Captives of Capital? Exploring economic models as recursive and performative agents

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Highlights

- Private capital will be essential to the energy transition.
- Techno-economic modelling could be used more effectively to mobilise resources for the transition.
- The performativity perspective can be usefully applied as a heuristic theory to provide directionality to financial markets.
- Areas for further research to achieve this objective are outlined.

Abstract

The financial sector could play a more significant and transformative role in supporting the energy transition. Portraying techno-economic models, upon which the sector depends for the support of its investment decisions, as performative or self-fulfilling agents which serve only to entrench the hegemony of the present incumbents, undermines the potential for using these approaches to accelerate the energy transition. In this article, we outline the role of capital markets in the energy transition and show how techno-economic modelling has attracted a growing interest from authors within the renewable energy sector. We summarise the concerns of social scientists about economic modelling, neatly captured by its depiction as a calculative agency intent on its self-replication. We argue that there is a need to align the two perspectives, especially as a means of strengthening the support of the financial sector for the energy transition, and suggest several ways in which this alignment could be achieved. Important research questions include further exploration of the recursive and performative relationship between economic models and the economy, the inclusion of externalities in modelling studies, the use of economic models as agents of change rather than recalcitrance, and finally strengthening capital markets in the Global South.

Keywords

Performativity
Economic modelling
Overflowing
Capital markets

1 Introduction

Economic modelling and its influence on financial investment are important topics for energy and climate research. Renewable energy technologies are unusually capital intensive, with upfront capital charges contributing at least 85% of the total levelized cost of energy [1]. The estimated cost of decarbonising energy systems alone is estimated to be about $5.7 trillion [2]. In the United States, the Biden administration's economic recovery plan, "Build Back Better", proposes an investment of $2 trillion over four years as an initial step towards achieving 100% clean electricity by 2035 [3].

An important question is how the necessary funds will be sourced. One possible scenario is that central banks will create the money 'out of thin air' to purchase government bonds, the proceeds of which governments can then use to finance decarbonisation programmes [4]. However, given that levels of public debt are at historically high levels, it is more likely that much of this capital will be sourced from private funders through capital markets. Understanding how such financial decisions will be made, and how directionality can be introduced into capital markets, is, therefore, highly significant for the energy transition.

Techno-economic modelling is a major part of the investment decision-making process for private investors. Given the increasing significance of private investment for the energy transition, it is concerning that the article by Sovacool et al. (2020) on future directions for energy and climate research neglects to mention techno-economics or economic modelling, other than to list model simulations as a research method commonly used by positivists [5, p4]. To address such a gap in the proposed energy research agenda, this article argues for a multi-theory approach in energy transitions, which includes techno-economic analysis as a means to influence financial markets and private firms, thereby supporting pro-sustainability decisions in complex contexts with diverse actors, overlapping priorities and social tensions.

The article is structured into five main sections. In Section 2, the importance of capital markets to the energy transition is initially outlined. The perceived binary between quantitative economic studies, broadly captured in the literature as techno-economic assessment, and qualitative STS critiques are then presented in more detail (Sections 3 and 4 respectively). In Section 5, several proposals for achieving greater alignment between the two approaches, and hence improving the policy coherence in respect of managing energy markets, are outlined. Finally, in Section 6, a set of new research questions, which will seek to resolve the conflict over the value and validity of techno-economic modelling, are presented.

2 Capital Markets and the Energy Transition

Piketty's analysis of global capital markets shows unequivocally that much of the credit is located in the private owners, including multinational investors, insurance companies, and pension funds [6]. Public capital (also known as public wealth and representing the net total of public assets minus public debt) is at historically low levels, whereas private capital is now the dominant form of national wealth in most countries. Furthermore, much of the public sector is under severe austerity measures, particularly following the COVID-19 pandemic. Financing the decarbonisation of the energy sector will, therefore, require the cooperation of owners of private capital, whose primary consideration has typically been the return on investment rather than the protection of public goods [7]. In this respect, it can be argued that private capital, provided mostly in the form of project finance, will drive the pace of the energy transition [8] and the power of this sector to accelerate or hinder this transition is evident [9].

