Socioeconomic Assessment and Cost-Benefit Analysis Frameworks for the TAMBO Research Infrastructure

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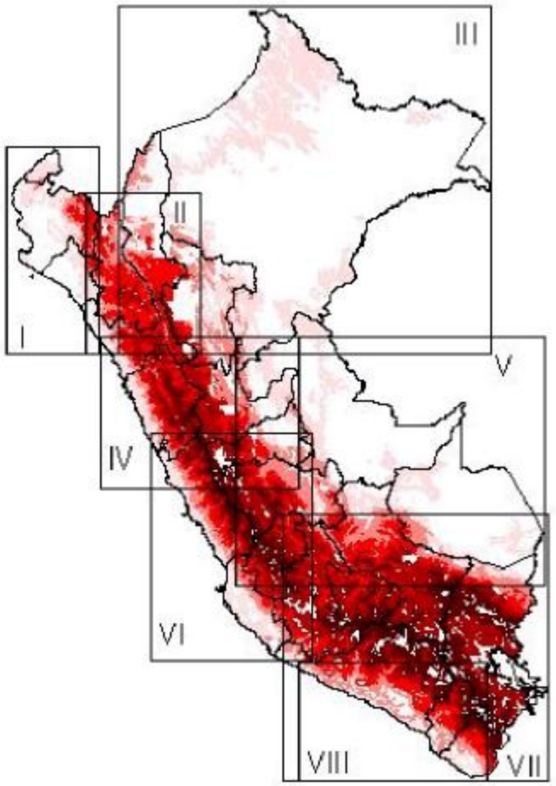
TAMBO

Outline

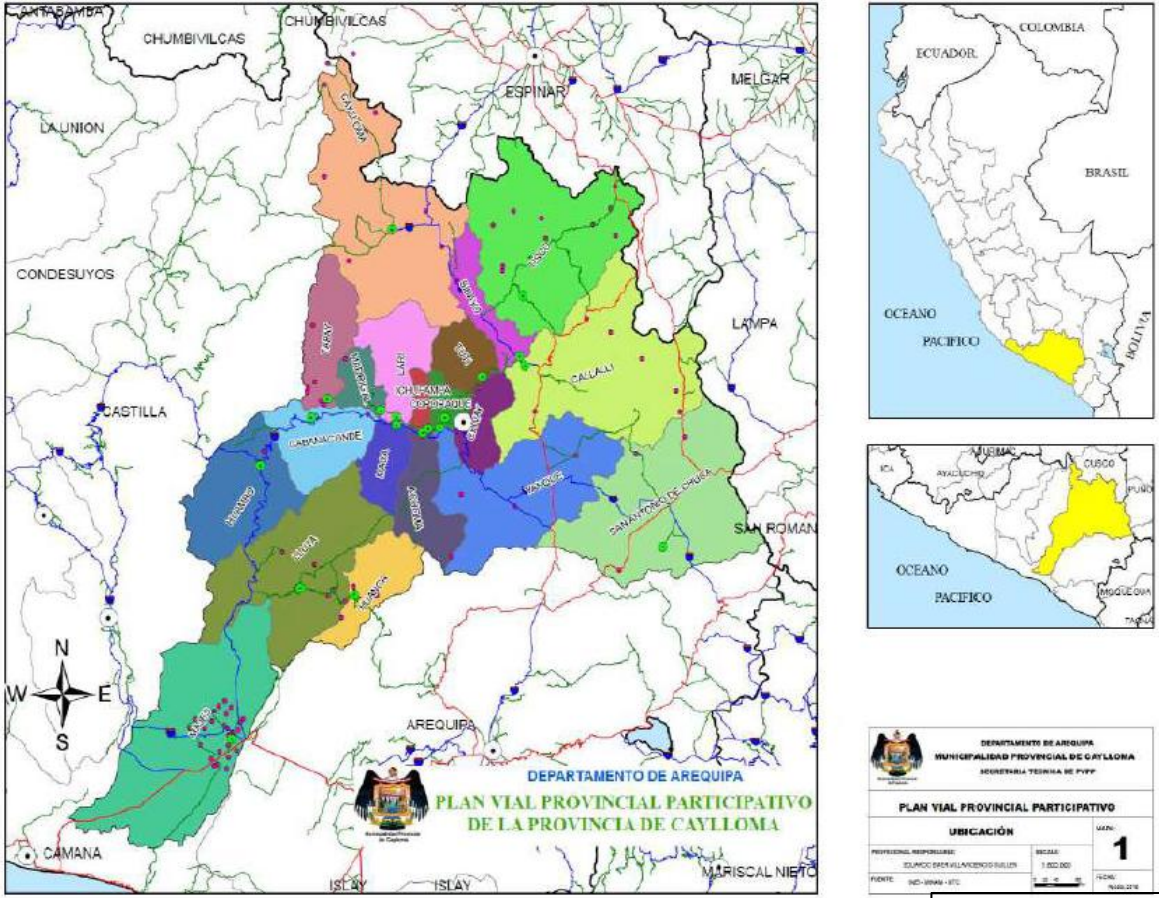
- Socioeconomic assestment of relevant districts.

- Cost-benefit analysis of Research Infrastructures.
    - Costs.
    - Non-use benefits.
    - Use-benefits.

