Valuation of Infrastructure Projects:
Recent Advances & Pending Issues

Arturo Cifuentes

Columbia University & CLAPES UC

August 2017

Infrastructure matters...

❑ The world invests about US $2.5 trillion a year in the transportation, power, water, and telecom systems

❑ From 2016 through 2030, the world needs to invest about 3.8 percent of GDP, or an average of US$3.3 trillion a year, in infrastructure (60% in EM)

❑ U.S. infrastructure (D+), US$ 2 trillions are needed (ASCE)

❑ Infrastructure spending as % of GDP, 1992-2013 average

China= 8.6%
Latin America= 2.4%

❑ MGI estimates that infrastructure typically has a socioeconomic rate of return of around 20 percent. In other words, one dollar of infrastructure investment can raise GDP by 20 cents in the long run

source: [1], [2]
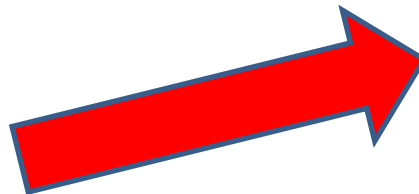
What's the Ultimate (the Most Fundamental) Financial Question?

Answer:

How Much Should I Pay for This?

OR

What's the Value of This?

Who is he? What did he say?

More Formally…

$$X_1 \qquad X_2 \qquad X_3 \qquad X_4 \qquad X_N$$

Time   0   1   2   3   4 ….   N
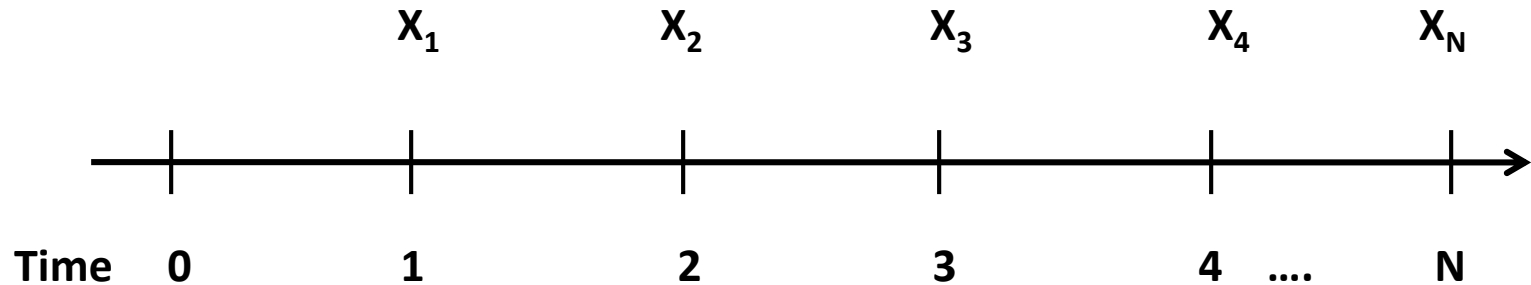
A Financial Asset Generates Cash Flows (X_1, X_2, …, X_N)
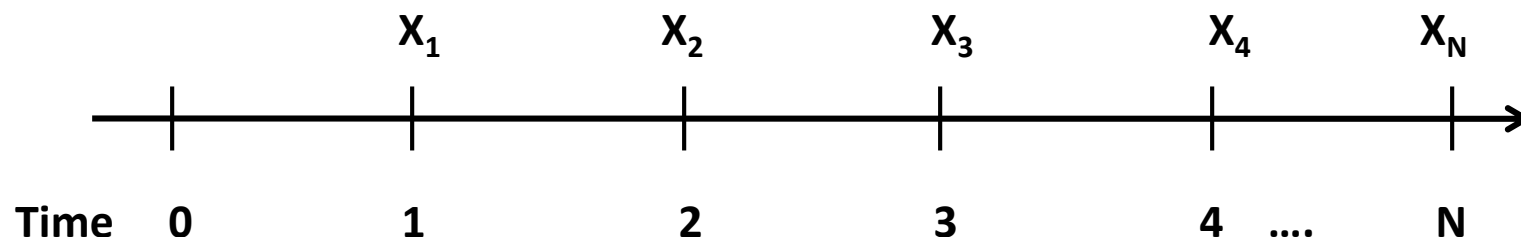
What's the Value of this Asset?

Answer: The Present Value (PV) of The Future Cash Flows

But How Do We Calculate the PV of These Cash Flows?

