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GREEN STATE INVESTMENT BANKS: THEIR ROLE IN MOBILISING FINANCE TO ACCELERATE THE ENERGY TRANSITION AND THE POLITICS BEHIND THEIR ESTABLISHMENT AND DESIGN

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Abstract

The adoption of the Paris Agreement in 2015 signified a shift away from the Kyoto Protocol's international burden-sharing outlook towards nationally driven mitigation action, and therefore national level policy tools. Significantly this agreement recognizes the crucial role finance must play in addressing climate change, highlighting the importance of "making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (Article 2.1c of the Paris Agreement). A major transition of our energy system will be required in order to reduce CO_2 emissions, but the investment necessary for the rapid and large-scale deployment of low-carbon technology may not materialise. Developers continue to face difficulties in sourcing finance, and many investors still perceive low-carbon projects as high risk. Thus there is a demand for policies that can harness countries' limited public finances to leverage in private sector finance. Subsequently, some governments have launched or appointed green state investment banks (GIBs), a relatively new policy tool, to support their country's transition to a more sustainable economy.

Thus this dissertation seeks to increase the understanding of this specific public finance policy tool, green state investment banks (GIBs), in order to derive practical insights for policymakers. It does so via three separate papers that each seeks to address a gap in the existing research. Collectively, the papers in this dissertation aim to explore the role of GIBs in mobilising finance to accelerate the energy transition, and to study the politics behind their establishment and design.

The first paper investigates the role of GIBs in addressing barriers to finance for developers of low-carbon projects. Then, building on insights from Paper 1 that GIBs may be a suitable policy tool for supporting energy transition, Paper 2 aims to better conceptualise and integrate finance into the Multi-Level Perspective (MLP) on transitions using the empirical GIB case. Finally paper 3 draws on insights from Papers 1 and 2 that how well a GIB can mobilise finance for transition is subject to its establishment, mandate and design, which in turn may be conditional on the national political and policymaking environment. Paper 3 therefore explores the political discourse and decisions behind the establishment and design of GIBs.

This dissertation makes three main contributions to the literature. First, it provides the first empirical analysis of the detailed roles and activities of GIBs that successfully address barriers and mobilise finance for the low-carbon energy sector. Previous GIB literature has been limited to focusing on their role in the overall economy, describing the various existing models and considering GIBs' potential to expand climate finance in emerging economies. Second, this dissertation makes a theoretical contribution to the literature on the Multi-Level

Perspective (MLP) on transitions. It takes a step towards better incorporating finance into the MLP, where finance has remained under-conceptualised despite the recognition of its importance by transitions studies. Third, it performs the first empirical exploration of the political decisions and discourse behind the establishment and design of GIBs by analysing parliamentary debates. To date there has been no analysis in the literature on how GIBs are established or why they exist in their present form.

Collectively the findings from the three papers are used to derive implications for policymakers. First this work demonstrates that GIBs are an important and effective policy tool for both mobilising finance for the diffusion of innovative low-carbon technology, thereby enabling technological change and helping to accelerate the energy transition. Second, policymakers should use both neoclassical and evolutionary perspectives when establishing, designing and assessing GIBs and other similar public finance policy tools. Policy that is established, designed and assessed exclusively under the neoclassical viewpoint may not be the most effective, and may also be underestimated in terms of its performance and capacity to accelerate transition. Finally, policymakers should keep in mind that politics matters when it comes to establishing and designing GIBs and that they are not 'immune' to a country's existing political controversy. Therefore a political consensus or government majority may be necessary in order for a country to establish a GIB. However if consensus exists, policymakers may then have greater opportunity to contribute to a GIB's design aspects, and potentially apply this dissertation's recommendations regarding neoclassical and evolutionary perspectives. This dissertation then concludes with a discussion on its limitations and avenues for further research.

Résumé

L'adoption de l'Accord de Paris en 2015 a marqué un changement important par rapport à la perspective internationale du partage des responsabilités associée au Protocole de Kyoto, au profit d'une action d'atténuation menée au niveau national, et donc de la mise en place d'instruments politiques à l'échelle des pays. Cet accord reconnaît de manière significative le rôle crucial que le financement doit jouer dans la lutte contre le changement climatique, en soulignant l'importance de « rendre les flux financiers compatibles avec la trajectoire d'un développement à faibles émissions de gaz à effet de serre et résistant au climat » (article 2.1c de l'Accord de Paris). Une transition majeure de notre système énergétique sera essentielle pour réduire les émissions de CO_2, mais les investissements nécessaires au déploiement rapide et à grande échelle de technologies à faible émission de carbone pourraient ne pas se concrétiser. À l'heure actuelle, les développeurs continuent d'éprouver des difficultés à trouver des sources de financement, et de nombreux investisseurs continuent de percevoir les projets à faible émission de carbone comme étant à haut risque. Il existe donc une demande pour des politiques et des instruments permettant de mobiliser la finance publique limitée des pays afin d'obtenir un effet de levier et garantir la participation du secteur privé. Dans cette optique, certains gouvernements ont lancé ou nommé des banques nationales dédiées aux investissements verts (GIBs en anglais, pour « Green State Investment Banks »), un outil politique relativement nouveau, pour soutenir la transition de leur pays vers une économie plus durable.

Cette thèse cherche ainsi à améliorer la compréhension de cet outil spécifique de la politique des finances publiques, les GIBs, afin de rassemble des connaissances pratiques et concrètes, et d'informer les décideurs et le législateur. Cette thèse est composée de trois articles distincts qui cherchent chacun à combler une lacune dans la littérature existante. Collectivement, ils visent à explorer le rôle des GIBs dans la mobilisation des financements pour accélérer la transition énergétique, et à étudier la politique derrière leur création et leur conception.

