What Drives Venture Investment in Renewables?

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ABSTRACT

The renewable energy market is growing rapidly, yet seemingly insufficient to counter the climate crisis and to meet demand globally, affected by market and regulatory factors as well as by private investor appetite. The extant literature, both academic and policy-level, describes that investor decision in the renewable energy industry is driven by expectations, by interest rates, and by pricing of viable market alternatives. While interest rates are largely exogeneous, expectations can be described reflecting projected valuations influenced by technological maturity, regulatory policy, as well as by prevailing market conditions. While many of the individual assessments have been made in research, an encompassing overview, linking micro to macro effects, has been lacking. Building such overview may contribute to stepping-up the thus far limited involvement of private entrepreneurial funding sources, to complement the public stimulus in funding of renewable energy initiatives. This research builds upon the macro E3ME model that was initiated by the European Commission and connects it to recent insights in investment selection and valuation at micro-economic level as to reveal how they complement one another as to entice the contribution of private entrepreneurial funding sources.

Keywords: Renewable Energy, Entrepreneurial Finance, Venture Capital, Investment Selection, Demand Stimulation, Feed-in-Tariffs

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1. Introduction

Investment selection in the renewable energy landscape is unique and special situation, influenced by highly specific factors, which is nevertheless at a key question of our times within both entrepreneurial finance and energy markets, given the substantial implications for both the macroeconomy and for the venture capital landscape. While we understand investment selection, an issue which has been modeled extensively, its application within the renewable energy landscape can be considered a special case.

Markets in the renewable energy industry – a particular focus of regulatory attention – behave differently than markets at large. Because the renewable energy industry finds itself at an intersection of energy markets, public policy, and entrepreneurial finance markets, operation costs, revenue and revenue models, business risks prices thereof, market access and network effects, all of which would traditionally influence both selection and valuation for entrepreneurial investment markets are both impacted and subject to particular sectoral market-forces.

Primarily, this study's contribution to the existing debate in the literature consists of a unified conception and modelling of the investment decision in the renewable energy industry, as well as their underlying causality-structure and their deterministic factors. In principle, this constitutes a substantial step-forward in unifying the understanding of venture capital and entrepreneurial finance markets with macro-level energy market and macroeconomic context.

This research is highly relevant given the idiosyncrasies of the renewable energy market vis-à-vis that of either the wider venture capital market or even the wider macroeconomy. While typically, causal interaction between macroeconomic market conditions and the venture capital industry flow downwards (i.e., macroeconomic market conditions influence venture capital investments and startup markets), the case for renewable energy markets is understood to be something of an exception to this trend.

The compelling question therefore is how specifically to further align private venture investment funding with existing and future renewable energy public policy goals. More specifically, for the determination of renewable energy investment levels, and to support energy transition. The objective of this research is to establish key drivers that prove to be deterministic in terms of involve the various private funding sources. These objectives can be considered highly policy-relevant, given that private investments are known to foster innovation and entrepreneurship (Kortum & Lerner, 1998; Moore et al., 2004). A second set of objectives of this research is to link macroeconomic research concerning renewable energy transition and determination of investment levels to entrepreneurial finance research focusing on renewable energy investment decisions. While published literature does exist on renewable energy investment, and also on renewable energy transition, few studies exist linking entrepreneurial finance to macroeconomic or macro-level energy policy (Budhwar et al., 2022).

2. Literature Review

Venture capital is an important funding source for renewable-industry entrepreneurship and, thus, drives its development. However, renewable startups have trouble acquiring venture capital. (Wohler, 2022). Overall, traditional, mainstream venture capital markets, while prepared to outwardly express a sustainability-focus, continue to rely on traditional economic calculations.

