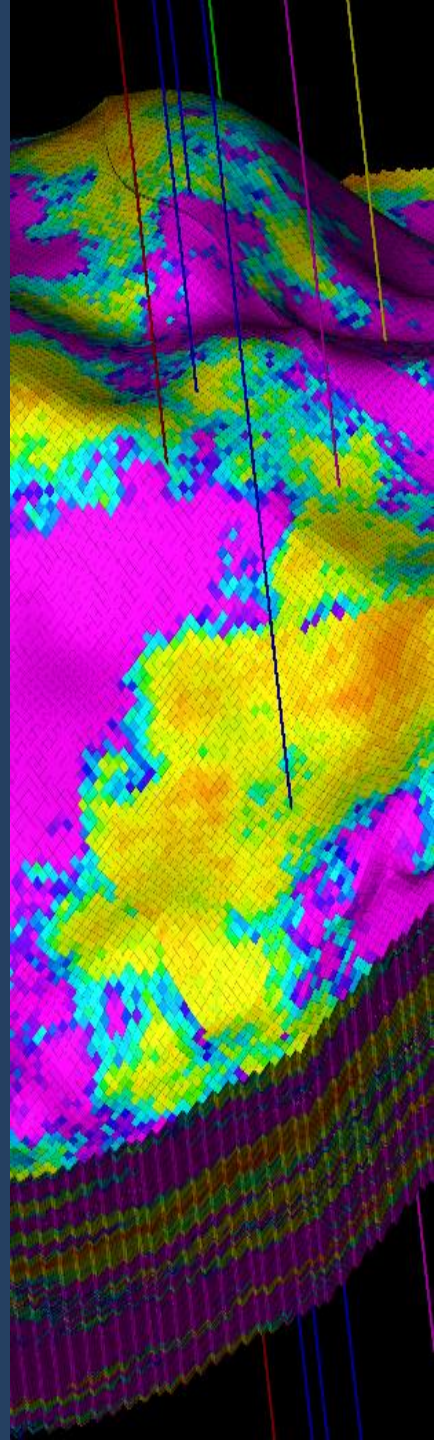
Use of reservoir simulation models to estimate recovery factor