Le premier article examine le rôle des GIBs dans l'élimination des obstacles au financement des développeurs de projets à faible intensité de carbone. En s'appuyant sur les conclusions du premier article selon lesquel les GIBs peuvent être un outil politique approprié pour soutenir la transition énergétique, le deuxième article vise à mieux conceptualiser et intégrer la finance au sein de la « Multi-Level Perspective » (MLP) portant sur les transitions en utilisant le cas empirique des GIBs. Enfin, le troisième article, qui s'appuie sur les résultats des deux premiers, étudie le lien entre la capacité d'une GIB à mobiliser des fonds et son mode de création, son mandat et de sa structure, aspects qui peuvent à leur tour dépendre de

l'environnement politique et décisionnel national. Le troisième article explore donc le discours politique et les décisions qui sous-tendent l'établissement et la conception des GIBs.

Cette thèse apporte trois contributions principales à la littérature. Premièrement, elle fournit la première analyse empirique des rôles et activités détaillés des GIBs qui permettent de lever les obstacles et de mobiliser des financements pour le secteur de l'énergie à faible émission de carbone. La littérature antérieure portant sur les GIBs s'est limitée à se concentrer sur leur rôle dans l'économie globale, à décrire les différents modèles existants et à considérer le potentiel des GIBs à développer la finance climatique dans les économies émergentes. Deuxièmement, cette thèse apporte une contribution théorique à la littérature sur la « Multi-Level Perspective » (MLP) portant sur les transitions. Elle fait un pas vers une meilleure intégration du financement dans la MLP, où le financement est resté sous-conceptualisé malgré la reconnaissance de son importance par les études portant sur la transition. Troisièmement, elle effectue la première exploration empirique des décisions politiques et du discours qui sous-tendent l'établissement et la conception des GIBs en analysant les débats parlementaires. Jusqu'à présent, il n'y a pas eu d'analyse dans la littérature sur la façon dont les GIBs sont établies ou pourquoi elles existent sous leur forme actuelle.

Collectivement, les résultats des trois articles sont utilisés pour en déduire les implications pour les décideurs politiques. Tout d'abord, ces travaux démontrent que les GIBs sont un outil politique important et efficace pour (i) mobiliser des financements pour la diffusion de technologies innovantes à faible émission de carbone, permettant ainsi le changement technologique et (ii) aider à accélérer la transition énergétique. Deuxièmement, les décideurs devraient utiliser des perspectives à la fois néoclassiques et évolutives lors de l'établissement, de la conception et de l'évaluation des GIBs et d'autres instruments de politique de finances publiques similaires. Une politique établie, conçue et évaluée exclusivement sous l'angle néoclassique peut ne pas être la plus efficace et peut aussi être sous-estimée en termes de performance et de capacité à accélérer la transition. Enfin, les décideurs et le législateur doivent garder à l'esprit que la politique est importante lorsqu'il s'agit d'établir et de concevoir des GIBs et qu'ils ne sont pas « à l'abri » d’une controverse politique existante au sein du pays. Par conséquent, un consensus politique ou une majorité gouvernementale peut être nécessaire pour qu'un pays puisse établir une GIB. Cependant, s'il existe un consensus, les décideurs politiques pourraient alors avoir plus d'opportunités de contribuer aux aspects de conception d'une GIB, et potentiellement appliquer les recommandations de cette thèse concernant les perspectives néoclassiques et évolutionnaires. Cette thèse se termine par une discussion sur ses limites et ses pistes de recherche.

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Synopsis

1 Introduction

The Paris Agreement, adopted by the world's governments in 2015, signified a shift away from the international burden-sharing mindset of the Kyoto Protocol towards one with a focus on nationally driven mitigation action, and hence national level policy instruments (Schmidt and Sewerin, 2017; United Nations, 2015). This also accompanied a shift in perspective towards one where countries see benefit in taking advantage of the economic and technological opportunities associated with climate change action (Schmidt and Sewerin, 2017). Furthermore, this agreement highlights the vital role of finance in addressing climate change, with signatories committed to "making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (Article 2.1c of the Paris Agreement) (United Nations, 2015; Whitley et al., 2018). There is a need to ensure that finance helps rather than hinders the transition towards a low-carbon future (Perez, 2002; Schmidt, 2014; Whitley et al., 2018).

The recent Intergovernmental Panel on Climate Change (IPCC) reports that limiting global warming to 1.5°C will require a rapid and significant transition of our society, demanding a "major reallocation of the investment portfolio" (IPCC, 2018; Rogelj et al., 2018, p154; Whitley et al., 2018). As the electricity and heat sectors account for just under half of global CO_2 emissions (IEA, 2018a, 2018b), mitigating climate change will require a major transition of our energy system in order to reduce CO_2 emissions (IPCC, 2014, 2018). The development and deployment of new renewable energy and energy efficiency technology is central to this energy transition and policy is needed to accelerate and drive this technological change (i.e. the invention, innovation and diffusion of new technologies) (Patt, 2015; Pizer and Popp, 2008; Schmidt et al., 2012).

However, there are concerns that the necessary investment required for the large-scale diffusion of low-carbon technology will not materialise, either fast enough or in the volumes required (IEA, 2014, 2016, 2019; IFC, 2010; SE4ALL, 2014). It is estimated that the annual global investment 'gap' in the low-carbon energy sector will be USD 130 billion or USD 480 billion each year until 2030 to achieve the Nationally Determined Contributions (NDCs) or 1.5^{o}C targets respectively (McCollum et al., 2018). Given that many countries' public finances are constrained, additional private finance is considered necessary to fill this gap (FS-UNEP and BNEF, 2016, 2017; GIBC, 2010; IEA, 2018b; Mathews et al., 2010; Rogelj et al., 2018). Although innovation has ensured a substantial fall in the cost of low-carbon technologies in recent years (Huenteler et al., 2015; Schmidt and Sewerin, 2017; Trancik et al., 2015), many private investors still perceive low-carbon projects as too risky and do not invest (CPI, 2013; Hall et al., 2015; Jacobsson and Jacobsson, 2012; Jacobsson and Karltorp, 2013; Karltorp, 2015; Lang et al., 2015; Ondraczek et al., 2015; Sadorsky, 2012). Developers continue to struggle to source finance for their projects, facing a wide range of barriers that vary by technology type, project size and context conditions (CPI, 2013; Hall et al., 2015; Kann, 2009; Polzin, 2017; Richards et al., 2012). Hence there are calls to use countries' limited public finances to leverage in private sector finance (Jacobsson and Jacobsson, 2012; Karltorp, 2015; Mathews et al., 2010; Schmidt, 2014; Steffen, 2018).

