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Financing renewable energy: Who is financing what and why it matters☆

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ABSTRACT

Successful financing of innovation in renewable energy (RE) requires a better understanding of the relationship between different types of finance and their willingness to invest in RE. We study the 'direction' of innovation that financial actors create. Focusing on the deployment phase of innovation, we use Bloomberg New Energy Finance (BNEF) data to construct a global dataset of RE asset finance flows from 2004 to 2014. We analyze the asset portfolios of different RE technologies financed by different financial actors according to their size, skew and level of risk. We use entropy-based indices to measure skew, and construct a heuristic index of risk that varies with the technology, time, and country of investment to measure risk. We start by comparing the behavior of private and public types of finance and then disaggregate further along 11 different financial actors (e.g. private banks, public banks, and utilities) and 11 types of RE technologies that are invested in (e.g. different kinds of power generation from solar radiation, wind or biomass). Financial actors vary considerably in the composition of their investment portfolio, creating directions towards particular technologies. Public financial actors invest in portfolios with higher risk technologies, also creating a direction; they also increased their share in total investment dramatically over time. We use these preliminary results to formulate new research questions about how finance affects the directionality of innovation, and the implications for RE policies.

1. Introduction

Mobilizing finance for investment and innovation in low-carbon energy is a key challenge for climate change mitigation (Dangerman and Schellnhuber, 2013; Grubb, 2014; Stern, 2015). Because cumulative carbon emissions determine the intensity of climate change, speed matters. Yet, fossil fuel investments continue to dwarf investments into renewable energy (RE).[1] In 2013, RE received investments of less than USD 260 billion, which represented only 16% of the USD 1.6 trillion in total energy sector investments (Fig. 1). Meanwhile, investment in fossil fuels in the power sector, where they compete directly with electricity from RE, rose by 7% from 2013 to 2014 (UNEP and BNEF, 2015). Clearly, fossil fuels still dominate energy investment; therefore, a major concern in the transition to low-carbon energy provision is how to obtain enough finance to steer investments into the RE direction.

A closer look shows that the news is not all discouraging. Total funding for RE has been rising at a remarkable rate. According to Bloomberg New Energy Finance (BNEF), the amount of RE finance along the entire innovation chain, from research and development (R & D) for new technologies to asset finance for full-scale power plants, rose from USD 45 billion in 2004 to 270 billion in 2014 globally (Fig. 2). This represents a compound annual growth rate of 18%. Moreover, in 2014, net investment into new capacity, as opposed to replacing depreciated assets, was twice as large for RE as it was for fossil fuels in the power sector; this trend is forecast to continue for the rest of this decade (International Energy Agency, 2015). Therefore, although investment in RE remains low relative to that in fossil fuels, the trajectory is a positive one.

The focus on achieving a greater amount of finance has diverted attention from what is being financed. Since finance flows towards concrete projects and firms, finance always—unless distributed uniformly—creates a direction towards areas and technologies that these organizations promote. This may result in a skewed distribution of investment in RE, so that some areas are over-financed, while others are

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[1] RE sources comprise solar radiation, wind, running water (hydro), marine waves and tides, biomass, and geothermal energy. Alternative low-carbon energy technologies are nuclear fission or fusion, as well as carbon capture and storage for fossil-fuel plants. The present paper only considers RE and further excludes large dams (> 50 MW capacity).

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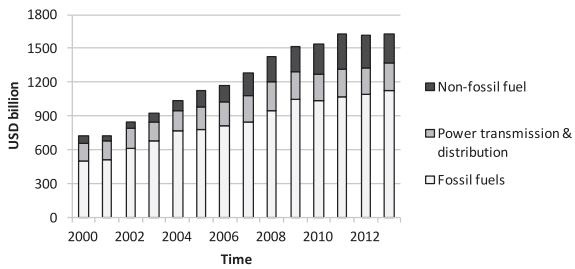

Fig. 1. Global investment into energy by destination.
Source: (International Energy Agency, 2014).

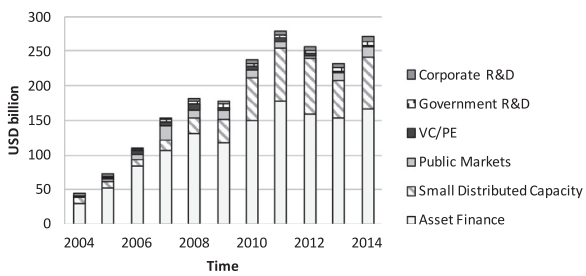

Fig. 2. Global investment into RE by area of finance.
Source: (UNEP and BNEF, 2015).

under-financed (relative to average). Lack of attention on the relationship between finance and directionality is surprising because it is widely recognized that a *diverse* set of RE technologies is desirable, for at least two reasons. Firstly, with a wide portfolio, if innovation is unsuccessful in one area, not all eggs are in one basket (Grubler, 2012); secondly, a diversified energy supply increases resilience of the energy system and hence energy security (Stern, 2015; Stirling, 2010b).