Use the DCF Method !!!

Discount the CFs with the <u>Appropriate</u> Rate

$$X_1 \qquad X_2 \qquad X_3 \qquad X_4 \qquad X_N$$

Time **0**   **1**   **2**   **3**   **4** **....**   **N**

$$PV = \sum_{i=1}^{N} \frac{X_i}{(1+R)^i}$$

The Mother of All Problems

R represents the "appropriate" discount rate:

(i) WACC (weighted average cost of capital) or

(ii)   opportunity cost of capital or

*(iii) use R = @%%%^**^%%%!!!!!!!*
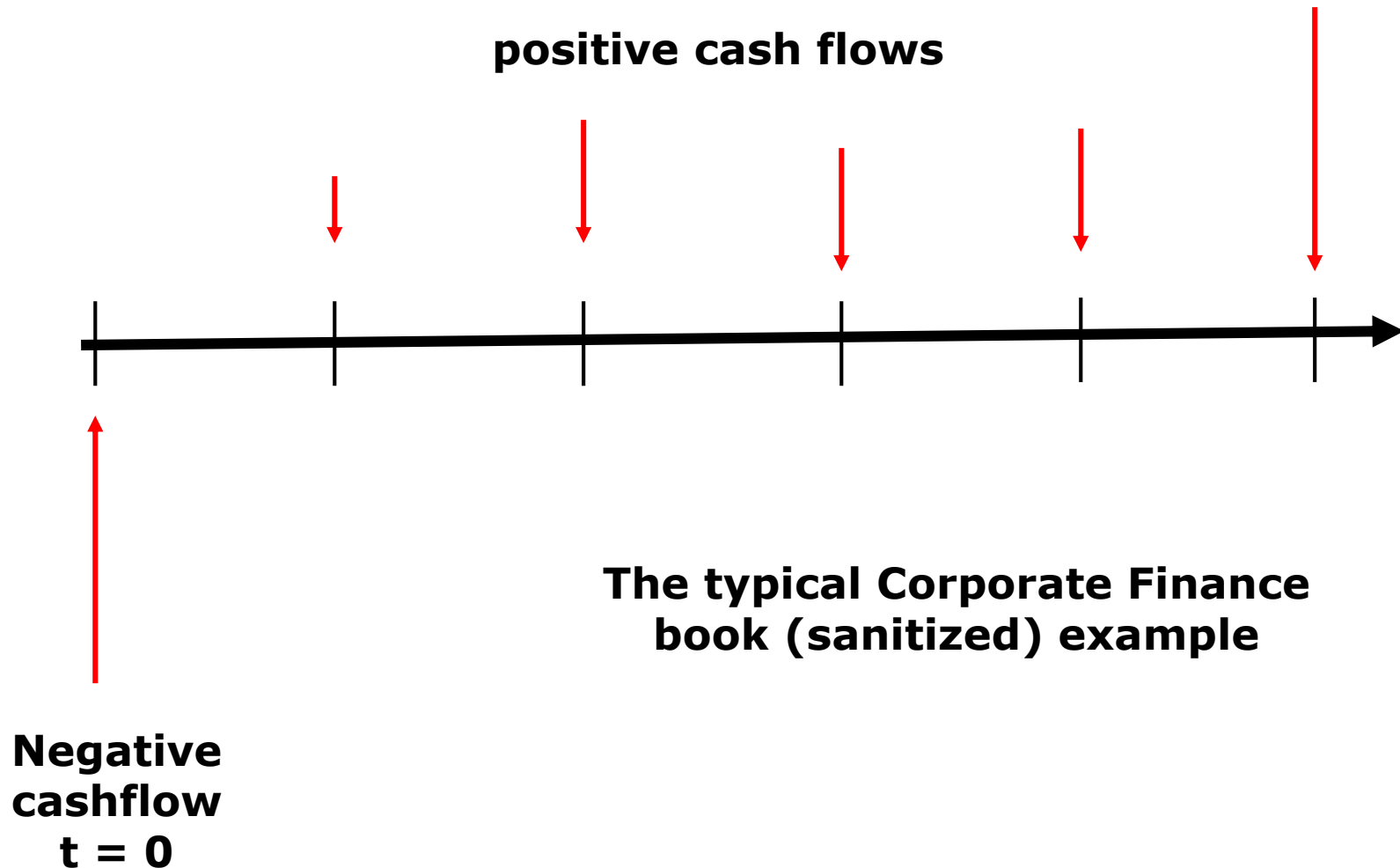
$$R = R_F + \delta \qquad \delta \geq 0$$