Consequently, some governments have established or appointed green state investment banks (GIBs)[1] to support their country's transition to a greener economy by mobilising private sector capital into low-carbon energy projects. The UK's Green Investment Bank (UKGIB) and Australia's Clean Energy Finance Corporation (CEFC) were both founded in 2012 to support low-carbon projects and foster more sustainable economies (CEFC, 2016a; GIB, 2016b). Germany's Kreditanstalt fuer Wiederaufbau[2] (KfW), while originally established as the country's development bank and not considered to be solely a 'green' state investment bank, actively supports Germany's energy transition and from 2007-2012 was the biggest development bank investor in clean energy projects globally (KfW, 2015; Louw, 2013). Meanwhile other countries are considering establishing such banks (Green Bank Network, 2018). The "Green Bank Act of 2019" was introduced to the US Senate in May, President Emmanuel Macron has called for a French climate bank (Green Bank Network, 2019) and Indonesia is investigating whether a green investment bank model will benefit its economy (Climate Policy Initiative, 2019).

Despite the interest in this public finance policy tool, and evidence that state investment banks can be effective in mobilising finance into certain green infrastructure projects (OECD, 2015, 2016, 2017), there is little literature on GIBs. There is a body of work exploring the overarching role of state investment banks in the economy, reporting that these banks address 'grand societal challenges' including climate change (Mazzucato and Penna, 2015) and that in addition to fixing market failures they also shape and create markets (Mazzucato and Penna, 2016). D'Orazio and Valente (2019) used an evolutionary agent-based model to show that the presence of a public investment bank increased the diffusion of environmental innovations and led to higher GDP growth. Other reports have investigated and compared various models of green and state investment banks (Berlin et al., 2012; Macfarlane and Mazzucato, 2018)

[1] Note that Papers 1 and 2 in this dissertation refer to State Investment Banks (SIBs) in lieu of GIBs and refer to the UK's UKGIB as the UK's GIB.

[2] Reconstruction Credit Institute

and explored the potential to scale up climate finance using state banks in developing and emerging markets (NRDC, 2016). However, overall the empirical (and theoretical) literature on GIBs remains limited.

The shift in focus of the Paris Agreement to national level mitigation action and the need for policy to redirect finance to support low-carbon technology diffusion opens up avenues for research on these little studied GIBs. Thus this dissertation aims to address the research question: *What is the role of GIBs in mobilising finance to accelerate the energy transition and what are the politics behind their establishment and design?*

The remainder of the dissertation is structured as follows. Section 2 provides some context on energy sector finance and innovation and Section 3 describes the literature this dissertation draws on to answer the research question, indicating where research gaps exist. Section 4 briefly presents some background on the GIBs selected for study. Section 5 describes the research framework behind the dissertation, the research objectives and outlines how each individual paper contributes to the dissertation. Section 6 presents a summary of each individual paper's findings and Section 7 concludes by describing the dissertation's empirical and theoretical contributions, implications for policymakers and avenues for future research. Finally Section 8 gives a brief overview of the three papers, including authors and the current publication or submission status. Each complete individual paper can be found at the end of this synopsis chapter.

2 Finance, innovation and the energy sector

This section presents some background on finance and innovation, and how finance works in the energy sector, in order to better understand where GIBs aim to intervene. First in Section 2.1 the role of finance in a technology's innovation chain is discussed, indicating where financing gaps occur (also known as valleys of death) and where GIBs typically operate. This is followed by a closer look at how energy sector finance works for both incumbents and new entrants in Section 2.2 and again highlights where GIBs seek to play a role.

2.1 Finance and the innovation chain

As a technology moves along its innovation chain from research, development and demonstration (RD&D) through to various stages of commercialisation and large-scale diffusion, it requires different types of finance to perform different functions (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2016). In the RD&D stage public finance plays a central role, whereas early stage commercialisation is often financed by venture capital and private equity (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2016). Banks and institutional investors then play a key role in financing the later commercialisation and diffusion stages (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2016). However there are several financing gaps along the innovation chain, known as valleys of death, where technology developers struggle to source the appropriate finance they need due to the presence of various risks and uncertainties (Grubb, 2004; Nemet et al., 2018). The first occurs upstream of the innovation chain as a technology tries to move from the demonstration phase to early stage commercialisation, with a transition from public to private financing required (Karltorp, 2016). The second valley of death occurs further downstream when the technology needs to move from commercialisation to large-scale diffusion or deployment, often struggling to find the much larger capital required for this diffusion (Karltorp, 2016). Banks and institutional investors often view new technologies at this diffusion stage as high risk and demand proven track records before they will provide the necessary finance (Geddes et al., 2018; Hall et al., 2015; Karltorp, 2016).

Studying finance (and the policy to mobilise it) in the second valley of death is worthwhile for two reasons. First, although finance is critical along the entire innovation chain, it is downstream finance that is especially crucial for the swift and widespread deployment of low-carbon technologies needed for transition (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2015; Mazzucato and Semieniuk, 2017). Second, knowledge and learning feedbacks (i.e. feedbacks from learning-by-doing, learning-by-using) gained when a technology is deployed into a system can lead to further technological (and project level) improvements (Huenteler et al., 2016a; Huenteler et al., 2016b; Malerba, 1992; Rosenberg, 1982). These improvements are frequently critical to enabling widespread deployment of technology (Sagar and van der Zwaan, 2006). GIBs largely operate here, in the second valley of death, to support the deployment of low-carbon technologies and projects.