The process by which decisions on resource allocation within private investors and financial intermediaries are made varies widely, and the relative importance of techno-economic models in the decision-making process is highly context-specific. Nevertheless, many such actors use economic models to evaluate investment options and develop investment portfolios that, at least within the boundaries and weaknesses of their internal assumptions, represent an optimal allocation of the firm's available resources.

Recognising the considerable level of financing that will be required, private capital has been somewhat proactive in terms of positioning itself as a source of capital and as a partner to governments, public utilities and private industry in the transition, albeit mostly in the lower risk/higher return opportunities [7, 8, 10]. Investments in clean energy have grown from $85 billion in 2005 to $350 billion in 2018, and the issuance of green bonds has increased from less than $1 billion to $177 billion over the same period. However, these levels have developed from a low base and remain only a fraction of the total requirement. The Climate Finance Leadership Initiative, an alliance of global banks and institutional investors, has outlined several ongoing challenges to the mobilisation of finance in support of a low-carbon transition, including the lack of incentives, the absence of profitable options for the decarbonisation of key emitting sectors, the high financial risks in developing countries and the prospect of social unrest as a consequence of transition [7].

From this articulation of the barriers to greater participation by private capital in the energy transition, it becomes evident that the financial sector is inflexible on its key investment criterion, namely financial return. Although it is increasingly possible to accommodate this requirement and simultaneously achieve an energy transition due to the growing financial viability of renewable energy technologies [1], such synchronicity is still not possible in all sectors and all locations. The difficulty of mobilising private capital has led to the proposal that central banks should fund energy projects directly, avoiding the role of financial intermediaries and asset managers [4]. Under such a scheme, the control of private capital markets over the energy transition would be weakened, and public finance would play a more focussed role in developing the sector. This option is further discussed in Section 6.

3 The Growth of Techno-Economics in Energy Studies

In this article, the term 'techno-economics' is used to describe the specific analytical framework for feasibility assessment which arises from the application of principles within the discipline of engineering economics. The latter is a branch of micro-economics, and covers the techniques used by firms to guide decisions on the allocation of financial resources within the firm. The use of techno-economics in this sense differs from its use in the literature on paradigms and technological revolutions, where the meaning is more broadly constructed as a set of sociotechnical practices, heuristic routines and norms that characterise a series of separate technological phases [11].

The practice of techno-economic assessment is nearly 150 years old, with the first explicit text being published in 1877 by Arthur Wellington on "The Economic Theory of the Location of Railways" [12]. The field of engineering economics as a separate module within microeconomics emerged about 50 years later with the work of several economists, including Grant [13] and Goldman [14]. Mostly these studies were undertaken within firms and remained unpublished. It is only since the 1980s that a significant number of academic studies have been published and began to provide the basis for a growing database of firm-level return on investment within the manufacturing and energy sectors.

The primary outcomes of these models are a set of financial indicators used to describe the expected return on investment, including the calculation of free cash flows, internal rates of return, net present values of discounted cash flows and payback periods [15]. Given the important role of these project indicators in the decision-making process within firms and investment agencies, it is not surprising that the techno-economics of energy technologies has attracted more attention from scholars in transition studies.

Based on the bibliometric indicators, the application of techno-economics as a means of evaluating emerging energy technologies has become routine. A Scopus search of research publications using the keywords (techno-economic) AND (energy) reveals that between 1980 and 2020, nearly 6,000 articles, books, book chapters and conference proceedings (referred to collectively as academic publications) listing these two words as part of the title, abstract or as a keyword, were published. Moreover, the number of such publications is growing exponentially, as shown in Figure 1, and energy studies have been a significant contributor to the overall growth in techno-economic studies, increasing from 30% in the 1980s to 70% in 2019 (see Figure 2).