Denis J. Schiozer

March – 2017

denis@unicamp.br

UNICAMP/CEPETRO/UNISIM



UNICAMP

ANO 50

ANO 50

CEPETRO

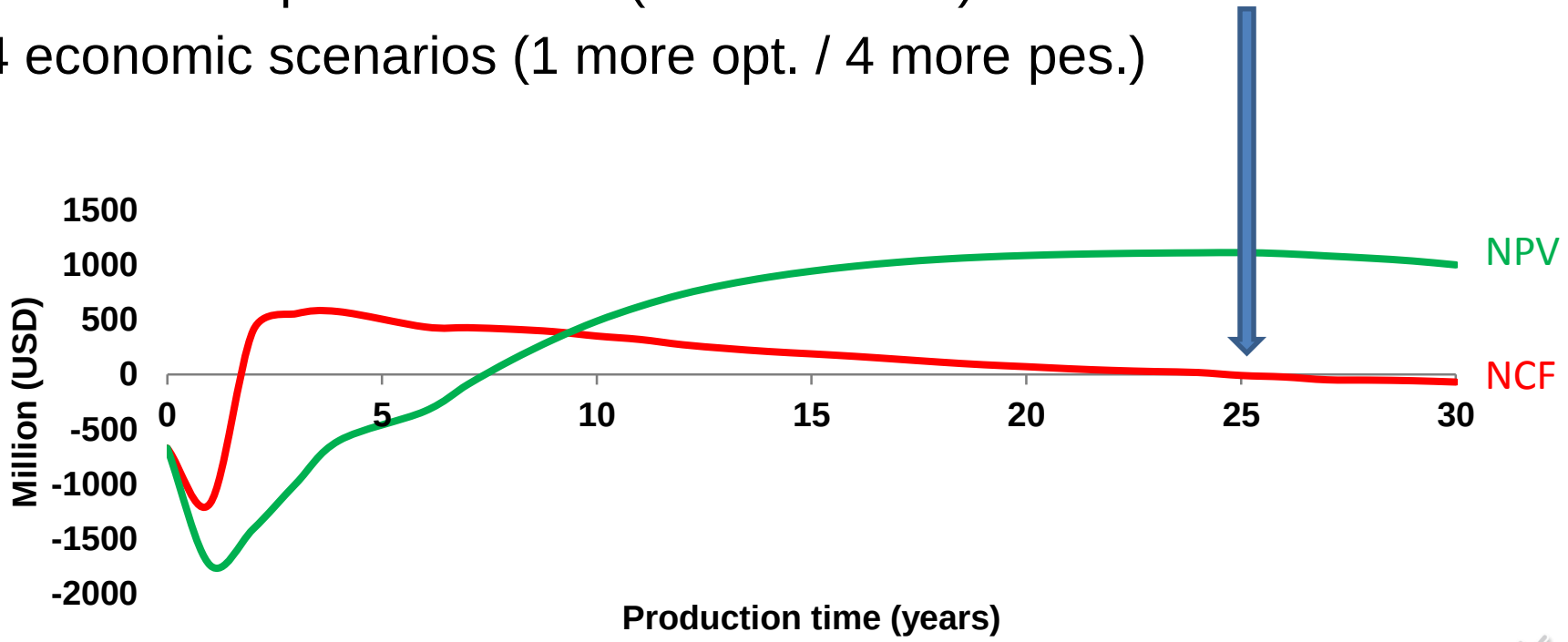
CENTRO DE ESTUDOS DE PETRÓLEO

UNISIM

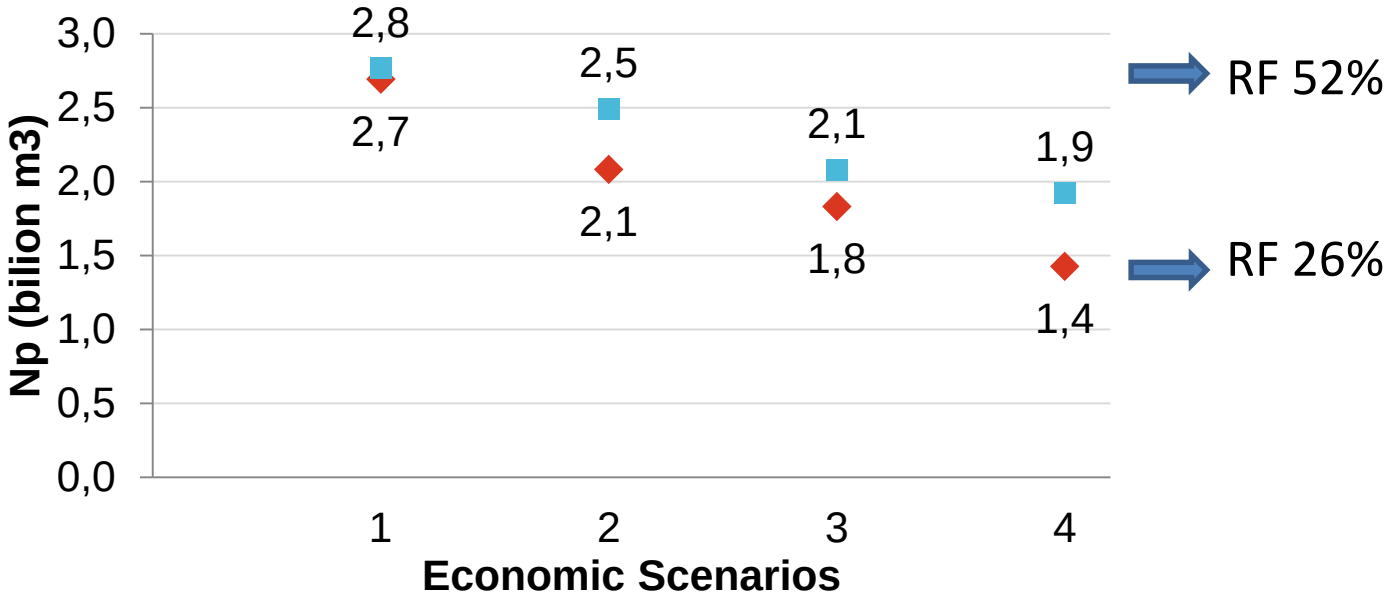
ANO 20

Reservoir simulation study 3

- Production Sharing (PS) vs Concession (Royaties&Income tax (R&T)
- Reservoir Example 5.4 billion m3
- 220 different strategies
- Production up to zero NCF (net cash flow)
- 4 economic scenarios (1 more opt. / 4 more pes.)