Solar radiation in Peru



Mapa N° 1
Mapa de Ubicación



Fuente: INEI-MINAM-MTC
INEI Compendio Estadístico Arequipa 2010/Censo 2017

Imagen obtenida del Plan Vial Provincial Participativo de Caylloma 2020 – 2024

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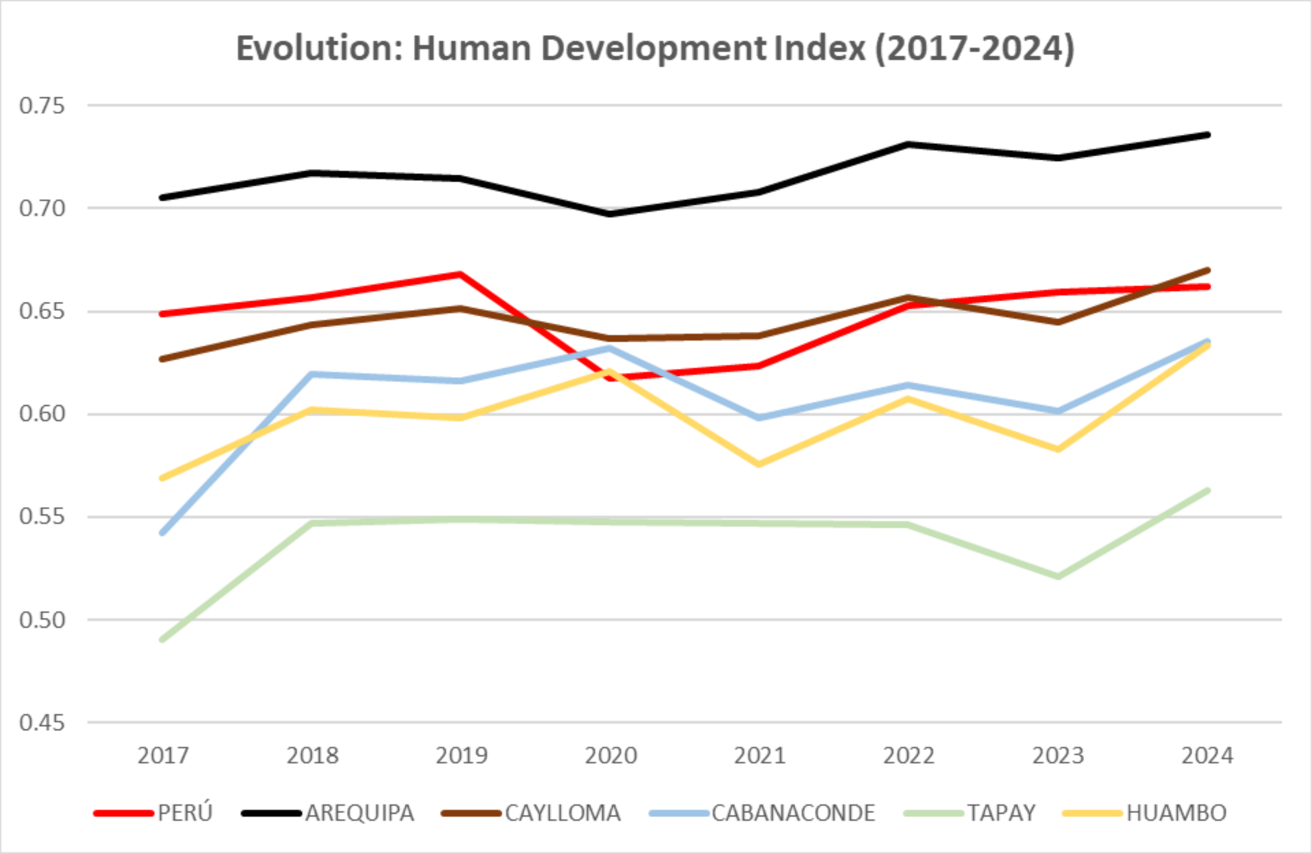
An approach based on the HDI



NUD (2025)

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An approach based on the HDI

2024						
Indicator / Place	Population	Life Expectancy at Birth	Years of Education	Monthly Real per capita Household Income*		HDI
				(S/)	($)	
PERÚ	**34038456**	**78.33**	**9.45**	**896.5**	**238.8**	**0.66**
AREQUIPA	**1605569**	**82.07**	**10.54**	**1,061.6**	**282.8**	**0.74**
CAYLLOMA	**104723**	**80.83**	**9.25**	**826.2**	**220.1**	**0.67**
CABANACONDE	2019	80.19	9.38	685.2	182.5	0.64
TAPAY	921	78.89	7.25	594.9	158.5	0.56
HUAMBO	636	80.24	9.46	657.2	175.1	0.63

*Nominal exchange rate (Annual Average 2024): 1 USD = 3.754 PEN (Central Reserve Bank of Peru)

Source: UNDP (2025)
Own elaboration

An approach based on the HDI

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Source: UNDP (2025)
Own elaboration

Cost-benefit analysis of Research Infrastructures

Charasteristics of a Research Infrastructure

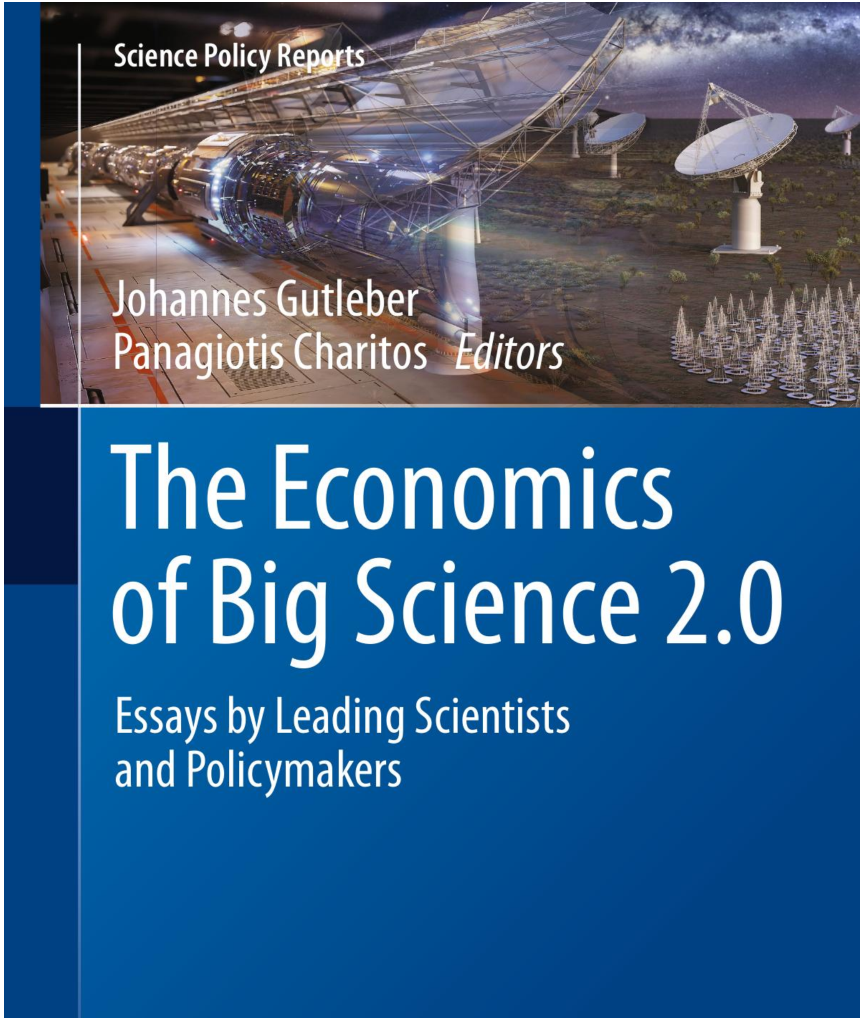
- **High capital** intensity at early stage.
- Long **time horizon** involved in the cost side and the benefit side.
- **Externalities** and **spillover** effects.
- There is **no explicit market** for the services of RI.
- Very **limited competition**.