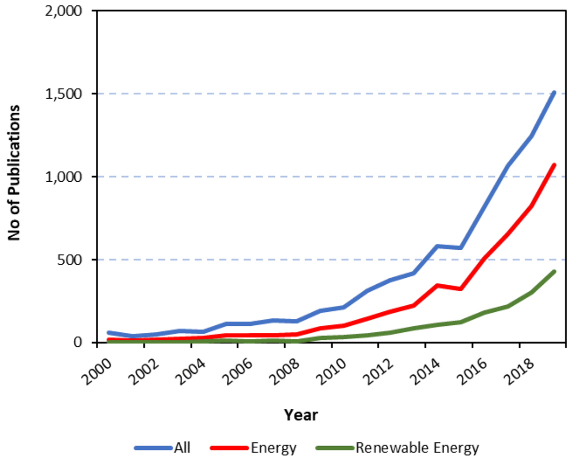

Figure 1. Numbers of publications in each topic area covering techno-economics (2000 to 2019)

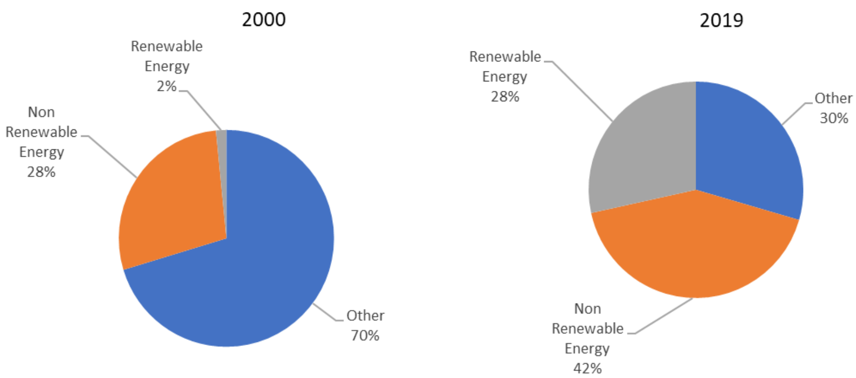

Figure 2. Proportion of techno-economic studies covering renewable energy technologies (2000 and 2019)

The increase is driven by not only a growing interest in the techno-economics of energy systems and technologies, but specifically, the increasing use of techno-economics in the evaluation of *renewable* energy technologies, as is also shown in Figure 2. Techno-economic assessments of renewable energy technologies (RET) now form 28% of all published techno-economic studies and 9% of all academic publications relating to RET, up from 2% and 0% respectively in the year 2000.

In other words, economists and engineers are increasingly applying techno-economics as a means of directing and evaluating the potential of renewable energy technologies. Unfortunately, this widespread application often ignores the limitations of the approach. For instance, although there are nearly 6,000 articles on techno-economics and energy over the period 1980 to 2019, there is only a single article on calculative agency and engineering economics. The two fields of microeconomics and energy social science appear to have evolved quite independently, leading to the perceived binary, which is the core focus of this perspective.

In the next section, the limitations of techno-economic assessments in driving the energy transition are outlined. The main arguments reside in the narrow conception of actors able to support or resist this transition, and the weakness of the standard input assumptions for the models.

4 Critiques of Economic Modelling in Energy Studies

Modelling has been a tool for decision making and evaluation of energy choices since the mid-1970s. Modelling techniques include econometrics, simulation, scenario analysis, and techno-economic assessments; each with identified advantages and problems [16-18]. While economic modelling has been acknowledged as a useful tool for purposes such as energy security planning, climate policy analysis, and technology innovation assessment, it has also received considerable criticism. STS scholars have been particularly critical of the way in which economic models are deployed by incumbents within existing sociotechnical regimes to entrench their hegemonic positions and the dominance of the regime.

There are several aspects to this critique. It is shown that the models are performative or self-fulfilling and constitutive of economic institutions [19-22]; the framing of the model results in the exclusion of important factors [23] and the remaining inputs are too easily loaded in favour of the desired result [19, 24]; the relationships within the sociotechnical network or assemblage are recursive, not linear; policies are framed as external, exogenous assumptions or normative targets, rather than objects for analysis, understanding and explanation; models cannot provide an adequate account of inertia, path dependence, and innovation in energy technologies; and that modelling has limited predictive ability since it is a microeconomic perspective [19].