In theory, functional and sustainable venture-capital-disruption based growth as an economic policy strategy, relies on three key boundary conditions, scalability, rapid, large-scale value-creation, and large, rapidly-growing markets (Hargadon, 2011). The extent to which venture capital may open new economic spaces within the clean technology landscape may largely depend on these. In this light, policy approaches such as large loan guarantees appear unlikely to yield the desired effect. On the other hand, policies such as SBIR grants, whereby public funding underwrites experimental and developmental research work, as well as university R&D support, certain (de)regulatory actions, large-scale demonstration projects, and/or procurement decisions make succeed in encouraging both incremental and disruptive innovation. Essentially, it should be noted that investment into the development of disruptive innovations can be influenced by reducing costs and financial risks associated with technological research and development, as well as policies guaranteeing market-demand.

A further complication may arise from policy risk – the risk that regulatory agencies will change policy decisions – as the footprint of economic policy within the renewable energy industry grows (Chassot et al, 2014).

Further downstream, to venture-capital investors, sustainable and predictable revenue-streams matter enormously. Using a survey of venture capital investors, Burer and Wustenhagen (2009) analyze the role of various policy approaches in attracting venture capital interest and investment in the renewable energy industry, finding that feed-in-tariffs (FiT) outperform most competing policy approaches, in terms of effectiveness, for the purposes of stimulating interest to invest in innovative clean energy technologies.

Van den Heuvel and Popp (2022) provide and extremely recent empirical view on the investment market, as well as the demand conditions faced by venture capital investors in the renewable energy industry. Van den Heuvel and Popp find demand-stimulation to be key for driving successful investments, given that the industry underperforms other industries on which venture capital investment focuses, such as the ICT industry. Overall, traditional, mainstream venture capital markets, while prepared to outwardly express a sustainability-focus, continue to rely on traditional economic calculations (Wohler, 2022).

In principle, the investment decisions taken by the venture capital industry towards the renewable sector have the potential to influence overall renewable investment levels across the macroeconomy. Cambridge Econometrics

(2019) provides the primary macroeconomic framework. Fundamentally, the Cambridge Econometrics E3ME model describes the interrelationship between the energy sector, emissions, and the wider macroeconomy.

Building on the work of Prokopczuk et al. (2007), Magnussen (2011) provides a volatility-based view on energy contracts and energy costs.

Because the model expressed in this study is structured as a structural equation model (SEM), the specific mechanical characteristics of SEM models bear consideration. In particular, a two-stage model approach requires that both direct and indirect impacts are taken into consideration (Gefen et al., 2000; 2011).

3. Research Questions

Overall, this study seeks to better understand and model in detail how specifically to further align private venture investment funding with existing and future renewable energy public policy goals. Because furthering energy-industry technological transition implies substantial investment in both development and implementation of renewable energy technologies, development of accurate and detailed research expressing the details of the investment-level determination decision are presently at the cutting-edge of research, given the immediate market and policy implications.

This leads us to the following three questions:

1: How can determination of renewable investment levels be modelled?

Given that the literature describes renewable investment to be determined by markets as a function of risks and revenues, which are driven by factors ranging from regulatory policy, to technological maturity, which play a clear role in determining revenues on one hand, and by demand-determinants such as market size and energy prices in the competing fossil fuels industry (source), how best can these be assembled into a coherent model?

2: How can determination of renewable investment decisions be modelled?

While entrepreneurial finance literature describes investment decision in more binary terms, venture capital markets are described by the literature as also being driven by revenue and risk factors. Investor-revenues in turn are driven by the valuation-growth of the VC's investment targets. In the renewable energy industry, this valuation growth would be drawn from energy generation revenues, whose growth and risk drivers are also described by the literature as being driven by regulatory policy, to technological maturity.

3: How can these be synchronized into a unified model?

Market landscapes modeled by macroeconomic-level models are understood to have micro-level foundations (Lucas, 1976). While this implies that the model-complexities present in macroeconomic models (e.g., endogeneity, multicollinearity, multistage effects), may also be present in in microeconomic models, meaning some overlap in econometric modelling, it also implies that entrepreneurial investment models have the potential to impact the macroeconomic level. Mechanically, this may mean that models describing macro-level renewable investment levels and renewable transition (or segments thereof) can have substantial intersectionality with entrepreneurial investor-selection models, provided that the model-inputs can be made analogous.