Eugene Fama (Fama, 1996):

"A fundamental open question nevertheless remains. Given the <u>massive uncertainties inherent in all aspects of project valuation</u>, does a discounting rule produce value estimates that have less measurement error than a less complicated approach, like payback? In advocating discounting rules, textbooks in corporate finance implicitly answer this question in the affirmative. But <u>the conclusion is based more on faith than evidence</u>."
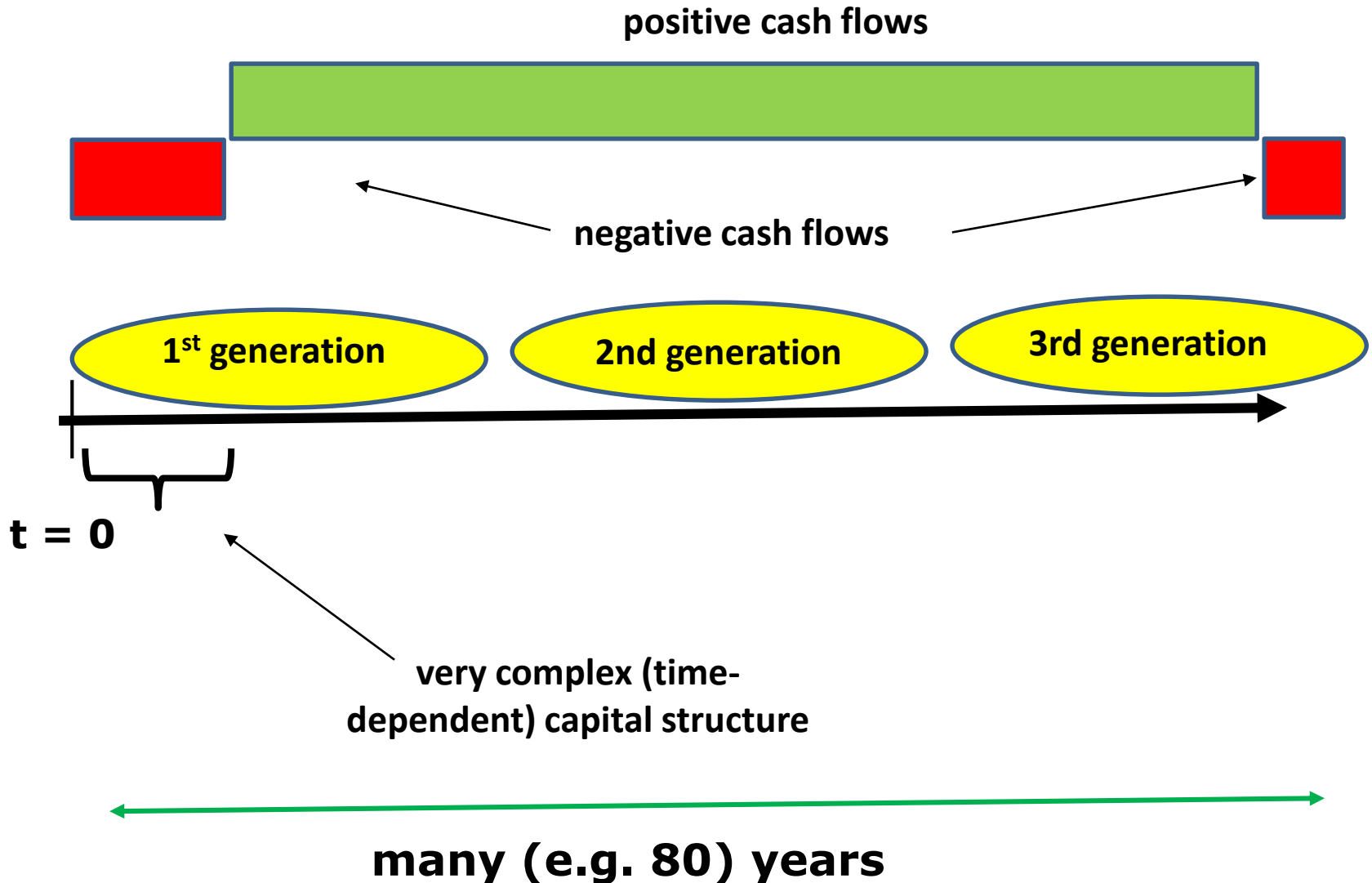

Nobel in Economics, 2013

Let us make things more difficult...

positive cash flows

**The typical Corporate Finance
book (sanitized) example**

**Negative
cashflow
t = 0**

A real-life infrastructure project

positive cash flows

negative cash flows

1st generation

2nd generation

3rd generation

t = 0

very complex (time-dependent) capital structure

many (e.g. 80) years

So, what is the correct (whatever that means) discount rate?