Indeed, economic models have been described as “engines, not as cameras” [19], referring to their ability of not merely attempting to (mis)represent reality but actively and intentionally shaping it, by encouraging, discouraging, guiding and legitimising certain actions and decisions [24]. In this respect, economic modelling can be regarded as self-fulfilling since it steers the direction of change, shaping institutions, norms, practices and expectations about behaviour. Models create the behaviour that they predict and exercise a powerful influence on economic outcomes. Whether an economic model is in fact performative depends on the extent to which it is used in practice. For instance, MacKenzie [18] shows how the practices enacting finance theory in the stock exchange, create a financial reality that resembles the premises behind that theory.

The validity of the concept of performativity of economics has been questioned by several authors [20, 25]. The debate is one of economic philosophy and relates to the extent to which economic theory and models describe the external world, or are recursively linked to it, being influenced by, and directly influencing or shaping it. The neoclassical assumption contends that models are objective reflections of the external world. In contrast, the relativists maintain that the economic model and the human actors undertaking the modelling can be considered as a single actor, referred to as a 'calculative agency'.

This depiction of the calculative agency as a self-replicating, identifiable and independent actor is a powerful concept originally defined by Callon [26]. It captures the underlying premise that calculative practices consist not only a set of ontological norms and assumptions but an entanglement of human actors and wider sociotechnical institutions, of which the techno-economic algorithms are just a component [27, 28]. In effect, these calculative practices have become so dominant that they are materialised through human actors and the systems which they follow in the implementation of their calculation-optimisation. Accounting and economic modelling are examples of the calculative agency's standard methods functioning within its underlying framing.

Other criticisms of economic modelling refer to its embedded unrealistic assumptions, and its inability to produce accurate predictions under the presupposed existence of closed systems (circular flow) [29]. Furthermore, the use of economic models to assess the effectiveness and merits of different policy options, is considered to be problematic. The modelling studies implicitly assume that energy policy is exogenous, an assumption that neglects the perspective of STS scholars, who consider policy and its effects as co-produced by various interested parties within society. Policy from an evolutionary STS perspective is considered to be endogenous, requiring specific analysis, understanding and explanation [30]. In this respect, STS scholars suggest the need to integrate various analytical approaches as a means of understanding the co-evolution of multiple sociotechnical systems and their governance [30]. This proposal is explored in more detail in the following section.

5 Proposed Changes to Techno-Economic Modelling

The path of the energy transition will depend on multiple and interrelated factors that are as yet unknown. Despite such uncertainty, governments and investors need to take important policy and investment decisions. Techno-economic models are, and will continue to be, used to inform and support such decisions. However, the imperfect framing and the underlying assumptions of this approach may result in biased outcomes and distorted recommendations. In the pursuit of more comprehensive models, these weaknesses need to be addressed, firstly by including several unacknowledged dimensions, such as environmental impact, and secondly by integrating the methodology with complementary techniques.

Despite their profound influence and importance, social and environmental impacts are generally omitted by techno-economic models [31]. This absence should be addressed; methodologies for techno-economic modelling should be expanded to include all the costs incurred during generation and operation, especially those aspects presently considered as externalities. For instance, a bibliometric analysis of the literature on the economic aspects of municipal solid waste management systems finds an apparent lack of studies considering the valuation of the impacts on society or the environment [32]. Techno-economic analyses typically focus on studying internal or private impacts, costs, and revenues. Efforts to combine techno-economic modelling with techniques that help quantify broader impacts, such as the environmental Life-Cycle Costing Analysis [31] and circular economy [33], may provide a way forward.

Secondly, the recent turmoil caused by COVID-19 and the high chances of instability becoming the "new normal" under a looming climate change crisis, raise the question of how economic modelling can provide better predictions under conditions of instability and shocks. External shocks for developing countries and economies in transition typically have a significant impact on the financial options for energy transitions. Techno-economic assessments ought to better reflect the vulnerability of energy transitions in developing countries to landscape-level disruptions.