4. Cambridge E3ME Model:

According to E3ME, investment is driven by only a handful of deterministic factors.

Expectations concerning future prices and market-developments drive views on likely future revenues, risks and potential opportunities.

Meanwhile, relative prices for existing energy markets (i.e., oil, coal, and natural gas markets) play a key deterministic role, given that the status-que fossil-fuels represent the dominant competitive alternative to renewable energy markets.

Lastly, like all investment markets in a modern economy, interest rates drive investment levels.

What macroeconomic effects renewable energy transition is modelled as likely to have, includes increased economic output, given both efficiency gains and knock-on effects of R&D expenditures linked to renewable energy transitions.

Macroeconomic Effects

Growth effects.

Impact on R&D landscape throughout the economy. As the renewable energy sector grows, an economic premium on research and development associated to the energy industry, renewable technologies, or the sector's ancillary landscape.

At its core, the E3ME model describes the linkages and interrelations between macro-level and energy-industry sectoral-level growth, emissions

Linking the Macroeconomic Landscape to the Venture Capital Investment Landscape

Mechanically speaking, venture capital investment decisions, in the aggregate, determine the overall investment level across the economy (we should link this to the Lucas Critique). Essentially, this can be taken to mean that architecturally, models which describe renewable energy sector investor selection, also describe overall macro-level renewable investment levels, and their underlying mechanics.

5. Revenue Streams. The Role FiT Plays

Overall, the investment levels are known to be driven by expectations of revenue, and by projected risks.
How FiT influence pricing and investor selection.

According to Burer and Wustenhagen (2009), Feed-in-Tariffs are found by renewable industry venture capital investors to be crucial in driving investment, given that they help provide stable revenue-modelling around which future investment can be planned. Seen from the contexts of the E3ME model, Feed-in-Tariffs drive expectations as a major deterministic factor driving renewable energy investments.

6. Existing Conceptual Startup Models

Overall, the general framework elaborated by the E3ME model can be synchronized to startup and venture capital markets in a number of places, as venture capital investment plays a role in driving investment levels in renewable energies, across the macroeconomy.

First, expectations, as described by E3ME, can be boiled down to expected valuation, which, within the entrepreneurial finance literature, has been modelled in extensive detail. While several startup valuation models exist within the literature, models expressing in detail both the relevant macroeconomic and sectoral market conditions, and specific industry-level risks and revenue models would be most appropriate in capturing expected valuations.

Second, while amounts invested are what is being captured by investment decision modelling at the macro-level, a refocusing on the venture capital investor would functionally reframe the matter as an investment decision or investment selection model.

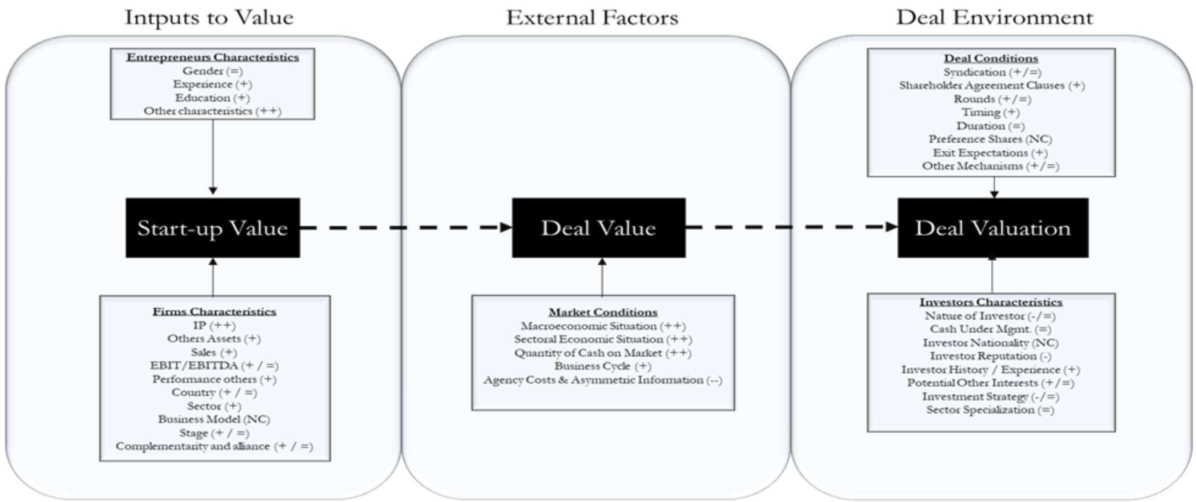
Expected Valuation in highly specific markets