	(%)
Stern	1.4
Cline	2.05
Nordhaus	4.3
Arrow et al.	DDR
France	DDR/ starts at 4%
UK	DDR/ starts at 1.5%
US OMB	3% & 7%

Based on ethical considerations

Based on market rates

source: [4], [5], [6]

PRESENT VALUE OF A CASH FLOW OF $1000 RECEIVED AFTER *T* YEARS

t	Value ($) of $1000 at a discount rate of				Certainty equivalent (%)
	1%	4%	7%	Equally likely 1% or 7% expected value	
1	990.05	960.79	932.39	961.22	3.94
10	904.84	670.32	496.59	700.71	3.13
50	606.53	135.34	30.20	318.36	1.28
100	367.88	18.32	0.91	184.40	1.02
150	223.13	2.48	0.03	111.58	1.01
200	135.34	0.34	0.00	67.67	1.01
300	49.79	0.01	0.00	24.89	1.01
400	18.32	0.00	0.00	9.16	1.01

Present value of a cash flow of $1000 received after *t* years. Expected value is the average of values from the 1% and 7% columns.

FINANCIAL TIMES, NOVEMBER 3, 2016

by: **Arturo Cifuentes and David Espinoza**

Infrastructure investing and the peril of discounted cash flow

Valuation techniques remain anchored in arcane ideas

Some countries, aware of the short-term bias embedded in the DCF approach, have advocated the use of time-declining discount rates to evaluate long-term climate mitigating infrastructure projects. **Kenneth Arrow,** another economics Nobel laureate, last year co-authored a paper endorsing this idea. **His suggestion, however looks a bit like rearranging the chairs in the Titanic.**

A more "refined" version of the NPV approach

$$Utility = \int_{0}^{\infty} U(x(t))e^{-Rt}\, dt$$

cash flows

Social welfare discount rate

exponential discounting

This "thing" is called exponential discounting, however, <u>real people and animals,</u> give more weight to events that are immediate or distant, and less weight to "intermediate" events. This phenomenon is handled via **hyperbolic discounting**

Real Options Applied To Infrastructure Valuation

Use Black & Scholes?

It seemed like a good idea at the time... BUT

The B-S assumptions are almost all violated by real projects; for example:

Volatility must be guessed

Financial options cannot be exercised instantaneously

Asset cannot be shorted

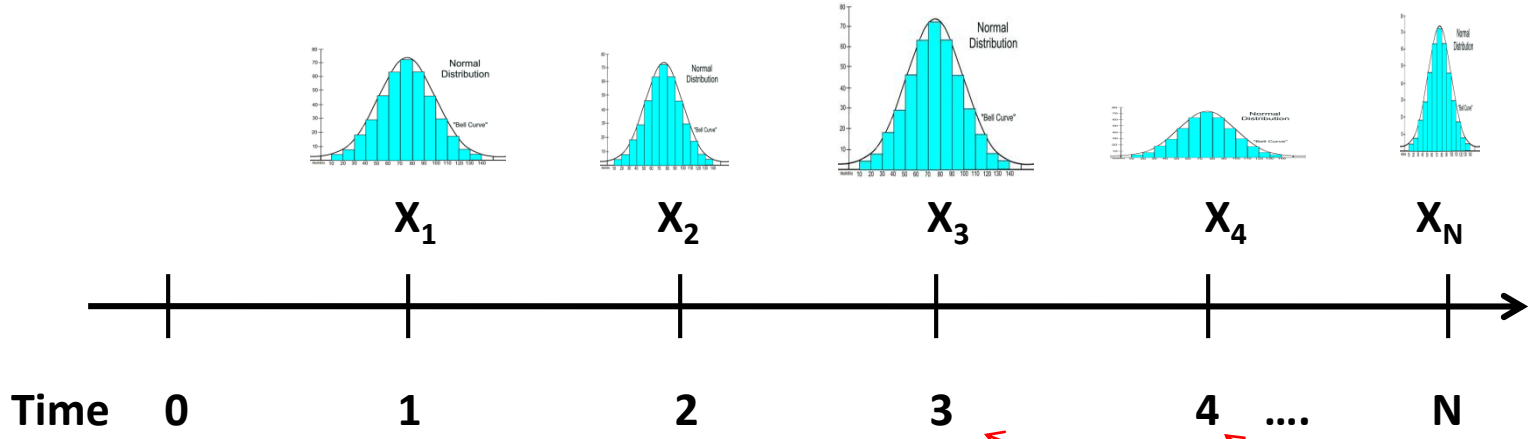# Better use a Probabilistic Present Worth Analysis, see [8]