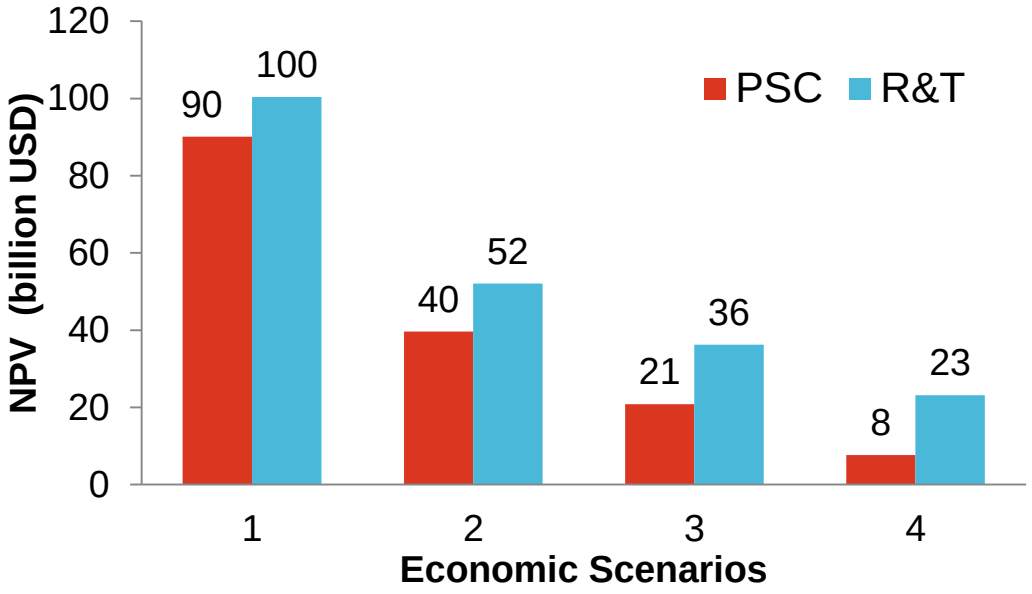


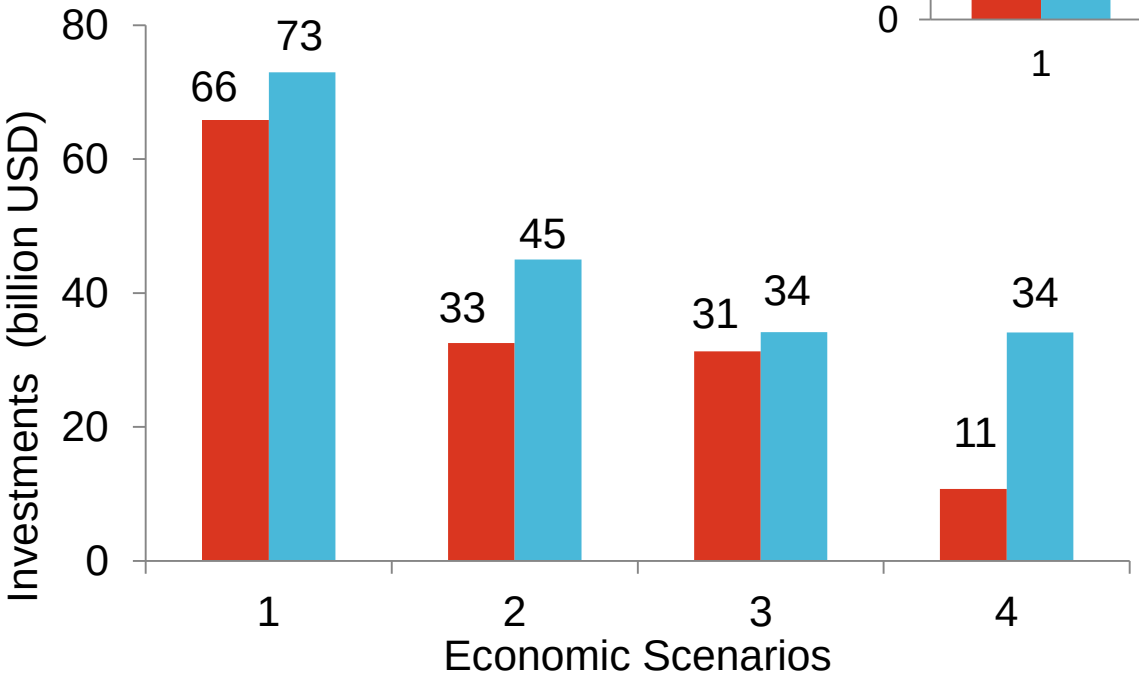
Reservoir simulation study 3



