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Building upcycling *vs.* building reconstruction investment decisions: a focus on the discount rate

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Abstract

This work continues the methodological exploration illustrated in a correlated contribution presented by the Authors to this Symposium. In this advancement, the focus is on selecting the appropriate discount rate for the NPV calculation, evaluating alternative scenarios in the building construction sector. Assuming the presence of environmental and financial input variables in the DCF model, a "time preference" discount rate seems inappropriate. Thus, as an alternative, the environmental hurdle rate technique is explored. This is based on using different rates considering the negative contribution to the environment due to an input variable or, conversely, considering the technological development expectations toward energy consumption and CO_2 emissions reduction over time. Simulations on two alternative scenarios are implemented: the retrofit scenario and the demolition and reconstruction scenario of an existing residential building. The results confirm the importance of the discount rate capability in influencing the DCF model output, even more in the presence of environmental input, highlighting their weight on increasing the asset residual value. Further, the environmental hurdle rate can perturb the final scenario ranking toward environmentally responsible investment decisions at different scales.

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Keywords: Discounted Cash-flow Analysis, Environmental Costs, Discounting, Environmental Hurdle Rate.

1. Introduction

The necessity to internalize environmental components in the investment decision processes concerning building upcycling vs. building reconstruction of the existing heritage is explored in a correlated contribution titled “Building Upcycling vs. Building Reconstruction: a Life Cycle Valuation for Investment Decisions” presented to this Symposium. In that work, a methodological proposal is presented to support the environmental-economic valuation of project options using the Discounted Cash Flow Analysis (DCFA), in which the global cost and global benefit concepts are assumed to formalize the NPV indicator, according to a life cycle perspective (Fregonara, 2017). A DCFA simulation shows the impact of Embodied Energy (EE) and CO_2 emitted during the management stage as hidden cost components on the NPVs calculation, adopting a set of simulation assumptions and operative modalities supported by the literature on the topic (Langdon, 2007. Gaspar and Santos, 2015. Moschetti and Brattebø, 2017. Lo Curcio et al., 2022).

To complete the reasoning in this contribution, the focus is on selecting an appropriate discount rate for the NPV calculation, assuming that in the presence of environmental and financial input variables in the DCF model, a “time preference” discount rate seems inappropriate. As discussed in the recent literature on the topic, selecting an appropriate discount rate is a delicate step in evaluative applications, both in private and public investment projects, particularly in the case of interventions highly impacting the environment and involving long time horizons. For example, studies focus on using the declinant discount rate, also according to a probabilistic approach, as an alternative to the traditional discounting procedures in the Cost-Benefit Analysis applications (Nesticò and Maselli, 2020. Maselli and Nesticò, 2020. Nesticò et al., 2023.). In another study (Maselli and Nesticò, 2022), attention is given to the social discount rate as an alternative to constant discount rates, specifically in evaluating projects oriented toward the strategies to contain global warming.

Assuming that the discount rate is capable of expressing the time value of money and assuming that it can be determined by summing up different components (i.e., cost of capital, inflation, opportunity cost, systematic risk, and specific risk, etc.) in this contribution two alternative discounting modalities are explored (Gray et al., 1993. Fregonara and Ferrando, 2023):

- The conventional approach calculates the NPV by adopting the financial (or market) discount rate value. This approach is founded on the “time preference” principle, adopting nominal costs and real/nominal discount rate
- The environmental hurdle rate approach is found on different rate values - green, yellow, and red -given the degree of the negative contribution to the environment produced by each input variable, according to the hurdle rate principle.

The hurdle rate approach is selected in this work as an alternative to the classic financial rate because it «is applicable in the case where an investment is financially economical but not environmentally favorable» (Thomas et al., 2021). Thus, centrality is posed on the environmental hurdle rate technique, considering the negative impact to the environment and related cost or, conversely, considering the technological development expectations toward energy consumption and CO_2 emissions reduction. The environmental hurdle rate is explored as an alternative to the financial discount rate in the presence of environmental components through simulations of two options: the retrofit of an existing residential building scenario and the demolition and reconstruction scenario. The results confirm the importance of the discount rate capability in influencing the DCF model output by modeling environmental cost components and their expectations, given the potential technological development over time. The results can impact their final preferability ranking by the environmental hurdle rate instead of financial rates. The second part of this work shows that the methodology can support environmentally responsible investment decisions at different scales and property contexts.