Solution:

Be honest, accept that cash flows are stochastic and treat them accordingly (same goes for the NPV)

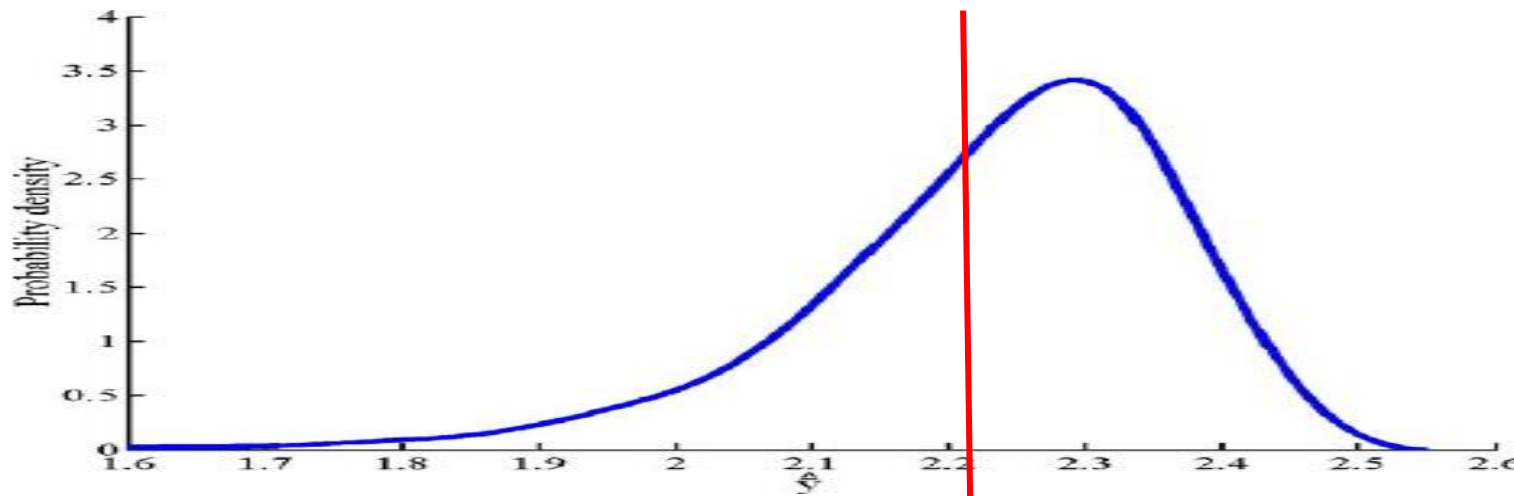**Use Monte Carlo simulations and discount the cash flows using the risk-free rate, see [9], ..., [16]**

In Short: The Problem is the Cash Flows, Stupid!! It is NOT the Discount Rate   %$##$^%$!!!!

X₁ X₂ X₃ X₄ Xₙ

Time 0   1   2   3   4 ....   N

ρ

$$X \backsim MN(\mu, \Sigma)$$

E(NPV)

References & Sources (1)

[1] McKinsey Global Institute (MGI), Bridging Global Infrastructure Gaps, June, 2016.

[2] American Society of Civil Engineers, 2017 Infrastructure Report Card, https://www.infrastructurereportcard.org/

[3] Fama, E. F. 1996. "Discounting Under Uncertainty." Journal of Business, Volume 69, Number 4, pages 415-428.

[4] L. Goulder and R. Williams, The Choice of Discount Rate for Climate Change Policy Evaluation, Climate Change Economics, Vol. 3, 2012.