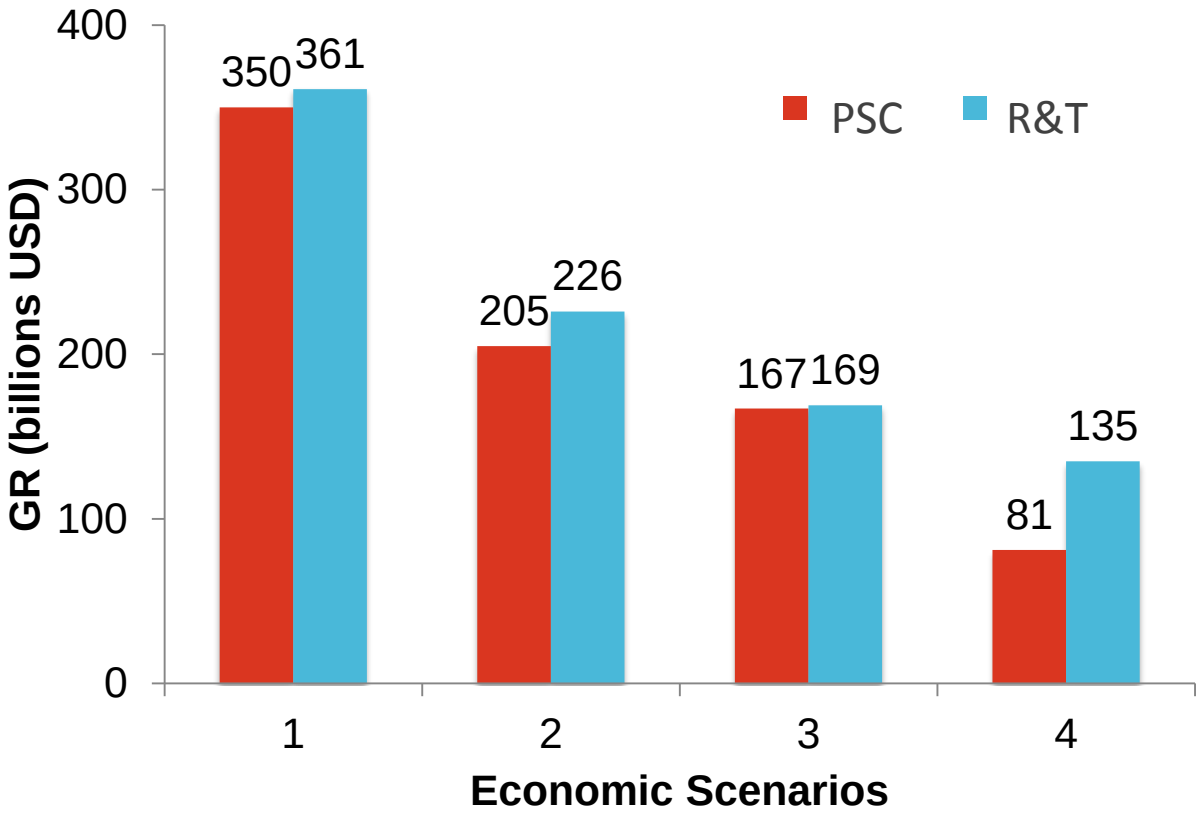
Total Number of Wells	Scenarios 1	2	3	4
Production Sharing	625	221	221	60
Royalty and Tax	625	255	221	221