We turn now to the integration of techno-economic modelling with complementary approaches and techniques; making decisions that affect the transformation of energy systems involves taking into consideration multiple dimensions, from technological innovations to societal acceptance, as well as the regulatory and institutional frameworks and the policy environment. All these dimensions constitute prominent factors defining the capacity of the system to change, either by promoting or hindering the success of various alternative paths. Such recognition has led various scholars to propose multi-theory approaches to analyse energy transitions [34, 35], combining quantitative economic modelling with insights from history, political science, sociology, ecological economics, behavioural sciences and others. Whilst the combination of insights from multiple theoretical approaches has been attempted by many, integration in a genuinely interdisciplinary fashion remains rare [30, 36, 37].

While techno-economic assessment provides valuable insights that help make decisions related to the techno-economic dimensions of energy systems, these decisions co-evolve with other sub-systems, which may predominantly rely on other analytical tools. These sub-systems have their own dynamics, guided and shaped by different, although sometimes overlapping, actors. Therefore, an important ingredient of a much-needed interdisciplinary integration requires a better understanding of the various sub-systems, their dynamics and their interactions. In this respect, Cherp, Vinichenko, Jewell, Brutschin and Sovacool [30 p 177] indicate that this may require understanding two types of mechanisms: (a) those explaining the evolution of each of the subsystems and (b) those connecting these subsystems.

6 New Research Questions

The main contention of this perspective is that the role of capital markets and financial intermediaries in supporting the energy transition has been overlooked in the proposed agenda for energy studies [5]. It is apparent that the calculated return on investment, as revealed by techno-economic studies and economic modelling, remains at the centre of investment decisions by financial intermediaries and private firms, whether such allocations relate to green financing or fossil-fuel projects. Furthermore, the expected level of return must be proportional to the perceived risk. The tension between risk/return and the imperative of the energy transition continues to delay the latter and undermines the prospects for minimising the impact of rising emissions on climate change.

A better understanding and hence possible resolution of this tension, suggests several important research questions, the details of which are now discussed. The questions have been grouped into the four categories of, firstly, understanding how the financial sector can itself be used as an agent of change through an expansion of transition-based economic modelling; secondly, exploring in more detail the question of performativity and directionality; thirdly, improving the analytical validity and integrity of techno-economic models by ensuring the externalities are incorporated in the modelling; and finally, options to de-risk capital markets in the Global South.

6.1 Deploying Economic Models as Agents of Change

It is argued that the global financial system is a key impediment to the energy transition [38], and a necessary shift of funding from finance capital, associated with short-term capital gains, to productive capital, referring to long-term dividend-yielding investments in the real economy, including green technologies, has yet to gain significant traction [39:130]. A possible solution to this ‘blocked transition' [38] is to critically review the inputs to techno-economic models, removing the evident bias in favour of fossil fuels and against technologies of the energy transition.

An example of such a process is the revision of South Africa's Integrated Resource Plan (IRP) [40]. The plan, updated in 2019, aims to dramatically shift energy production from its historical base of a single national coal-dominated power utility (Eskom) to a diversified sector incorporating a range of independent suppliers, with the contribution of coal as a primary energy source decreasing from 95% in 2015 to 45% by 2030 [40]. The IRP was primarily informed by the techno-economic modelling of the Integrated Energy Plan [41:28], and despite its methodological limitations [42], has triggered various changes across the energy system, including energy policy and diversification of energy technologies [43]. Drawing largely from this example and experiences in other countries, the International Renewable Energy Agency (IRENA) concluded that "techno-economic modelling of future scenarios for the power sector has become a critical tool in planning the transition to renewable energy" [44:102]. The agency has since developed a set of guidelines for power system planning based on the IRP modelling tools, identifying specific areas in which these tools can be applied [44].