Cost-Benefit Analysis (CBA)

- Decision-making **framework**.
- Compares the total **quantified costs** and **benefits** of a project or policy in monetary terms.
- Determines its **economic viability**.

In the last decades, several methods have been developed to conduct a CBA analysis of **Research Infrastructures**.


INVESTING IN SCIENCE
Social Cost-Benefit Analysis
of Research Infrastructures
MASSIMO FLORIO


Science Policy Reports
Johannes Gutleber
Panagiotis Charitos Editors
The Economics
of Big Science 2.0
Essays by Leading Scientists
and Policymakers

Socioeconomic Impact of the Pierre Auger Observatory

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[c]

January 2022

Socio-economic impact evaluation study of the UK subscription to ESO

Final Report – Summary

Projecting the socio-economic impact of a Big Science Center: the world's largest particle accelerator at CERN

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Integration of Socio-Economic Impact in the Development of the Square Kilometre Array of South Africa

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Costs

K	Economic value of capital.
L_s	Scientific labor cost.
L_O	Administrative and technical labour cost.
O	Other operating costs.
E	Negative economic externalities: - Environmental impact. - Social impact. The **Responsible Siting Team** is actively mitigating this cost.

1. Non-use benefits

QOV_0	Potential value of scientific discovery.
EXV_0	Intrinsic value of the existence of the RI.

Value that individuals assign to a resource or public good **independent of their current, future, or potential physical utilization of it**.

2. Use-Benefits

T	Technological externalities (spillovers).
H	Human capital formation.
S	Scientific knowledge output
C	Cultural impact and outreach
A	Services to third parties and consumers.

Value generated when individuals actively **consume**, **experience**, or **utilize** a resource.

We will briefly list all the use-benefits of Research Infrastructures.

We ask you to think of ways TAMBO can maximize these benefits.

2.1 Technological externalities (T).

Benefits to **firms** (reduction of costs, new markets, efficiency increase, etc.).

Does **not** include **off-the-shelf** goods.

Includes **spin-offs**.

2.1 Technological externalities (T).

Key initiatives:

1. High **tech** instrument development at **local universities or companies**.
2. Train **local manufacturers** to fabricate the RI's electronics at scale.
3. Company **visibility** is highly valuable.

2.2 Human capital formation (H).

Increase in **earnings** of students and junior researchers.

Up to 12%.

2.2 Human capital formation (H).

Key initiatives:

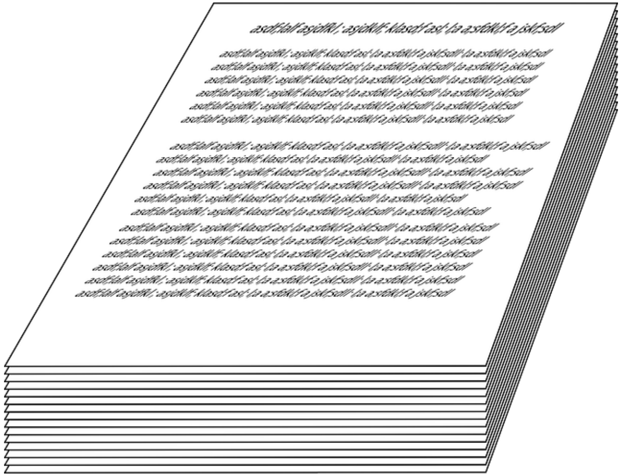
1. Promote **double-degree** programs.
2. Target **mechatronics and data science graduates** for funded **internships** (learning by doing).
3. Fellowship where funded postgraduates spend a portion of their time **tutoring in high schools**.

2.2 Human capital formation (H).

Key initiatives:

4. Focus on **transferable** technical skills instead of facility-specific ones.
5. Offer practical/technical programs.
6. Strengthen **regional** talent pipelines.
7. Create new local research groups.

2.3 Scientific knowledge output (S)

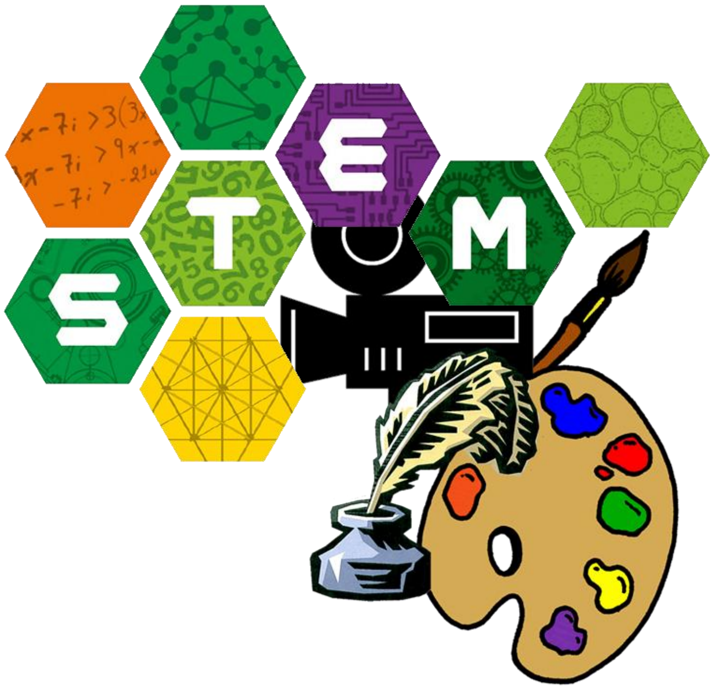


Academic **publication waves**.