Berre-Le Pendeven Startup Meta-model

In principle, this would frame and anchor expectations concerning how startups mare likely to develop.

Equation X1: Berre-Le Pendeven (2022) Startup Valuation Meta- Model

$$Expected\ Valuation = f(((\sum Start - Up\ Value) \sum Deal\ Value) \sum Deal\ Valuation)$$



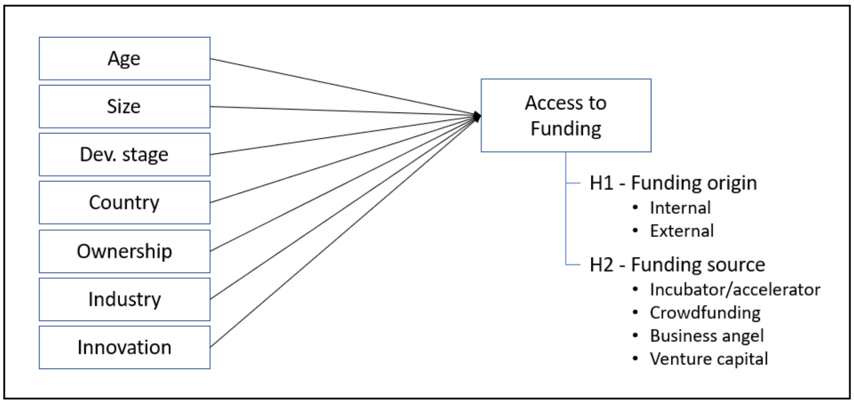
Investor Selection

Downstream from questions of valuations and expectations, comes the question of investment selection.

Andreoli Startup Selection Model

The Andreoli Startup Selection Model describes the likelihoods of access to funding as well as funding sources on the basis of seven venture characteristics, ranging from a startup's age to its level of innovation, determining the venture's access to external funding, and more in particular, funding sources.

Figure 1: Andreoli Startup Selection Model



Fundamentally, startup selection is driven by investor views on the scenario-likelihood of the firm's future development, which in turn could determine the likelihood, type, and time-horizon of investor exits.

7. Towards an Overall Conceptualization of Renewable Energy Investment

In order to approach a global, combined sector-wide view of renewable-energy investment, it should be noted that existing models and views need to be combined into a combined multi-stage model capturing their various insights. For this purpose, conceptualization of selection of investment-levels as expressed at the macro-level can be restated as an investment-selection decision in the entrepreneurial finance context.

Architecturally, the existing literature and models communicate the idea that, from a macro-perspective, investment levels are driven by expectations, relative prices, and interest rates, while expectations, from the point of view on a venture capital investor, are driven by valuations reflecting revenues and the expected growth thereof. These factors, in turn, are driven by expectations of firm-level performance and of market-conditions, both present and future. In the renewable energy industry, this may boil down to projected revenues and projections of present and future technological maturity.

At the core of our approach is the E3ME-model, which was developed by Cambridge Econometrics as result of the European Commission's research framework for policy assessment, developed specifically to analyze the impact of Energy-Environment-Economy (E3) policies, aiming to better understand the level of investment. In particular, and further underlining the choice for this model, is its global coverage, E3 integral treatment and empirical grounding (Cambridge Econometrics, 2019).