2.2 Energy sector finance

Finance in the energy sector has historically played a role that sustains incumbent energy companies and technologies e.g. fossil fuel technologies. Larger, more established incumbents - often listed companies issuing bonds - have been able to rely on their existing balance sheets[3] to raise any additional finance from banks or other investors in order to finance their activities, whether innovative or otherwise. (Mazzucato, 2013; Steffen, 2018). In addition, standardised and well-known de-risking products (mostly financial tools and some

[3] Developers typically either develop projects using corporate finance (i.e. on their balance sheet), or source project finance. When using corporate finance all assets and cash flows from the development company are used to guarantee required credit. When sourcing project finance, a new legal entity (i.e. a special purpose vehicle, SPV) is created to incorporate the project. The required credit is then guaranteed against the cash flows of the new project only, with no or very limited claim (recourse) on the development company's assets (Steffen, 2018).

insurances) are readily provided to incumbents by banks and other intermediaries to help address any risks and fill any financing gaps they may encounter.

However, incumbent companies and/ or investors have not traditionally supported new low-carbon technologies (Geels, 2014). Moreover many new independent, and usually smaller, developers of new low-carbon technologies, do not feature the large enough balance sheets needed to develop and deploy projects (Steffen, 2018). These smaller and newer firms and developers that perform more ‘exploratory and innovative’ activities are often only able to source finance from equity markets and venture capitalists (Mazzucato, 2013). However venture capital is not ideally suited to longer term energy sector projects as it is not always able or willing to provide the longer term patient capital that is needed (Mazzucato, 2013; Mazzucato and Semieniuk, 2017; Nanda and Ghosh, 2014).

As an alternative to balance sheet investment, low-carbon developers can, and often, use project finance[3] (Steffen, 2018). However to raise funds, project finance still relies on additional investors and intermediaries (Polzin et al., 2016; Steffen, 2018) who perceive a range of high risks and uncertainties associated with these new developments (Jacobsson and Jacobsson, 2012; Jacobsson and Karltorp, 2013; Karltorp, 2015; Sadorsky, 2012). Attempts to source finance are exacerbated by two factors: first many low-carbon technology projects are capital[4] intensive (such that even some larger companies have been unable to use corporate finance to develop projects on their balance sheets). Second, projects featuring low-carbon technologies can exhibit various different risk and cost structures than those seen in incumbent technology projects (Schmidt, 2014; Waissbein et al., 2013). Consequently, on the whole commercial banks and investors have viewed the uncertainty around the deployment of more innovative low-carbon projects as too risky and have declined to invest. Therefore, with traditional banks, and capital markets, less prepared to finance low-carbon projects, public finance interventions, like GIBs, can be effective in this space (Polzin et al., 2019).

3 Literature and research gaps

This dissertation draws on various theoretical concepts and literature streams in order to answer the overarching research question. First it applies two theoretical lenses to explore finance and the policy needed to mobilise it for the energy transition[5] – the neoclassical and

[4] Capital intensive projects feature very high up-front capital costs (investment) compared to their operational (variable) costs. They usually need a very high volume of production in order to produce an acceptable return on investment.

[5] By energy transition this dissertation refers to a socio-technical transition of the energy system. A Socio-technical system is composed of actors (individuals, firms etc.), knowledge, artifacts and institutions (norms, regulations etc.) (Geels, 2004; Markard, 2011; Markard et al., 2012). A socio-technical transition is a sequence of developments that brings about a fundamental transformation of such a system (Kemp, 1994). During such a

evolutionary economics perspectives discussed in Sections 3.1.1 and 3.1.2 respectively. Then it raises questions around the politics behind GIBs as a public finance policy in Section 3.2, under the assumption that the establishment and design of a GIB (and therefore its effectiveness as a policy tool) may be influenced by its political policymaking environment. The discussion of the two theoretical concepts, and the background on politics behind climate change mitigation and its policy, serves to highlight the three research gaps this dissertation aims to address in each of its contributions: Papers 1, 2 and 3.

3.1 Theoretical concepts

3.1.1 Neoclassical economics perspective on policy and finance

The neoclassical economics perspective on policy and finance focuses on market failures and inefficiencies, arguing that policy is needed to 'fix' or 'correct' these failures and inefficiencies in order to enable finance to flow (Grubb et al., 2014; Hall et al., 2015; Styhre, 2014). This perspective underpins the efficient market hypothesis (EMH), which is the dominant theory on financial markets (Fama, 1970; Hall et al., 2015; Sharif, 2006). The EMH concept assumes that markets are efficient as prices always 'fully reflect' current and available information (Fama, 1970). Thus markets always price risk (and return) expectations perfectly, rationally and instantaneously and when new information arrives (e.g. on investment opportunities in new technologies), it is instantly integrated into asset prices (Hiremath and Kumari, 2014). Hence on average, an asset should not be mispriced. It also assumes that if the risk-return[6] profile of a new investment opportunity is favourable, investors will invest, implying that finance is technology neutral[7].

However it is also acknowledged that in the energy sector, market failures and market inefficiencies exist that prevent the flow of finance into new low-carbon technologies (Jaffe et al., 2005). These include namely the negative externalities related to the social cost of carbon, positive externalities associated with knowledge and adoption spill-overs and additional failures related to incomplete information and uncertainties related to investments in innovation and diffusion of new technology in the context of climate change (Gillingham and Sweeney, 2012; Hall et al., 2015; Jaffe et al., 2005; Nordhaus, 2017). These market failures play out in the form of a wide range of barriers to sourcing financing for low-carbon energy developers, even as the cost of these technologies and projects has dropped in recent years

transition significant technological, institutional, economic, socio-cultural and political change occurs (Markard et al., 2012).