Collaboration publications have zero net value.

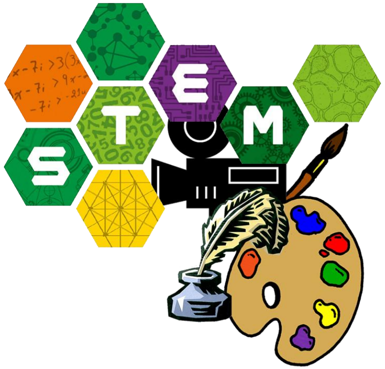
Secondary waves of publication have net value (opportunity cost).

2.4 Cultural impact and outreach (C)



Public utility generated through **scientific communication** and **education** directed at the general public.

2.4 Cultural impact and outreach (C)



Key initiatives:

- Bilingual **etnoastronomy program.**
- State-of-the-art **Science Visitor Centre**.
- Launch regional **science fairs.** This can be done quite early.
- Promote webiste, social media, traditional media, etc: this increases **existence value**.

2.5 Services to third parties and consumers (A)

Direct **social welfare enhancements** passed down to external users or the public.

2.5 Services to third parties and consumers (A)

Key initiatives:

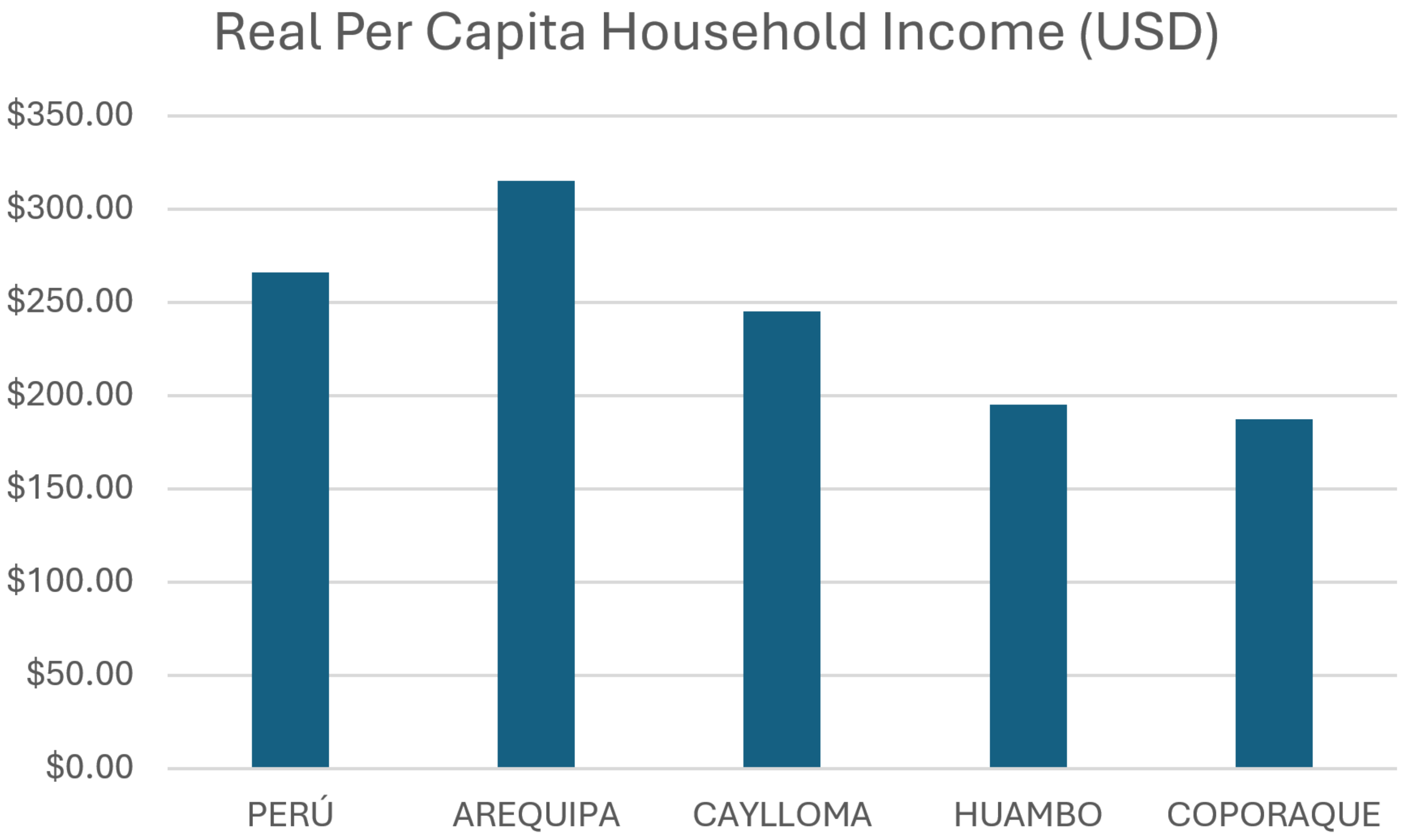
- **Open source** software.
- Donate **decommissioned or upgraded** power units**.**
- Economics of scale: produce **marginal numbers** of units.
- Improve community **connectivity**.
- Real-time **environmental data**.
- **Topography?**

What’s next?

- Study the particular challenges of estimating the social benefits of RIs in developing countries.
- Adapt the CBA methodology for RIs to developing-country contexts.
- Forecast TAMBO’s NPV
  - Collect data.
  - Benefit transfer method from similar infrastructures.
  - Risk analysis: Montecarlo simulation.