While the E3ME model is used globally to analyze the inter-relationship between emissions, the macroeconomy, and the environment, and is linked to numerous peer-review publications, including Lehmann et al. (2019), Mercure et al. (2016), and Lee at al. (2018), it is nevertheless apparent from the model's elements, that the model primarily takes macroeconomic variables into account, overlooking considerations and impact that investors and intermediaries (i.e. VCs) may have on renewable energy generation and the growth of energy generation capacity.

In addition, effectively, these private forms of funding typically determine a substantial share of investments into any sector, yet remain insufficient in renewable energy (Masini & Menichetti, 2013; Wohler, 2022). So far, while venture capital markets seem able to provide more suitable incentives as to improve the effectiveness of energy investments (Masini et al., 2012), reliance in these private markets largely revolves around debt financing (Menendez et al., 2021).

While, as per E3ME, renewable-energy-industry investment levels are determined by expectations, relative prices and interest rates, zooming in to the entrepreneurial and venture capital perspective, in which investors are faced with selection and access-to-funding decisions, revealing that investement selection criteria prove to be a a substantially more complex matter (Gompers et al. 2020; Andreoli, 2022). The latter micro perspectives reveal that expectations primarily take the form of expected valuations, driven by expected revenues, regulatory-impacts, and market size, and are influenced by public policy measures which for the renewable energy sector include Feed-in-Tariffs (Burer, 2009; Fleis, 2017), stimulating demand (Van den Heuvel & Popp, 2022), and underwriting research and development expenditures (Hargadon, 2011) as proven approaches in effectively promoting climate goals directly while indirectly also stimulating private investments (Wu et al., 2020).

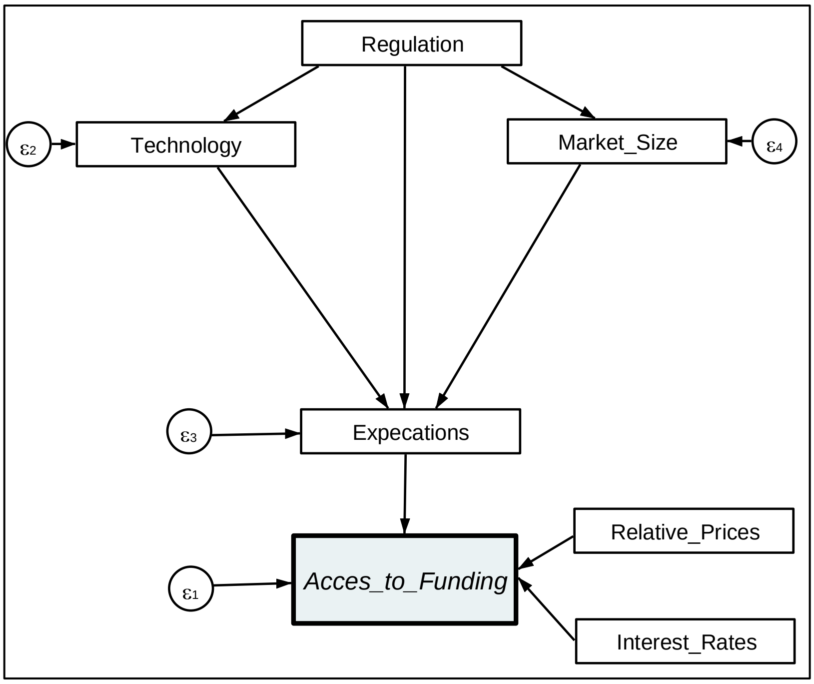
Mechanically, conceptualization of selection of investment-levels expressed at the macro-level can be restated as an investment-selection decision in the entrepreneurial finance context, along the lines of a microfoundations argument (Lucas, 1976), in terms of macroeconomic theory.