[6] Investors decide whether to invest or not according to the risk-return trade-off principle: the principle that potential return rises only by accepting an increase in risk (possible losses) (Brealey et al., 2017). That is, an investor will consider if an investment displays too much risk or too little potential for return as compared to their pre-determined desired limits, to decide whether to take action and invest.

[7] That finance (markets, investors etc.) do not prefer one type of technology over another.

(IRENA, 2018). Barriers vary by context and technology but some examples include high transaction costs (for small scale renewable and energy efficiency projects), various uncertainties (e.g. policy uncertainty) resulting in both perceived and actual high risks and mismatches between the availability of short-term finance and the need for long-term, patient finance for renewable projects (Allen and Santomero, 1997; CPI, 2013; Geddes et al., 2018).

Thus under the neoclassical perspective, policies should aim to address the various barriers to financing that exist e.g. by improving the risk-return profile[8] of an innovation or project (Polzin et al., 2019). There is evidence that GIBs seek to improve the risk-return profile of projects and leverage in private finance by performing de-risking activities and providing capital (OECD, 2015, 2016, 2017). In addition Mazzucato and Penna (2016) showed that state investment banks make strategic investments to address 'grand societal challenges', such as climate change, and Mazzucato and Semieniuk (2017) showed that especially high-risk renewable projects have received support from state owned entities. However there is little empirical work on the roles these banks can take to overcome barriers to mobilising private finance into the low-carbon energy sector. These gaps open up questions for research on how and how well GIBs address the barriers to finance faced by low-carbon developers. This thesis explores these gaps via the contribution of Paper 1.

3.1.2 Evolutionary economics perspective on policy and finance

The evolutionary economics perspective challenges the neoclassical position and insists that policy needs to take a broader role than just fix market failures (Foxon and Pearson, 2008; Foxon, 2011; Grubb, 2004; Hall et al., 2015). Policy is required to also shape, create and adapt the markets (including financial), (innovation) systems and institutions around a technology. Hall et al. (2015) propose the adaptive market hypothesis (AMH) as an evolutionary perspective on financial markets that can co-exist with EMH (Hiremath and Kumari, 2014; Lo, 2004, 2005, 2007). The AMH assumes that markets are not always efficient but are adaptable, moving between efficiency and inefficiency as though along a spectrum (Buttonwood, 2015; Lo, 2004, 2005, 2007, 2012). Key to AMH are the processes of learning, heuristics management and adaptive decision making; economic agents' 'rational decisions' constantly evolve, adapt and are discarded as markets and environments change (Hiremath and Kumari, 2014; Soufian et al., 2014). Hence AMH asserts that relatively new financial markets (e.g. for new low-carbon technologies) are likely to be less efficient than established markets and that inefficiency can exist in established markets if the environment or investor population changes (Hall et al., 2015; Hiremath and Kumari, 2014; Soufian et al.,

[8] For example by de-risking via risk transfer, reduction or diversification activities, size transformation via capital aggregation and securitization activities to lower transaction costs etc.

2014). In a socio-technical transition such as the energy transition, investment conditions are inherently subject to major shifts. One way to view the difference between the EMH and AMH is in terms of the temporal dimension – EMH assumes all new information is incorporated instantly into the market, prices and by all participants, whereas AMH assumes that new information takes time to integrate and that the market and its participants will adapt, shift and change.

The evolutionary perspective's broader role for policy also stems from its recognition of the concept of path dependency[9] resulting in potential lock-in i.e. the tendency for the system to continue to lock-in incumbent technologies and systems and lock-out new, hindering the diffusion of new low-carbon technology even if market failures are addressed (Arthur, 1989; Foxon and Pearson, 2008; Foxon, 2011; Grubb, 2004; Unruh, 2000). This can be extended to explain financial system stability, with its tendency to continue to invest in incumbents rather than new technology even if policy 'fixes' market failures and ensures the risk-return profile of new projects is acceptable (Foxon, 2011; Hall et al., 2015; Markard, 2011; Unruh, 2000). Recent empirical proof that investors undergo a learning process when financing new projects and technologies, presented by Egli et al. (2018), further supports the idea that path dependency can exist within the finance sector. Under the evolutionary perspective, the need for adaptation processes is recognised and policies should aim to adapt and shape the institutional context to overcome stability and lock-in and to enable finance to flow to new technologies, e.g. by enabling processes of learning, heuristics management and adaptive decision making.

Evolutionary scholars in particular highlight the crucial importance of finance as an enabler for innovation and transition, highlighting the need for a fundamental shift of capital towards new technologies (Mazzucato, 2011; Mazzucato and Penna, 2015; Perez, 2002, 2010, 2011; Schmidt, 2014; Schumpeter, 2010/1942). The predominant evolutionary transitions framework, the MLP, includes financial markets as part of the existing regime (Geels, 2002, 2013), however the analysis of finance in the MLP literature remains understudied. This opens up a research avenue for better conceptualising and integrating evolutionary finance concepts into this transitions framework using GIBs. Neoclassical perspective implies that GIBs would only provide tools and activities to fix market failures and to address and improve the risk-return profile. Yet there are indications that GIBs do much more than this, potentially shaping and creating markets, rather than merely fixing their failures, taking a

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[9] Learning and network effects (in combination with increasing economies of scale) can ensure a system facing various potential outcomes (e.g. technologies) will move towards one specific outcome, even if that outcome is not socially optimal in the long run. Therefore some systems become 'path dependent' and subject to eventual 'lock-in' (Arthur, 1989).

'mission-oriented' role by investing in new sectors to enable transitions needed to address 'grand societal transitions' and supporting evolutionary type processes around adaptation and learning (Mazzucato and Penna, 2015; Mazzucato and Penna, 2016). There are also indications that GIBs work on both the technology sector and the finance sector, implying that as a policy tool it can have a systemic effect, something that is considered necessary for transitions (Wieczorek and Hekkert, 2012). In Paper 2 this dissertation aims to make a step towards addressing this theoretical gap in the MLP by examining how GIBs affect the interaction between the finance sector (regime) and the low-carbon energy technology sector (niche).