There has been much research linking the research and commercialization phase of the innovation chain to specific financing needs. High-risk upstream research is widely understood to require public financing due to the characteristics of public goods (Arrow, 1962). Similarly, venture capital financing helps to solve the asymmetric information problem in the "Valley of Death" which requires carrying technologies from proof of concept to commercial scale (Auerswald and Branscomb, 2003). The public finance and venture capital that solve these "market failures" are shown in Fig. 2.

However, less studied are the diverse types of finance in the downstream phase of innovation: deployment and diffusion. And yet, more than two thirds of total RE finance went to asset finance for deployment of utility scale RE power plants, also shown in Fig. 2, and so can affect directions in innovation.[2] Channels of influence work both directly through the finance committed favoring a certain technology, and indirectly through the effects of increasing returns to scale and learning by doing, where feedback loops from deployment to upstream innovation can create technology lock-ins (Arthur, 1989). Yet the literature on the 'directionality' of innovation, which has looked for example at the way that policy measures can affect directions of innovation either knowingly or unknowingly (Stirling, 2010a), has ignored the role of finance in this process.

In this paper, we link the literature on the directionality (and pathways) of innovation, with the literature on the relationship between finance and innovation. We study how different types of finance create directions in RE deployment. Our aim is to understand whether and how financial actors differ in their investments, thereby achieving a more granular understanding of the financing process and direction within it. We look at two types of directions: towards specific technologies (such as onshore or offshore wind) and towards sets of more or less commercialized and hence risky technologies.

We consider the aggregate categories of "public" and "private" finance, which are typical distinctions in both theoretical and applied work about RE innovation (Popp, 2011; Veugelers, 2012). We also study 10 more disaggregated *financial actors* active in deployment (including private banks, public banks, private utilities, and public utilities). This perspective differs from the conventional focus on the *sources* of finance, e.g. different types of equity, debt and grants (Kerr and Nanda, 2015), and is connected to a growing body of literature (reviewed below) that demonstrates differences in financing behavior between financial actors.

Our disaggregated analysis is based on data from the BNEF database of deal-level global RE asset finance, from 2004 to 2014, as well as aggregate BNEF data on public banks. We distinguish financial flows from particular organizations to particular technologies. We draw on both ownership and industry classifications in the BNEF database to categorize financial actors. We update and correct the classification extensively using information from organizations' websites and reports. We also create a heuristic risk measure based on the literature on technology and market risk (Szabó et al., 2010), and Ernst and Young's (2015) Renewable Energy Country Attractiveness Index, which we applied to measure and compare the risk exposure that financial actors have, given their investment portfolio across technologies and countries. We analyze technology direction using entropy-based measures of portfolio balance, and risk direction by the share of finance flowing to high risk investments.

Our results suggest that not all sources of finance have the same impact on RE. Some financial actors skew their investment to a subset of technologies (e.g. public utilities towards offshore wind), while others spread their investments more evenly over a wide portfolio of competing technologies, creating *technology* directions. We also find that public actors not only invest in far riskier portfolios, influencing the risk direction, but also account for an increasing share of total investment.

Section 2 briefly reviews the literature on the relationship between finance and the direction of innovation, both generally and for RE. Section 3 introduces the data and our methods of analyzing differences in investment behavior. Section 4 discusses results on technological directions created through the skew of portfolios of private and public finance as well as 10 financial actors. Section 5 discusses results on risk directions through varying risk exposure of actors, and examines patterns of finance in four high-risk technologies. Section 6 concludes by discussing the implications of our results for climate change policy, and for future research on financing innovation. Two appendices provide details on the construction of our database and the risk index, respectively.

2. Finance and energy innovation

2.1. Financial actors and innovation directions

Joseph Schumpeter placed finance at the center of his theory of innovation, as providing the funds necessary for the entrepreneur to spring into action. However, he focused on only one type of finance: banks (Schumpeter, 1939, 114), and did not elaborate on the question of whether different financial actors' characteristics might impact what innovation is being financed, thus creating directions. The Miller–Modigliani theorem, which states that sources of finance (equity or debt financing from any actor) do not matter to firms and hence do not affect the real economy (Modigliani and Miller, 1959) has further detracted attention away from distinguishing between types of finance in innovation. In subsequent literature, the only types of actors typically singled out were "government" and "venture capitalists" (Hall, 2002). The job of the former was to overcome underinvestment in research due to the positive externality of knowledge (Arrow, 1962); the purpose of

[2] Small distributed capacity deals for residential and business rooftop solar modules of < 1 MW make up another 25%. A typical household rooftop solar module has a capacity of 1–4 kW. This study focuses on utility scale asset finance due to data availability.