[5] K. Arrow et al., Determining Benefits and Costs for Future Generations, Science, July, 2013.

[6] M. Cropper et al., Declining Discount Rates, American Economic Review, 104(5), 538-543, 2014.

[7] J. D. Farmer and J. Geanakoplos, Hyperbolic Discounting Is Rational, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1448811

[8] Carmichael, D.G., Hersh, A.M. and Parasu, P. (2011) Real options estimate using probabilistic present worth analysis. *The Engineering Economist, 56, 295-320*

[9] Espinoza, R.D., Morris J.W.F. (2013) Decoupled NPV: A simple, improved method to value infrastructure investments. *Construction Management and Economics, 31, 471–496*

References & Sources (2)

[10] Espinoza, R.D. (2014) Decoupling the time value of money and risk: A step toward the integration of risk management and quantification. *International Journal of Project Management, 32, 1056-1072*

[11] Espinoza R.D., Rojo J. (2015) Using DNPV for valuing investments in the energy sector: A solar project case study. *Renewable Energy, 75, 44-49*

[12] Johar K; Carmichael, D G, and Balatbat, MC. 2010, A study of correlation aspects in probabilistic NPV analysis', *Engineering Economist*, vol. 55, pp. 181 - 199, http://dx.doi.org/10.1080/0013791X.2010.481185

[13] Carmichael D G;Balatbat MC A, 2008, 'Probabilistic DCF analysis and capital budgeting and investment - A survey', *Engineering Economist*, vol. 53, pp. 84 - 102, http://dx.doi.org/10.1080/00137910701864809

[14] F. Hawas and A. Cifuentes, Valuation of Projects with Minimum Revenue Guarantees, The Engineering Economist, March, 2016,

[15] F. Hawas and A. Cifuentes, Valuation of Projects with Stochastic Cash Flows and Inter-Temporal Correlations, ASCE Journal of Construction Engineering and Management, Vol. 40, Issue 6, June 2014.

[16] A. Cifuentes and D. Espinoza, Infrastructure Investing and the Peril of the Discounted Cash Flow, Financial Times, November, 2016.

ARTURO CIFUENTES, Ph. D.

Adjunct Professor, Division of Finance & Economics; Columbia University, New York
e-mail: ac4170@columbia.edu

Research Associate, CLAPES-UC, Santiago
e-mail: aocusa@gmail.com

Arturo holds a Ph.D. in applied mechanics and a M. S. in civil engineering from the California Institute of Technology (Caltech); an MBA in finance from New York University (Stern scholar award); and a civil engineering degree from the University of Chile.

Currently, he divides his time between New York and Chile. In New York, he is an Adjunct Professor at the Division of Finance & Economics of Columbia University. In Chile, he is a Research Associate at CLAPES-UC, a research/public policy center affiliated with the Catholic University. He also advises the Chilean Association of Insurance Companies on financial regulation issues and, the board of an important power company on investment-related matters. Additionally, he is actively engaged in consulting with a focus on alternative investments, derivatives products and financial litigation.

Previously, he served three years as a member and President of the Chilean Sovereign Fund investment committee (US$ 25 billion); and four years as a member of the Advisory Board of the Division of Humanities and Social Sciences of the California Institute of Technology (Caltech). He also participated in the Financial Regulation Reform Commission that was appointed by the Chilean Minister of Finance (2010-2011).

Arturo brings more than twenty years of experience as an investment banker, hedge fund manager, risk analyst, scientist, university professor, consultant, and newspaper columnist. His focus is mainly on the fixed income arena, asset management, derivatives and securitization. Before switching to the financial field he worked as a scientist doing research on applied mathematics and mechanical engineering related problems.

In the financial arena, he has acted as an advisor/consultant to government entities and private firms in Chile, the United States, and Asia. He has participated as lecturer or keynote speaker in many events in more than twenty countries. Furthermore, he has written two books, four book chapters, and numerous academic articles (refereed papers) on topics related to finance, portfolio management, applied mathematics, and engineering. His opinion pieces have been published by the Financial Times, CAPITAL and La Tercera. At present, he is a regular columnist for El Mercurio and PULSO (both Chilean publications).

As a result of the subprime financial crisis, he was invited twice to testify, as expert witness, by the U.S. Senate. He has also been consulted by the U.S. Congress, the U.S. Treasury, and the Connecticut State Insurance Commissioner.