Thank you

Backups



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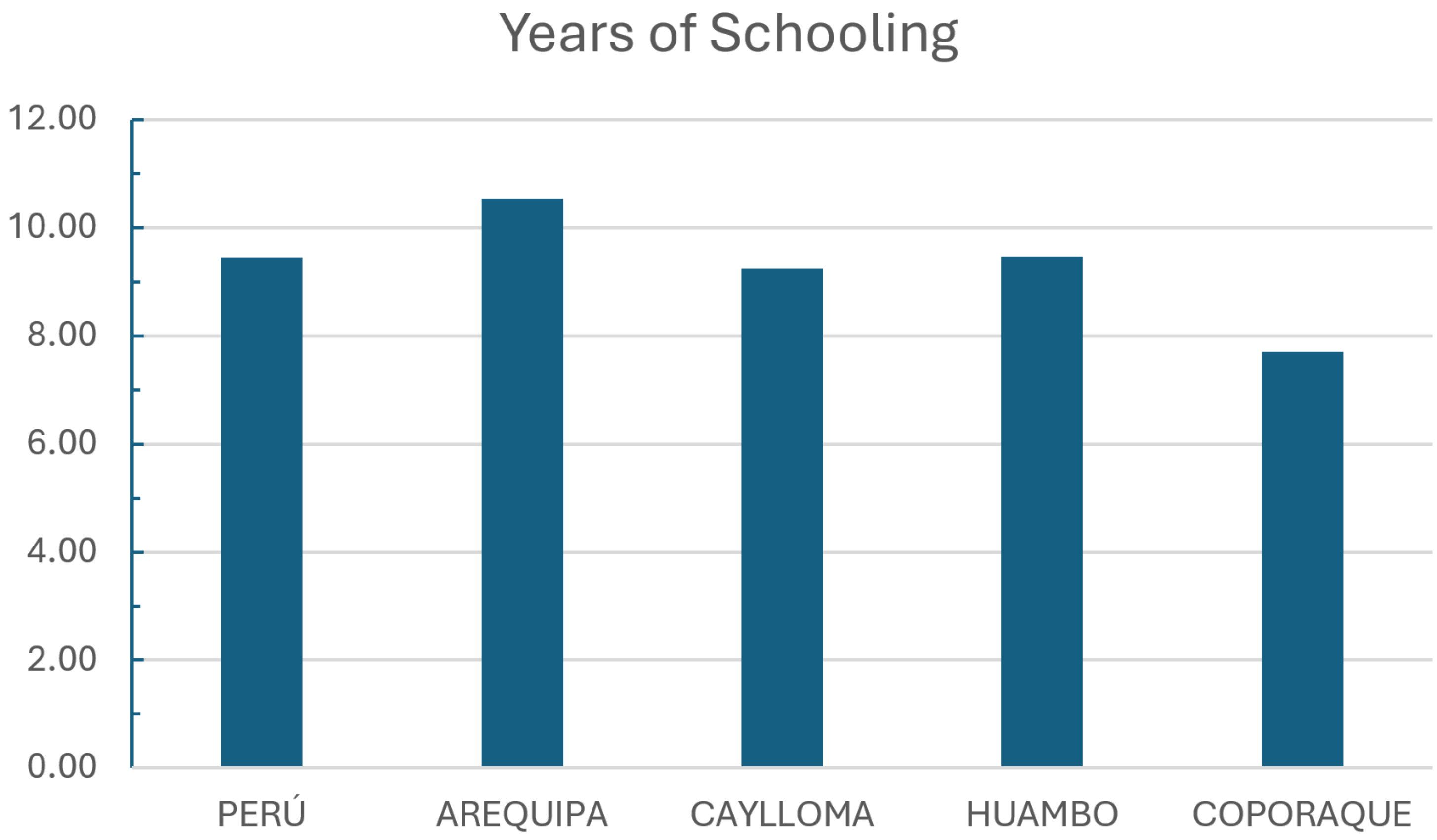