The proposed model's goal is twofold. First, the model grows from a need to model the amount and apparent growth of private investments across renewable energy industries, a detail which is omitted in the E3ME-model, whose focus is primarily macro-economic in nature. Second, the model also grows from the policy prerogative to accelerate renewable energy generation and consumption to boost investments as to realize the goals in Copenhagen Climate Treaty and Paris Agreement (Koponen et al., 2021; Meyer et al., 2009; Wustenhagen & Menichetti, 2012).

Composite Multistage Model for Renewable Investment

Based on the relationships outlined by Cambridge Econometrics (2019), as well as by Andreoli (2022), and by Berre and Le Pendeven 2022, our model proposes a path diagram describing access to funding in the renewable energy as a function of expectations, interest rates, and relative prices, which are in turn driven by revenues, technological maturity, monetary policy and cash availability on venture capital markets. While relative prices can be conceptualized as prices for competing non-renewable energy prices at large, E3ME specifically models these as being coal, oil, gas, and nuclear (Cambridge Econometrics, 2019). Meanwhile, whereas expectations in the macro-level model refer to macroeconomic output and demand expectations, can be mapped onto the venture capital scale as expected valuations and evolution of valuations (i.e., valuation-growth), given market conditions likely to drive revenues and total market size. Additionally, the fact that renewable energy markets are the subject of substantial regulatory focus, which can exogenously impact valuations over time by impacting revenues, costs, risks, and market-demand, are included in the model.

Figure 2: Composite Multistage Model for Renewable Investment



Architecturally, we describe venture capital renewable energy investment as a three-stage model, as outlined in Figure 2, wherein renewable investments are driven by valuation expectations, alongside relative energy prices, and interest rates, while valuation expectations, in turn are driven by technologies, market size, and regulation. Meanwhile, technologies and market size are each influenced by regulation and by market factors. Specifically, this means that while some policy decisions influence renewable energy firm valuations directly, such as grants, in-kind transfers, and guarantees, others impact the revenues and economic maturities tied to given renewable technologies, such as R&D subsidies, or feed-in-tariffs, while other policy measures, such as procurement policies or demand-stimulation, impact market size. Formally, renewable-energy sector access to venture capital funding can be described via:

Equation 1

$$Access\ to\ funding = \phi(f(\beta_1 Expectations + \beta_2 Relative\ Prices + \beta_3 Interest\ Rates)$$

Equation 2

s.t.: $$Expected\ Valuation = f(\gamma_1 Technology + \gamma_2 Market\ Size + \gamma_3 Regulation)$$

Equations 3 and 4

and: $$Technology = f(\delta_1 Regulation + Market\ Factors)$$

and: $$Market\ Size = f(\delta_2 Regulation + Market\ Factors)$$

Therefore:

Equation 5

$$Access\ to\ funding = \phi(f(\beta_1[\gamma_1 Technology + \gamma_2 Market\ Size + \ \gamma_3 Regulation] + \beta_2 Relative\ Prices + \ \beta_3 Interest\ Rates))$$

Therefore:

Equation 6

$$Access\ to\ funding = \phi(f(\beta_1[\gamma_1(\delta_1 Regulation + \ Market\ Factors) + \gamma_2(\delta_2 Regulation + Market\ Factors)\ \gamma_3 Regulation] + \beta_2 Relative\ Prices + \ \beta_3 Interest\ Rates))$$

While the deterministic model we propose is a three-stage model, it can be considered to be a simplification of renewable energy investment markets, given that the model's exogeneous factors, technology, market size, regulation, interest rates, and relative prices may all be linked, in principle to potentially complex models describing each of these.

Moreover, this model can also be considered a simplification of renewable energy investment markets, given that each of the input factors, which have heretofore been given as exogeneous factors, can also be modelled as functions, with their own deterministic factor-inputs. For example, while relative prices, interest rates, and technology can be considered exogeneous model-inputs, a volatility-based model for oil and gas pricing proposed by Prokopczuk et al. (2007) and Magnussen (2011) can instead be applied to model the impact of relative prices, while interest rates can be driven by monetary policy and lending market reactions to business cycles.