Reservoir simulation study 3



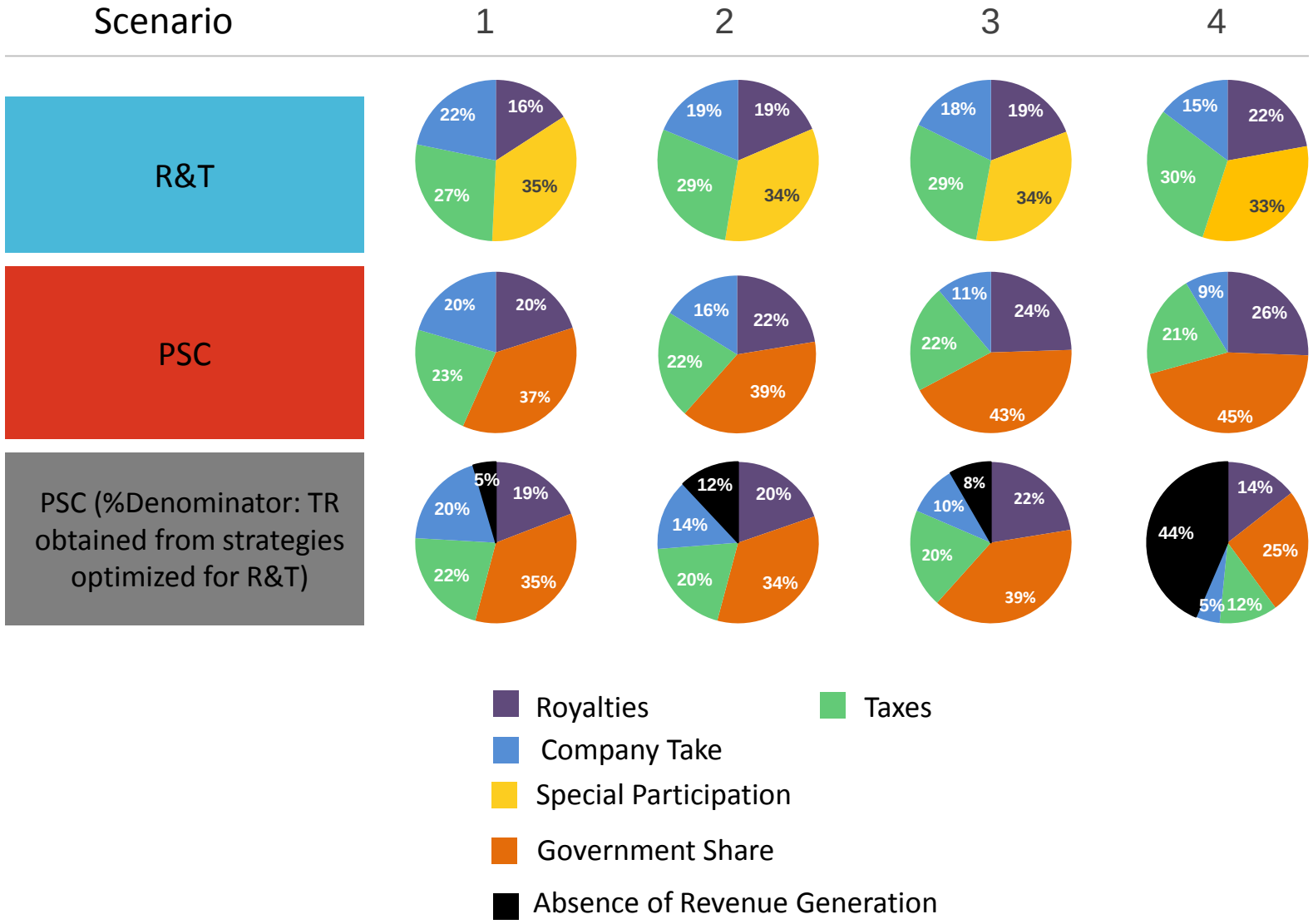


Reservoir simulation study 3



GR – govern revenue

Reservoir simulation study 3



Uso de modelos de simulação para estimar fator de recuperação

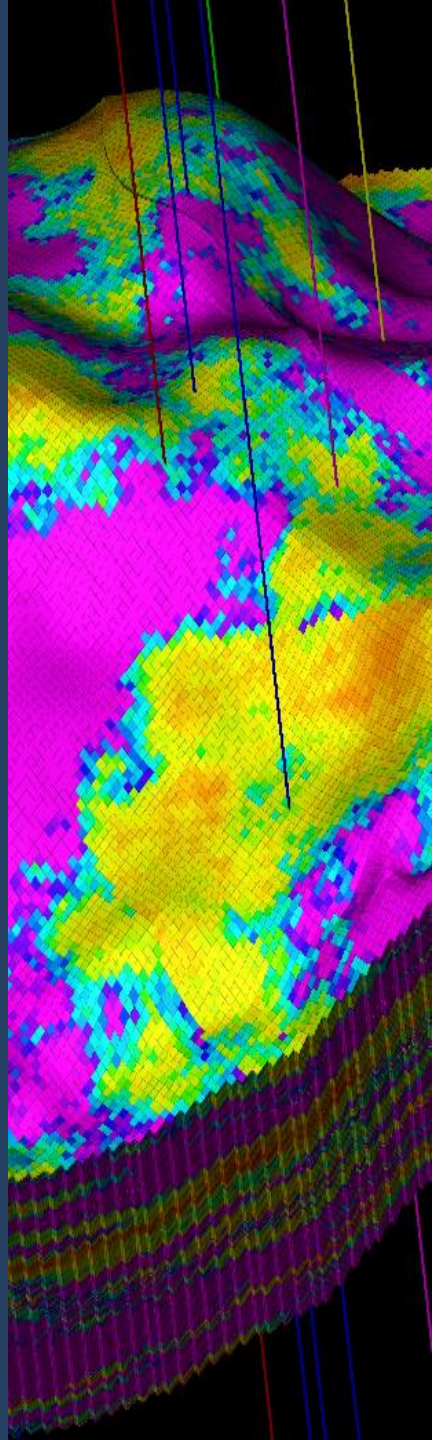
Use of reservoir simulation models to estimate recovery factor

Denis J. Schiozer

March – 2017

denis@unicamp.br

UNICAMP/CEPETRO/UNISIM



UNICAMP

ANO 50

CEPETRO

CENTRO DE ESTUDOS DE PETRÓLEO

ANO 30

UNISIM

ANO 20

Final Remarks

- Estimation of recovery factor is complex
  - Reservoir (rock/fluid) properties
  - Economic model
  - Tax regime
  - Investments / objective
- Literature examples: high variability – hard to find strong correlations
- Numerical Examples
  - 1 and 2) Maximum NPV x Maximum RF
  - 3) influence of tax regime
  - 4) influence of uncertainties