The way in which techno-economic modelling, as a means of supporting power system planning and the energy transition, can be institutionalised, becoming a widespread and routine practice, is an important area of future research. In this respect, the performativity perspective, as a heuristic theory with a focus on how models are taken up and implemented, could be usefully applied. Some guidance could be drawn from similar studies on organisational strategy [45] and rational decision making [46].

Research should also be undertaken on the use of interest rates as the sole criteria for the control of money supply. Central banks could play a more effective role in facilitating the energy transition by adopting metrics that relate not only to the cost of money, but also the environmental impact of how the money is distributed. It is conceded that this proposal represents a significant departure from the present economic frameworks, and particularly how the money supply is managed within a national economy, but it could provide the means through which the necessary directionality is introduced into financial systems. Financial intermediaries seeking to exploit public goods should be either prevented from access to central bank funds or incur significantly higher interest rates. Additional research is needed to understand whether such an approach is indeed possible, and if so, how it could be implemented.

6.2 Modelling Performativity

Techno-economic modelling is a calculative practice which, together with broader economic models and policy, may become a calculative agency capable of framing decision-making [22]. The assignation of agency to these heterogenous assemblages highlights the question of performativity, and the recursive relationship between the model and the sociotechnical system or technological innovation which it attempts to portray. This bidirectional relationship implies that models go beyond simply depicting an economic outcome; they also shape and determine the system so that it is consistent with the model [22].

In mathematical modelling and computer programming, a recursive function is one that calls itself to generate a solution. Importantly, for a solution to be generated, the calculation must start with a well-defined base case, the properties of which are changed each time according to the rules of the function. The same term is used somewhat confusingly in the literature on structural equation modelling to describe linear as opposed to bidirectional relationships between variables [47]. A recursive relationship between variables assumes the existence of mutual dependency in which the variables are connected through feed-forward and feedback loops.

In recognition of this interdependency, it is proposed that techno-economic modelling is extended beyond its present input/output or linear approach, to the methods of structural equation modelling that allow for recursive properties to be applied to all variables. Further studies on the following questions are also recommended; where is agency located, in the model itself or with the actor that implements it; what are the circumstances governing the choice of one model over another; under what conditions can techno-economic models be performative; and, how can bidirectional interactions be accommodated in model design?

6.3 Ensuring Externalities are Internalised

The externalities of energy investments, such as the impact of emissions and climate change and the health of ecosystems, are rarely acknowledged and incorporated in techno-economic models, despite the existence of several approaches, such as life cycle analysis [31, 48], circular economy [49] and multi-criteria decision making [50], all of which attempt to adopt a more comprehensive view of the full costs associated with such projects.

Further research is required to develop global standards for the scope and input assumptions as used by economic modellers. Standard costs for process items such as carbon capture and storage, the recovery and recycling of minerals, and the remediation of land affected by mining should be developed and published by multi-lateral organisations such as the United Nations Environmental Programme. Some progress towards global standards has possibly been realised with the recent adoption of the System of Environmental Economic Accounting - Ecosystem Accounting [51]. If private firms (and hence private financiers) are going to be at the forefront of implementing the energy transition, a more comprehensive framework for techno-economic modelling will be necessary. Micro-economics may be a valid approach at the firm level, but it needs to take greater account of the externalities and adopt a more uniform approach, especially in terms of circular economy and lifecycle analysis.

The reframing of the dimensions of the model or assemblage is a recognised strategy to manage externalities, and indeed other manifestations of overflowing [22]. The latter refers to a much wider set of concerns resulting from the inadequacy of calculative practices in capturing the complexity of the world and has broader utility. As insightfully described by Hess and Sovacool in the initial review [22], the concept of overflowing can be used together with a performativity perspective to reveal not only the limitations of economic theory but also the way in which models are able to channel political conflict [21]. Their powerful combination allows the weaknesses in the framing of economic models to be identified and challenged. Further research in this area, leading to improvements in techno-economic modelling, is therefore recommended.