Expected Valuation

While access to funding is driven by valuation expectations – that is, current valuations and projected valuation-growth – alongside macroeconomic market conditions (i.e., relative pricing of fossil fuels), startup valuations in the renewable energy industry are also driven by industry-level factors technologies, market size, and regulation, which represent both supply side technological maturity, as well as demand-side market dynamics.

Technology

Fundamentally, this factor describes both the technology's current state of development, maturity, and economic viability, as well as the technology's projected future development. Overall, expected revenues drawn from a given technology can be influenced by both regulatory policy decisions, such as public R&D, R&D subsidies or feed-in-tariffs and by market factors such as changes in the economic maturity and viability of a given renewable energy technology.

That being said, it is simultaneously possible to represent technology as a straightforward exogeneous factor, as is the case in the Payne Scorecard Model, but also as a complex technological maturity driven model.

Market Size

While a seemingly straightforward demand-side conceptualization, market size can include not only the size of the renewable energy market's userbase and energy consumption, but also projected future development paths for these. Additionally, market size can be influenced by both regulatory policy decisions, procurement policies or by demand-stimulation policies, as well as by market factors, which the E3ME model describes as being tied to wider macroeconomic output and consumption levels. Furthermore, second-order dynamics such as induced demand and network externalities can also be considered market-size factors which can influence valuation expectations.

Regulation

While in principle, regulation can encompass a wide range of economic and energy policy, as well as regulatory measures which have a direct impact on revenues, expenditures, risks, and valuations in the renewable energy industry, as well as an indirect impact via impacts on market size and on technologies, the literature describes that the most effective policy measure is the Feed-in-Tariff (Burer and Wustenhagen, 2009). Additional regulatory measures known to impact expected valuations include measures aimed at underwriting research and development expenditures, and measures aimed at demand stimulation, such as use of procurements (Hargadon, 2011).

For the purposes of formal definition, a more fully-developed taxonomy of regulation might be given by the EU Commission regulation 651/2014, which, while existing primarily for purposes of regulating EU state aid, enumerates "favouring certain undertakings or the production of certain goods" (TFEU Art. 107), as consisting of not only subsidies and preferential tariffs, which would incentivize specific economic activities by creating or expanding revenue streams, but also:

- tax exemptions and reductions of tax burden, which would lower the firm's operating cost;
- guarantees, assurances and insurance, which could mitigate both risks and associated costs;
- loans and lines of credit, which may help to overcome time-horizon and maturity mismatches and help the recipient project or undertaking survive the valley of death;
- in-kind support, which may consist of services, goods, and tangible assets, or access to goods.

While each of these would impact expected valuation differently, it can be expected that these would be priced-in to expected valuations, as per Fama (1970), since these essentially drive revenues, risks, and/or operational costs, thereby impacting expected valuations.

8. Discussions, Conclusion, Implications

Overall, this study is in a position to contribute to the existing debate within the literature by proposing the theoretical architecture underpinning both concrete conceptual understanding of venture capital markets in the renewable industry, and also future empirical research focusing on renewable energy markets, on venture capital investment markets, or on combinations thereof. The former of these is relevant not only to investors and energy companies, but also to policy-makers. Meanwhile, the latter of these demands further academic discussion, since the possible research directions are varied and substantial.

Because our model is expressed as a structural equation model, it is implied that any model describing venture capital investment in renewables includes various specific model characteristics. First, it should be noted that the decision process is multistage in nature, with the investment decision being driven by expected valuation, while expect valuation, in turn, is driven by regulation, market size and technological factors. Second, empirical validation of structural equation model functional forms may require validation of their mediating variables. In our case, it the mediating variable positions occupied by both technology and market size within our model may need to be empirically-validated via Sobel testing.

This study contributes a theoretical framework by which future empirical research can have the opportunity to examine and potentially address the observed insufficiency of private funding to address the needs of the renewable energy industry going forward.

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