3.2 The politics behind climate change mitigation policy

Climate change mitigation, and its policy, have been politicized in many countries and are associated with political controversy and partisanship (Dessler and Parson, 2005; Mildenberger et al., 2017; Oreskes and Conway, 2010). In Australia, the UK, the United States and Canada, for example, partisanship and ideological divides remain around this issue (Carter, 2014; Carter and Clements, 2015; Cheung and Davies, 2017; Hale, 2010; McCright et al., 2016; Young and Coutinho, 2013). This is in part due to efforts to downplay the importance of climate change by conservative actors (Dunlap and McCright, 2015; Hamilton, 2007; McCright and Dunlap, 2011; McCright et al., 2016; McKewon, 2012). There has also been a growing ideological movement in many countries against state 'interference' in markets, meaning governments are more reluctant to intervene in order to address society's major challenges (Hale, 2010). This political controversy can block the introduction of policies needed to support low-carbon technology development (Meckling et al., 2015; Schmid et al., 2019; Stokes and Warshaw, 2017).

GIBs may be less politically controversial than other policy instruments, such as carbon pricing, because there are claims that they are linked more with technological and economical opportunity-seizing activities and less with divisive 'market distorting state intervention' (Eggleton, 2015; Geddes et al., 2018; Mazzucato and Penna, 2016). However there is no account of how or why GIBs were first created, or of why GIBs are designed the way they are. Limited literature reports on the advantages and disadvantages of various existing GIB models (Berlin et al., 2012; NRDC, 2016) and on how different design features of state investment banks can address the opportunities and challenges for patient strategic finance (Macfarlane and Mazzucato, 2018). But there is no empirical account on the political decisions and discourse behind the establishment and design of these banks and nor is there any exploration of whether GIBs are also subject to the political controversy that surrounds other climate change mitigation policies. This dissertation aims to address these research gaps in Paper 3 by providing a better understanding of how politics may shape GIBs' establishment and design.

4 GIB case background

To address the research gaps discussed above, this dissertation studies three GIBs that primarily or heavily support low-carbon projects: Australia's CEFC, Germany's KfW Group and the UK's UKGIB. Table 1 provides some background on each GIB selected for study. For more detail justifying the GIB case selection for each paper see Paper 1, Section 2.1, Paper 2, Section 3.1 and Paper 3, Section 2.1.

Australia's CEFC is mandated to mobilise finance for the deployment of low-carbon technologies necessary for a transition to a lower carbon economy (CEFC, 2016c) while operating on commercial terms similar to commercial banks. At the time of the CEFC's introduction Australia's low-carbon sector was considered to be in its infancy (and still is apart from rooftop solar) thanks in part to limited federal policy support for low-carbon technologies and policy-induced uncertainty (Cheung and Davies, 2017; Kann, 2009; Nelson et al., 2013; Nelson et al., 2012). Australia's market-based financial system is highly concentrated under four main banks and features short-term funding activity unsuited to low-carbon projects with longer lifetimes (RBA, 2006, 2017).

The UK's UKGIB was founded to help the UK meet its ambitious emissions targets in a more cost effective way by leveraging private finance into low-carbon projects while also operating on commercial terms, like the CEFC (CCA, 2008; EAC, 2011; Holmes, 2013). The UK's low-carbon sector is more mature than Australia's, in part due to increasing renewable energy support from various policy schemes over recent years but policy-induced uncertainty has also been an issue (Bolton et al., 2016). Like Australia, the UK's financial system is market-based but its banking sector is much less concentrated (Hall et al., 2016; Wójcik and MacDonald-Korth, 2015). In 2017, driven by national budgetary concerns, the UKGIB was privatized under its sale to a Macquarie Bank led consortium and no longer supports exclusively UK based projects, nor is it bound to meet its original green performance requirements (Cumbo, 2019; Pratley, 2018; Vaughan, 2018).

Although originally established as Germany's reconstruction and development bank in 1948, KfW has been heavily active in supporting the Federal Government's energy transition (Energiewende), an initiative to move away from high carbon and nuclear energy to a low-carbon and renewable energy system (Lauber and Jacobsson, 2016; Morris and Pehnt, 2016). Unlike the CEFC and UKGIB, KfW mostly provides finance on concessional terms (Carrington, 2012; Kraft, 2003). Germany has ambitious carbon reduction targets, a supportive policy environment for low-carbon technologies and its low-carbon energy sector is considered to better established than Australia's and the UK's (EEG, 2000; Lauber and Jacobsson, 2016; Lauber and Mez, 2006). Germany's finance sector is more bank-based with a large network of local banking institutions that have become knowledgeable and experienced with financing low-carbon projects (Hall et al., 2016; Wójcik and MacDonald-Korth, 2015).

For a more detailed description of each GIB, and its national policy and financial sector context, see Paper 1, Sections 2.2 to 2.4 and Paper 3, Sections 2.2 and 2.3.