The work is articulated as follows. In section 2, the methodological background is synthesized. In section 3, the simulation assumptions and results are illustrated. Finally, section 4 concludes.

2. Methodology

A methodological proposal is illustrated in the abovementioned contribution to this Symposium. This represents the theoretical framework in which this work is placed. Synthetically, the methodology assumes the proposal illustrated in (Fregonara, 2023), which is based on the following premises:

- The Global Cost concept (EN 15459:2007 Standard, and Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012).
- The economic-environmental indicator which is formalized through the Life Cycle Assessment (ISO 14040:2006) and the Life Cycle Costing (ISO 15686:2008) approaches. This indicator, presented in (Fregonara et al., 2017), includes recycled materials, dismantling, and waste produced in the building construction processes. In the mentioned study, the Global Cost is rewritten as in equation (1):

$$C_{GEnEnv} = C_I + C_{EE} + C_{EC} + \sum_{t=1}^{N} (C_m + C_r) . R_d(i) + (C_{dm} + C_{dp} - V_r) . R_d(i) \qquad (1)$$

  where: C_{GEnEc} is the Life Cycle Cost, which includes environmental and economic components; C_I is the investment cost; C_{EE} is the cost related to EE; C_{EC} is the cost associated with the EC; C_m is the maintenance cost, C_r is the replacement cost; C_{dm} and C_{dp} the dismantling and disposal cost respectively; V_r is the residual value; t is the year in which the cost occurred and N the number of years of the analysis; R_d is the discount factor.
- Finally, the end-of-life stage and the building's final value, which can be positive or negative.

Assuming these premises, the "Global Benefit" concept is proposed as a first step. This last is conceived as the sum of the incomes deriving from an investment in a building reconstruction/retrofitting intervention, incorporating the energy-environmental value components of the existing building as implicit or 'hidden' values. The environmental impact on the value is monetized through the embodied residual energy, which can be reused in a building's upcycling process, and through the quantity of CO_2 embodied in material/component/system production and operation, saved/avoided by building recycling, avoiding a dismantling and reconstruction intervention. Formally, the Global Benefit can be expressed as in the following equation (2):

$$B_{gEnEnv} = V_{tr} + V_{en} + V_{env} + \sum_{t=1}^{N} (R_{Revenue}) . R_d(i) + V_r . R_d(i) \qquad (2)$$

where: B_{gEnEnv} is the economic-energy-environmental Global Benefit, V_{tr} is the market value of the asset to be transformed, V_{en} is the residual energy value, and V_{env} is the environmental value (avoided EC). $R_{Revenue}$ is the market income, t the year in which the income occurred, and N is the number of years assumed for the analysis. Finally, V_r is the residual value, and R_d is the discount factor.

As a second step, the methodology assumes the Net Present Value (NPV) synthetic indicator calculation (as theorized in the Discounted Cash-Flow Analysis), which, according to the Global Cost and Global Benefit concepts, can be rewritten by encompassing externalities in the life cycle:

$$NPV = \sum_{t=1}^{n} \frac{B_{gEnEnv} - C_{gEnEnv}}{(1+r)^n} \qquad (3)$$

As a third step, equation (3) can be rewritten as in equations (4) and (5), assuming the cost/value input in a DCFA model respectively for the retrofit scenario and the demolition and reconstruction one:

$$NPV = \sum_{t=1}^{n} \left[\left(\frac{B_{gRetrofit}}{(1+r')^{n}} \right) - \left(\frac{C_{\mathrm{gEnEnv}Retrofit}}{(1+r'')^{n}} \right) \right] \qquad (4)$$

$$NPV = \sum_{t=1}^{n} \left[\left(\frac{B_{gReconstr}}{(1+r')^{n}} \right) - \left(\frac{C_{\mathrm{gEnEnv}Reconstr}}{(1+r'')^{n}} \right) \right] \qquad (5)$$

Assuming the methodological proposal synthesized here, this work focuses on the discounting procedure. As mentioned in the introduction section, two alternative discounting approaches are explored. Precisely:

1) the conventional discounting approach, based on the time preference principle. In this case, the Net Present Value is obtained by discounting the costs and incomes and by adopting the classic financial (or market) discount rate, as formalized in Equation (6):

$$NPV = \sum_{t=0}^{T} C_n (1+i)^{-t} \qquad (6)$$

The time preference approach is consolidated in DCFA applications according to the Linear Economy in the presence of financial model input. Conversely, the conventional approach presents some criticalities when there are environmental components besides financial ones. For example, it does not consider the potential increase in environmental costs, which, on the contrary, are highly affected by uncertainty over time.