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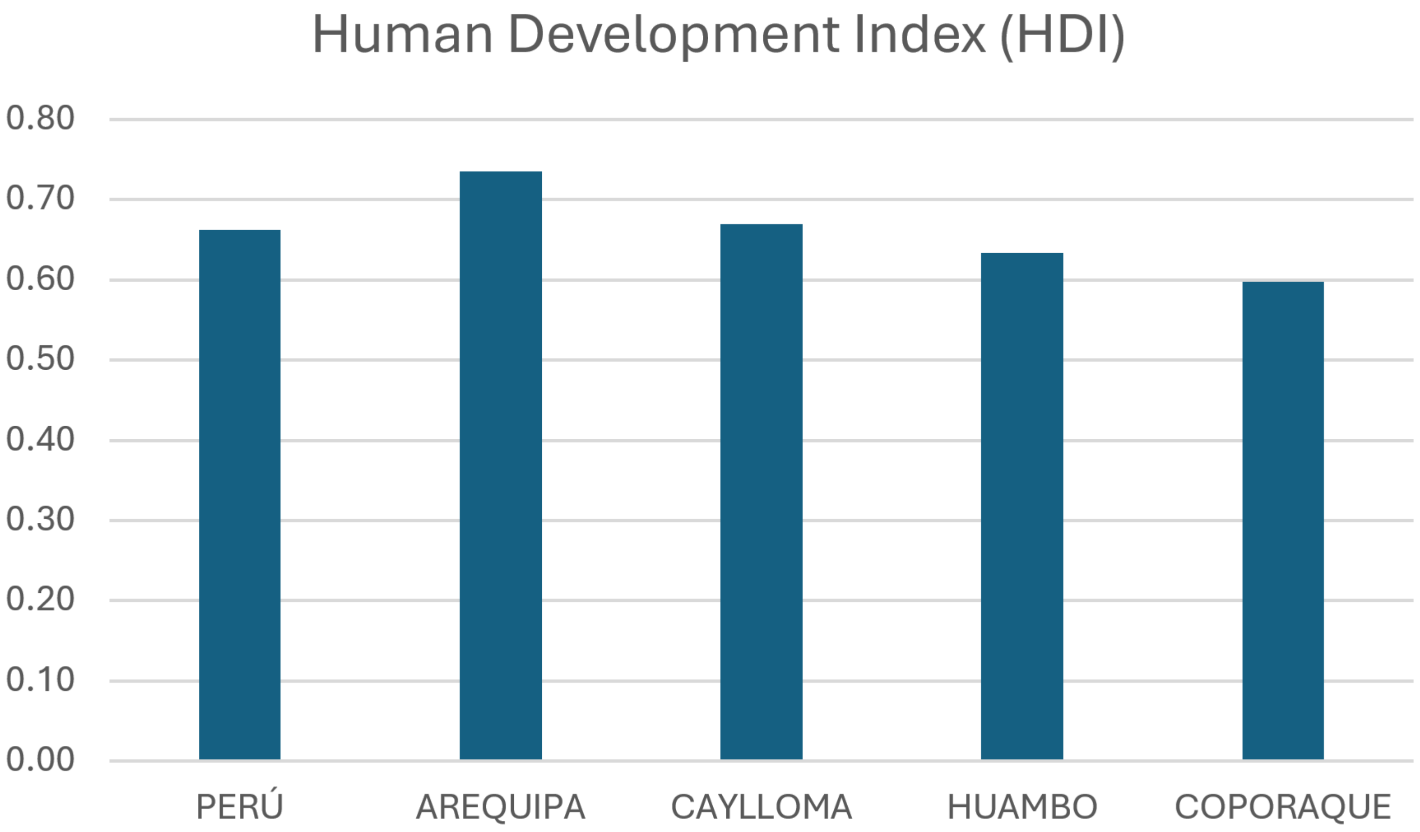
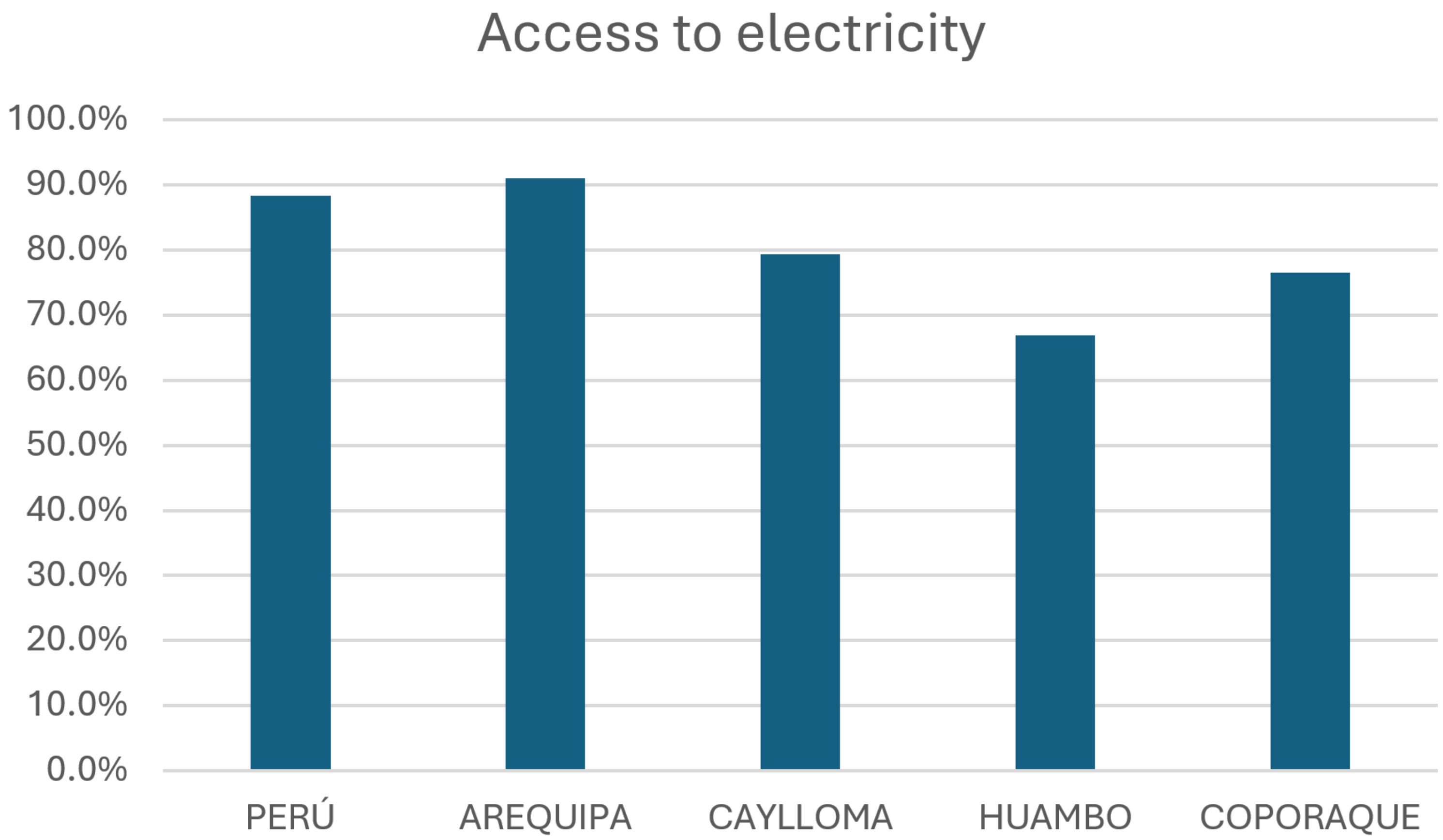
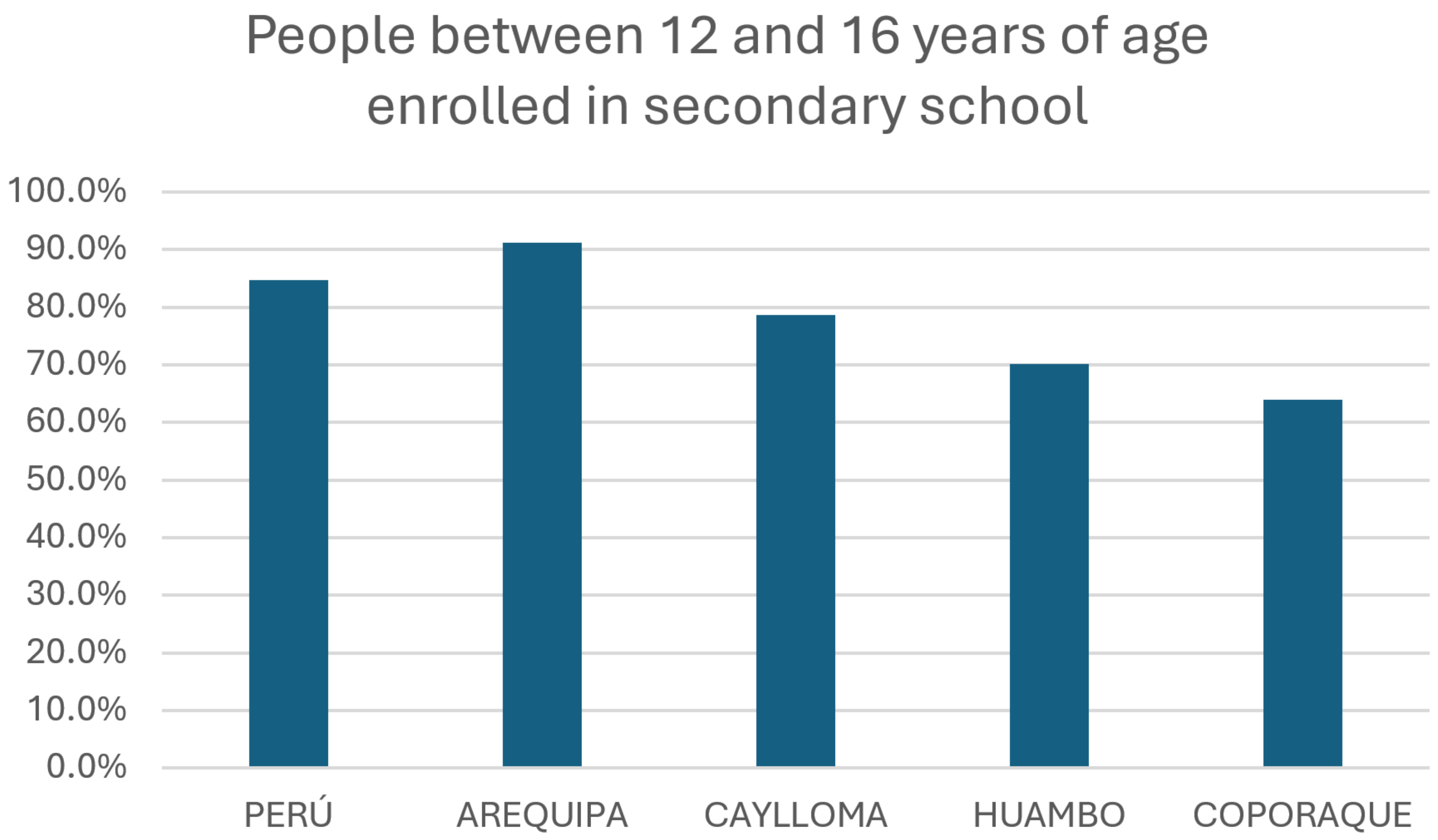