6.4 Derisking Capital Markets in the Global South

Countries in the Global South are generally perceived as high-risk investment destinations and attract a higher cost of borrowing [52]. Given that renewable energy technologies are capital intensive, reducing the cost of finance through de-risking renewable energy projects is recommended as a key objective for the decarbonisation of the energy sector [52]. One possible approach would be for such countries to establish energy agencies within the public sector, outside of the formal financial sector and funded directly by the central bank [4]. No interest rates would be charged; instead, the central bank would lend the money in perpetuity to the government, and use the project assets as the underlying asset, to be re-possessed in the event of financial failure. This option, still speculative, would require the development of substantial project expertise within the public sector, capable of designing, implementing and managing renewable energy projects.

In contrast to this public sector-based implementation, the South African Renewable Energy Independent Power Producer Procurement Programme provides a good example of a Global South initiative that was able to successfully de-risk investment in renewable energy projects and hence attract private capital for the diversification of the country's energy sector [43, 53]. Key to the positive impact of the programme was the comprehensive capability in efficient procurement process within the project office, the use of competitive tendering, and agreement by the state to long-term demand-side supply contracts, the latter allowing the bidders to access capital at a lower cost [54]. Other contributory factors include a clear regulatory framework and dynamic energy planning, particularly the ability to forecast future demand, evaluate the techno-economics of different energy technologies and mitigate any financial risks such as inflation and capital cost [54]. This last example illustrates clearly an earlier claim in this article, namely that a multi-theory approach to techno-economic modelling, leading to the design of suitable investment incentives, will help to leverage capital markets in the Global South in the energy transition.

7 Conclusion

Throughout this perspective, it is recognised that modelling cannot claim to be a unique and direct representation of a system, or more broadly, of a single reality, external to an independent observer. In a philosophical sense, this is an ontological issue. Techno-economic modelling is a subjective and imperfect attempt to describe one version of a micro-economy, and hence predict the consequences of a financial decision. Choices as to the inputs to the models, and the values for these inputs, are determined by the modeller and, in this sense, are relational properties.

Acknowledging this inherent flaw in quantitative evaluation may lead to the conclusion that the technique cannot be improved, but rather scrapped altogether. Such a response is not pursued in this article. Rather, it is argued that the rejection of techno-economics and economic modelling as performative interventions designed to perpetuate existing sociotechnical regimes is unhelpful in mobilising the support of private capital for the energy transition [25]. Similarly, the categorical acceptance of the results of such models, and particularly the claim that green financing is unprofitable without large government instruments to mitigate the present risk, is equally deleterious to releasing the necessary capital for the transition. This paper argues for further research on the opposing views with a particular focus on the calculation of externalities, the testing of recursive relationships, capital markets in the Global South, and economic models as agents of change.

In response to recent calls for pluralism and the integration of multiple theoretical perspectives in the analysis of energy transitions [5, 22], this paper highlights that techno-economics are largely ignored in the discussion on sociotechnical agendas. It argues for greater attention to the integration of micro-economics or techno-economics with the approaches being followed by the two fields of the sociology of technology and political science.

The paper is not unique in making such an argument. Cherp, Vinichenko, Jewell, Brutschin and Sovacool [30] use the three analytical frames of the techno-economic, the sociotechnical and the political to show how an integrated approach applied to a comparison of the evolution of the electricity sectors in Germany and Japan provides greater insight and improved understanding of the process of transition than either theory on its own. However, the present paper adds to the literature by making two distinct contributions. Firstly, it unpacks the strengths and weaknesses of techno-economic analysis, proposing concrete changes to techno-economic modelling that may assist in addressing some of its limitations. These include reflections related to the expansion of the methodology, as well as the integration of techno-economic modelling with complementary approaches and techniques. While the critique of TEA has focused on its portrayal as a tool for the preservation of the status quo, we argue that techno-economic modelling may also serve as an agent of change, in particular when some of its limitations are addressed, and its explanatory power expanded. Several examples have been included of how this transformative potential can be realised.

Secondly, this paper argues that by failing to engage with economic modelling, there may be a missed opportunity in understanding how investment can be released to drive and support energy transitions in the Global South. This is, therefore, a call for a more nuanced understanding of how to de-risk investments for successful energy transitions in the Global South.

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