Table 1: GIB Background

GIB[a]	CEFC	UKGIB	KfW
Study Case	Papers 1, 2 & 3	Papers 1, 2 & 3	Papers 1 & 2
Founding Year	2012	2012	1948
Source of Capitalisation	AUD 10 billion (USD 7.9 bn) provided by Australian Government, the sole shareholder	GBP 3 billion (USD 3.9 bn) provided by UK Government, the sole shareholder (originally with a view to giving the bank full access to capital markets to borrow freely. UKGIB has now been privatized via sale to a Macquarie Bank led consortium.)	EUR 3.75 billion equity (USD 4.4 bn) provided by German Federal (80%) & State (80%) shareholders EUR 76.1 billion (USD 89.7 bn) borrowed in 2018 from capital markets via government guaranteed bonds
Private to public finance leverage ratio	(AUD) 2: 1	(GBP) 3:1	Not reported
Number of Staff	121 (average 2018)	130 (as of 2016)	KfW Group: 5,072 (2018) KfW IPEX: 697 (2018)
Focus Sectors			
Solar PV	X		X
Onshore wind	X	X (from 2016)	X
Offshore wind		X	X
Waste-to-energy, bioenergy	X	X	X (until ca. 2014)
Energy efficiency	X	X	X
Small scale renewables	X	X	X
Financial instruments	Debt (market rate, long-term) Debt (concessional, limited to AUD 300 million (USD 237 mn) in NPV terms per year) Equity (introduced after interviews) Securitisation/ aggregation products Guarantees (restricted to 5% uncommitted balance)	Debt (market rate, long-term) Debt (subordinated, mezzanine) Equity (incl. bridging equity loans) Securitisation/ aggregation products	Debt (concessional, long-term) Debt (market rate, long-term, for offshore wind, energy transition related R&D, SME & large corporate projects) Equity (limited amount) Grants Guarantees/ insurance
Major finance channels	Direct lending via co-investment/ syndication On-lending via local intermediaries 3rd party & own managed investment funds Climate bond investment	Direct lending/ investing via co-investment/ syndication 3rd party & own managed equity and debt investment funds Joint Venture	On-lending via local intermediaries Limited direct lending to municipalities and some large corporations KfW IPEX: Direct lending/ investing via co-investment/ syndication
Example programs and funds	Commercial on-bill financing program Clean Energy Innovation Fund Australian Bioenergy Fund (cornerstone investor)	UK GIB Operating Offshore Wind Fund Foresight UKWREI (UK Waste Resources and Energy Investments) Fund Societe Generale Equipment Finance (SGEF) Partnership for energy efficiency	Renewable Energy Program - Standard (Renewable electricity and small scale heat) Energy Efficiency for the Housing Sector - Energy Efficient Construction and Rehabilitation program (EECR) KfW Offshore Wind Energy Program Energy Advice program for SMEs

[a]Data based on (CEFC, 2016a, 2016b, 2018), Australian Government Directory (2019), GIB (2016a, 2016b) and (KfW, 2015, 2016, 2017a, 2017b, 2019)

5 Objectives and research design

The overarching objective of this dissertation is to develop a more detailed understanding of the specific public finance policy tool, green state investment banks (GIBs). In doing so it seeks to derive insights to support and inform policymakers who are considering national policy to mobilise finance for the deployment of low-carbon technology and accelerate energy transition. Thus, this dissertation aims to answer the overall research question: *"What is the role of GIBs in mobilising finance to accelerate the energy transition and what are the politics behind their establishment and design?"*

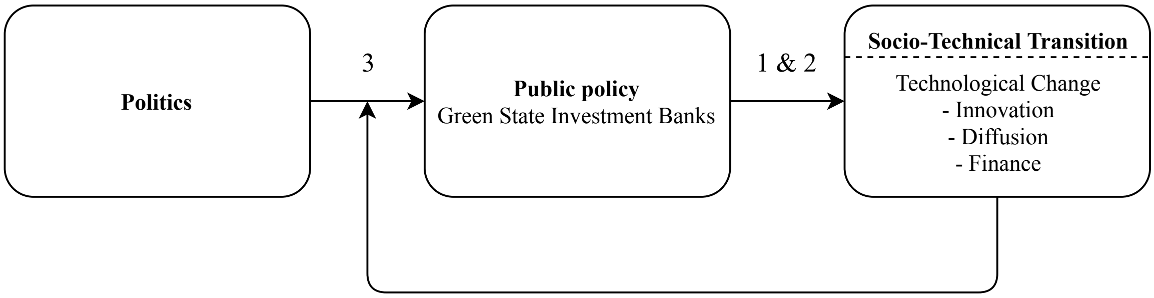

Figure 1: Research framework and where each paper contributes within it. The numbers represent each paper that contributes to this dissertation.

This thesis has produced a set of three separate contributions (papers) that aim to address the research gaps outlined in Section 3 above and in doing so address the overall research question. Figure 1 presents the research framework behind this dissertation. The position of the number of each paper in Figure 1 shows where each paper contributes within the research framework. Papers 1 and 2 explore the link between public policy, namely GIBs, and technological change and transition. Paper 3 explores the link between politics (and the policymaking process) and GIBs.

Paper 1 aims to improve the understanding of the role of GIBs in overcoming barriers to sourcing finance for the deployment of low-carbon projects. In particular it examines how GIBs address barriers to financing for developers and in doing so it derives the key roles taken by SIBs that successfully do so. It aims to answer the research question "*What is the role of SIBs in addressing the barriers faced by low-carbon project developers in sourcing finance?"*

Drawing on insights from Paper 1 that GIBs may be well-suited to enable and accelerate energy transition, Paper 2 aims to advance the understanding of finance in transitions by using the empirical GIB case to better conceptualise and incorporate finance into the Multi-level Perspective (MLP) on transitions. It does so by analysing how GIB interventions affect the interactions between the finance regime and low-carbon energy technology niches: namely whether the interventions help 'fit and conform' low-carbon technology niches to existing expectations in the finance regime, or 'stretch and transform' the finance regime, in both cases allowing finance to flow to the niche and for the niche to enter the regime. It aims to answer the research question "*What are the factors that determine the interactions between the finance regime and technology niches and how are these interactions affected by policy interventions?"*

Paper 3 extends insights from Papers 1 and 2 that a GIB's roles and effectiveness may be linked to its establishment and design. Given that a GIB is a national policy instrument the national political and policymaking environment may impact upon the decisions behind its creation and design. It therefore aims to investigate the political decisions and discourse behind the establishment and design of GIBs by endeavouring to answer the question "*What core arguments and conflict patterns can be observed in the political discourse behind the (i) establishment and (ii) design of a GIB?"*

6 Summary of results

This section provides a summary of the key findings and implications of each paper. A discussion of the overall contributions and implications from these findings can be found in Section 7.