Human Development Index (HDI)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
PERÚ
AREQUIPA
CAYLLOMA
HUAMBO
COPORAQUE


Access to electricity
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
PERÚ
AREQUIPA
CAYLLOMA
HUAMBO
COPORAQUE



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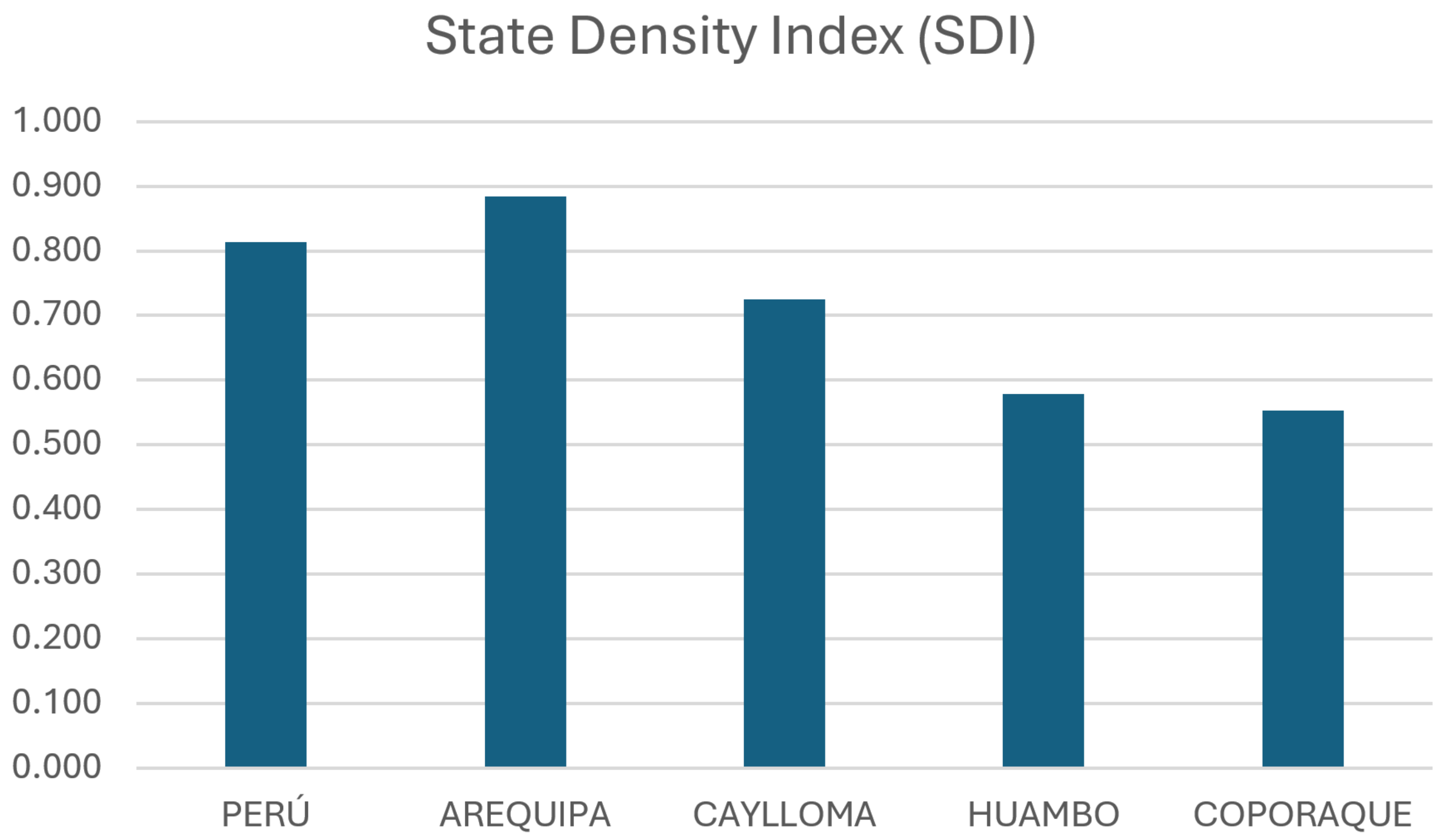