2) the environmental hurdle rate approach. This approach focuses on adopting differentiated discount "hurdle" rates in view of the weight of the impact on the environment potentially produced during the construction/management activities. The correlated cost amount expresses the environmental impact, and, according to the hurdle rate principle, the higher environmental cost is discounted by adopting a red discount rate, a less relevant cost is discounted by assuming a yellow discount rate, an expected decreasing cost is discounted by adopting a green discount rate. This approach is preferable to the previous one given its capability to introduce flexibility over time in the cash-flows, for example, the potential technological development, changes in the cost weights, etc. The hurdle rate can be formalized as in the Equation (3):

$$NPV = \sum_{t=0}^{T} C_{n,r}(1+r)^{-t} + \sum_{t=0}^{T} C_{n,y}(1+y)^{-t} + \sum_{t=0}^{T} C_{n,g}(1+g)^{-t}$$

where C represents the capital (incomes and costs), r represents the red rate, y represents the yellow rate, g represents the green rate, and t represents the time. In our case, by adopting the global benefit and the global cost, the previous Equation can be rewritten as the following Equations 7 and 8 referred to the case of reconstruction and retrofit, respectively:

$$NPV = \sum_{t=1}^{n} \frac{B_{gEnEnv}Rec - C_{gEnEnv}Rec}{(1+r)^{n}} + \sum_{t=1}^{n} \frac{B_{gEnEnv}Rec - C_{gEnEnv}Rec}{(1+y)^{n}} + \sum_{t=1}^{n} \frac{B_{gEnEnv}Rec - C_{gEnEnv}Rec}{(1+g)^{n}} \qquad (7)$$

$$NPV = \sum_{t=1}^{n} \frac{B_{gEnEnv}Retr - C_{gEnEnv}Retr}{(1+r)^n} + \sum_{t=1}^{n} \frac{B_{gEnEnv}Retr - C_{gEnEnv}Retr}{(1+y)^n} + \sum_{t=1}^{n} \frac{B_{gEnEnv}Retr - C_{gEnEnv}Retr}{(1+g)^n} \quad (8)$$

The simulation assumptions and results of these premises are shown in the following section.

3. Simulation and results

This simulation assumes the input data and the time horizon adopted in the correlated work. Conversely, differentiated discount rates are selected to test the model results by adopting financial vs hurdle rates. For clearness, the simulation assumptions are summarized in Table 1.

Table 1. Simulation assumptions.

Input Drivers	Unit of measurement	Upcycling scenario	Reconstruction scenario
Investment cost	€	900,000	900,000
Incomes (rent)	€ per year	68,600	68,600
Value of the building (after 30 years)	€	2,155,973	2,155,973
Maintenance cost	€ per year	686	686
Replacement cost	€ per year	13,500	13,500
Operation costs (heating + electric power)	€ per year	12,836	12,836
End-of-life costs (dismantling + disposal)	€	30,000	30,000
Embodied Energy (in investment cost)	MJ/m^2	5,666	7,271
Embodied Energy (in investment cost)	€	157,401	201,988
CO_2 (in operation costs)	kg/m^2 per year	14.90	14.90
CO_2 (in operation costs)	€ per year	331	331
Discount rate - Financial	%	6.50	6.50
Discount rate – Environmental Red	%	0.00	0.00
Discount rate – Environmental Yellow	%	4.00	4.00
Period of analysis	years	30	30

Precisely, Table 1 presents the same list of input drivers illustrated in the correlated paper, except for the items listed in the next bullet point:

- Value of the building. This value results from the assessment of the market residual value of the building at the end of the holding period (30 years), calculated through the income capitalization procedure. A capitalization rate equal to 5% is assumed by comparing to a reference market value
- The financial rate. The value of 6.50 is hypothesized, assuming the rate is usually dimensioned to verify the financial conveniences in the specific market context (see the correlated contribution). The financial, or market, rate is adopted specifically for discounting the relevant cost items in the construction phases
- The environmental rates, red and yellow. These rates are adopted to discount the environmental input and the other items directly impacting, or correlated, the technologically weighted development for environmental impact mitigation and the impact these can produce on asset value. Precisely, the red rate equal to 0% is adopted for items directly impacting on environment (EE and CO_2), and a yellow rate equal

to 4% is adopted for discounting input quantities which could benefit mitigation effects with the adoption of technologies for mitigation and appreciated by the market demand. Besides, the yellow rate is adopted to discount operational costs, end-of-life costs, and residual asset value.

Notice that adopting environmental rates can highlight the input driver weight on the financial results, as shown in Table 2.

Table 2. Simulation results.

Input Drivers	Unit	Upcycling scenario	Unit	Reconstruction scenario
Investment cost	%	6.5	%	6.5
Incomes (rent)	%	6.5	%	6.5
Value of the building (after 30 years)	%	4	%	4
Maintenance cost	%	6.5	%	6.5
Replacement cost	%	6.5	%	6.5
Operation costs (heating + electric power)	%	4	%	4
End-of-life costs (dismantling + disposal)	%	4	%	4
Embodied Energy (in investment cost)	%	0	%	0
CO_2 (in operation costs)	%	0	%	0
NPV (different hurdle rates)	€	298,966.04	€	254,379.14
NPV (6.5% uniform discount rate)	€	46,316.40	€	4,450.77
NPV (6.5% discount rate - only "financial" inputs)	€	388,239.11	€	388,239.11

Following the first simulation, the upcycling scenario preferability is confirmed even when adopting differentiated rates. The difference between the upcycling scenario NPV and the reconstruction scenario NPV is slight. Still, it must be considered that in this simulation, the CO2 input during the construction phases and the EE during the management stage is not included in the model. An application with the complete set of quantities could produce a more pronounced gap. Then, if the EE should be spread over time in place of the solely initial (not discounted) amount, the effect of the hurdle rate adoption could be further highlighted.

In conclusion, it is worth noticing that the results obtained confirm the theoretical assumption that the constant discount rate value, traditionally adopted in the discounting processes, is not appropriate when evaluating environmentally impacting projects. In this sense, the application of the hurdle rate method demonstrates a strength, as the results show the significant impact that the use of different rates determines on the results of the analysis themselves. This aligns with the theoretical premises in the mentioned literature on the topic and with the fundamental literature produced for decades on the use of discounting, particularly in public project evaluation.

Nevertheless, besides the potentialities of the hurdle rate method explored here, some weaknesses should be highlighted. The weakness points can be summarized as follows:

- Firstly, the difficulty in identifying expectations for the evolution of technology environmentally oriented over time.
- Secondly, in analogy with the previous aspect, the difficulty to predict the trend of the economy as a whole, and in particular the trend of inflation, prices and financial variables, as well as energy costs, considering that all these aspects are fundamental for quantify the rate values in the hurdle rate approach.
- Thirdly, the subjectivity in attributing the different rate levels in relation to the different cost items, considering their capability to influence the results.

4. Conclusions

This work presents a simulation that compares alternative discounting approaches, assuming the methodological proposal illustrated in a correlated contribution and the same case study and assumptions. The NPV calculation using the DCFA has been calculated using differentiated rates, given financial or environmental model input. The results in favor of the upcycling scenario are confirmed and highlighted. Besides the capability of the hurdle rate to improve the modeling when in the presence of environmental input drivers, the most significant aspect evidenced by the simulation is the ability of the methodology to quantify, even in a simplified operative modality, the effect of environmental components on the asset residual value, and the capability to monetize the weighted mitigation over time, in favor of retrofit intervention, not only in terms of recycling potential but also in terms of environmental plus value creation. Further, concerning the results of this research in the context of the scientific background, a comparative simulation could be produced by adopting other approaches emerging from the literature. These last aspects will be the object of future research insights.

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