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2024 - Human Development Index (HDI)

Ubigeo	DEPARTAMENTO PROVINCIA DISTRITO	Population	Life Expectancy at Birth	Expected Value of Years of Schooling in the Household	Years of Schooling	Real Per Capita Household Income	Human Development Index (HDI)	Ranking
000000	PERÚ	34038456	78.33	0.67	9.45	S/ 896.5	0.66	
040000	AREQUIPA	1605569	82.07	0.72	10.54	S/ 1,061.6	0.74	
040500	CAYLLOMA	104723	80.83	0.69	9.25	S/ 826.2	0.67	
040507	HUAMBO	636	80.24	0.69	9.46	S/ 657.2	0.63	283
040506	COPORAQUE	1114	80.64	0.62	7.70	S/ 631.0	0.60	439

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2024 - State Density Index (SDI)

Ubigeo	DEPARTAMENTO PROVINCIA DISTRITO	Population	Access to water and sanitation	Access to electricity	Education			Health		
					People between 12 and 16 years of age enrolled in secondary school	% of population living less than 60 minutes away from a secondary school	index	Physicians per 10,000 inhabitants	% of population living less than 60 minutes away from a health center	index
000000	PERÚ	34038456	80.8%	88.3%	84.7%	98.0%	0.914	17.789	83.7%	0.676
040000	AREQUIPA	1605569	87.4%	91.0%	91.2%	99.1%	0.952	22.372	90.5%	0.777
040500	CAYLLOMA	104723	67.8%	79.4%	78.6%	95.8%	0.872	13.751	68.9%	0.544
040507	HUAMBO	636	56.8%	66.9%	70.1%	92.5%	0.813	31.447	0.0%	0.456
040506	COPORAQUE	1114	69.7%	76.5%	64.0%	88.8%	0.764	17.953	0.0%	0.260

Ubigeo	DEPARTAMENTO PROVINCIA DISTRITO	Security			Connectivity			State Density Index (SDI)	Ranking
		Police officers per 100,000 inhabitants	% of population living less than 60 minutes away from a police station	index	People with access to connectivity	% of population living less than 60 minutes away from a city	index		
000000	PERÚ	397.345	93.8%	0.866	81.9%	64.7%	0.733	0.813	
040000	AREQUIPA	418.917	97.8%	0.908	92.8%	83.3%	0.881	0.884	
040500	CAYLLOMA	274.056	95.0%	0.749	75.9%	67.2%	0.716	0.725	
040507	HUAMBO	1257.862	92.5%	0.963	0.0%	0.0%	0.000	0.578	880
040506	COPORAQUE	0.000	88.8%	0.444	77.1%	0.0%	0.386	0.553	977

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TAMBO’s modular approach

- Modular, Stage-Gated Deployment: Restructures massive, high-risk CapEx into sequential phases separated by explicit decision gates.
- Contingent Progression: Makes the execution of each subsequent stage strictly dependent on the technical and socioeconomic validation of the previous one.
- Real Options Framework: Converts a rigid, "all-or-nothing" financial commitment into a portfolio of real options that minimizes fiscal risk.
- Downside Protection: Limits the maximum potential financial loss strictly to the cost of the initial pilot.
- Evidence-Based Scaling: Ties all future infrastructure expansion directly to real-time scientific evidence.

Limitations of CBA Analysis

1. It trivially (conservatively) assumes that the Potential Value of Scientific Discovery is zero. This point could be reconsidered, as the history of physics is full of unplanned discoveries that brought tremendous value to society.
2. In the context of developing countries, there are many additional unconsidered risks (geographic, cultural, health-related, security, educational, etc.), but also benefits (for example, the positive externalities of installing solar panels).
3. In this high-risk environment, the modular approach of the project (moving from the simplest to the most complex) becomes especially relevant.

Net Present Value (NPV)

- **Present Value (PV)**: **current** monetary worth of any future sum of money: benefits, revenues, costs, etc.
- **Net Present Value (NPV):**

$$NPV = PV_{\text{Benefits}} - PV_{\text{Costs}}$$

NPV > 0	Adds value to society
NPV = 0	Neither adds or subtracts value
NPV < 0	Subtracts value

$$NPV_{RI} = NPV_u + B_n$$

$$NPV_u = PV_{B_u} - PV_{C_u}$$

$$B_n = QOV_0 + EXV_0$$

$$T = \sum_{j=1}^{J} \sum_{t=0}^{T} \frac{1}{(1+r)^t} \cdot \Pi_{jt} = \sum_{j=1}^{J} \sum_{t=0}^{T} \frac{1}{(1+r)^t} \cdot (\Delta\text{revenues}_{jt} - \Delta\text{costs}_{jt}),$$

$$S = \sum_{t=0}^{\mathcal{T}} s_t \cdot P_{0t} + \sum_{i=1}^{n} \sum_{t=1}^{\mathcal{T}} \frac{s_t \cdot P_{it}}{k_{it}} + \sum_{i=0}^{n} \sum_{t=1}^{\mathcal{T}} s_t \cdot Q_{it}$$

$$C = \sum_{x=1}^{X} \sum_{g=1}^{G} \sum_{t=1}^{\mathcal{T}} \frac{1}{(1+r)^t} W_{xgt} \qquad A = \sum_{a=1}^{A} \sum_{t=0}^{\mathcal{T}} \frac{1}{(1+r)^t} a_{at}$$