6.1 Paper 1: The multiple roles of state investment banks[10] in low-carbon energy finance: An analysis of Australia, the UK and Germany

A significant transition of the energy sector, via the rapid deployment of renewable energy and energy efficiency technologies, is necessary to mitigate climate change (IPCC, 2018). However, renewable energy and energy efficiency projects are still perceived as high-risk by investors and developers continue to face barriers to financing their projects (CPI, 2013; Hall et al., 2015; Jacobsson and Jacobsson, 2012; Karltorp, 2015; Ondraczek et al., 2015; Polzin, 2017; Sadorsky, 2012). Several countries have appointed (green) state investment banks (SIBs) to use public finance to address these barriers, leverage in private finance to these projects and help foster greener economies.

Paper 1, the first contribution to this dissertation, investigates the role of SIBs in addressing the barriers faced by low-carbon project developers in sourcing finance. It explores the activities and financial instruments offered by three SIBs (Australia's Clean Energy Finance

[10] Note that Papers 1 and 2 in this dissertation refer to State Investment Banks (SIBs) in lieu of green state investment banks GIBs and refer to the UK's UKGIB as the UK's GIB.

Corporation (CEFC), the UK's Green Investment Bank (GIB) and Germany's Kreditanstalt fuer Wiederaufbau (KfW)), and compares these to low-carbon developers' needs when sourcing finance. It also analyses how and how well these needs are met. To do so, Paper 1 employs a qualitative case study design (Eisenhardt, 1989), drawing on a primary data set of 52 semi-structured interviews held from late 2015 to mid 2016 and a range of secondary desktop data sourced from SIBs, developers and financial intermediaries.

Paper 1's results[11] can be abstracted into five prevalent roles that SIBs that successfully address barriers to financing take. First SIBs take a capital provision role and have helped fill investment gaps for projects featuring very high upfront capital costs (such as off-shore wind). Second they perform a de-risking role, implementing diverse instruments to de-risk particularly higher risk projects. But SIBs go beyond these traditionally neoclassical interventions. Third by fostering internal capabilities, SIBs take on an educational role to facilitate both developer and financial sector learning, so that the finance on offer is better suited to that needed by low-carbon projects, and more bankable projects are available for investment. Fourth, once SIBs develop an expert reputation, merely 'signalling' to the market that they will support a project can directly crowd-in additional private finance to that project. Thus having created trust they play a signalling role. Fifth, SIBs perform a first or early-mover role to help produce a track record for risky projects that feature some sort of innovation or novelty, such as a first time developer or technology. While the signalling role directly crowds-in additional private finance to projects that are 'signalled', when a SIB performs the first or early mover role it does so to establish a track record, which then crowds-in private investment to successive later projects.

The findings of this paper have four implications for policymakers. First this paper shows that GIBs can be an important and effective policy tool to address barriers to finance for developers, helping to diffuse innovative low-carbon technologies thereby supporting innovation and technological change. This implies that SIBs could play an important role in helping to accelerate the energy transition. Second, SIBs can be especially effective when thought of as part of an overall policy mix. Other low-carbon technology support policies do not address all of the barriers to finance for projects. SIBs can address many of these. Third, policymakers need to ensure a policy that provides direct government investment, such as an SIB, is designed with appropriate phase-out triggers to prevent crowding-out[12] of private

[11] Paper 1, Figure 2 presents the SIB specific results, summarising how and how well each SIB addresses barriers to finance faced by developers in each country

[12] 'Crowding out' occurs when public institutions investing in the place of private financiers, displacing and/or reducing private investment participation, and therefore preventing the development of an effective private sector market for financing (Cumming and MacIntosh, 2006).

investment once markets mature. Finally, policymakers need to carefully consider how to design a GIB in order to ensure it can effectively mobilise the required finance into low-carbon energy projects and can fulfil the roles observed in this paper.

6.2 Paper 2: Integrating finance into the Multi-Level Perspective: technology niche-finance regime interactions and financial policy interventions

Findings from Paper 1 show that SIBs can be effective in mobilising finance for the diffusion of low-carbon technology projects, ultimately helping to foster innovation and support technological change. In addition, the paper demonstrated that a successful SIB intervenes in both the finance and technology sectors. Together these findings imply that SIBs could be important in accelerating the energy transition. The Multi-Level Perspective (MLP) on transitions explores regimes (selection environments, including the finance sector), technological niches (e.g. where low-carbon technological innovation occurs), the landscape (e.g. structural trends and technology-external factors) and the interactions between them (Geels, 2002, 2012, 2013; Geels, 2014; Geels and Schot, 2007; Smith et al., 2005). Using the empirical case of SIBs, Paper 2 draws on evolutionary economics perspectives on finance, to make a theoretical contribution on finance in the MLP.

Paper 2 proceeds in two steps. Building on the same primary and secondary data collected in Paper 1 (52 semi-structured interviews and desktop data, coded differently for separate analysis) first the paper empirically observes how incumbents source finance from the finance regime. This is in order to identify the factors that determine the interactions between the regime and niche (i.e. whether finance will flow to the niche technology and projects will be financed). Second it identifies SIB interventions and classifies the effect these interventions have on the technology niche - finance regime interaction: either the niche 'fits and conforms' (F&C) to the expectations and rules of the existing financial sector (finance regime) or the finance regime is 'stretched and transformed' (S&T) in order for finance to flow to the niche.

Paper 2's results, the SIB interventions and their observed effect upon the technological niche-financial regime interaction, are displayed in Figure 2. First, results show that the factors that determine whether the niche is financed include acceptable risk and transaction size, adequate knowledge in both the finance regime and technology niche and large and well co-ordinated industry networks. Second, SIB interventions that 'fit and conform' the low-carbon technology niche include de-risking and capital provision, size transformation and capital aggregation activities and educating the niche whereas educating the finance regime is a 'stretch and transform' type intervention. Interestingly, the industry co-ordination intervention simultaneously 'fits and conforms' the niche while 'stretching and transforming' the finance sector.

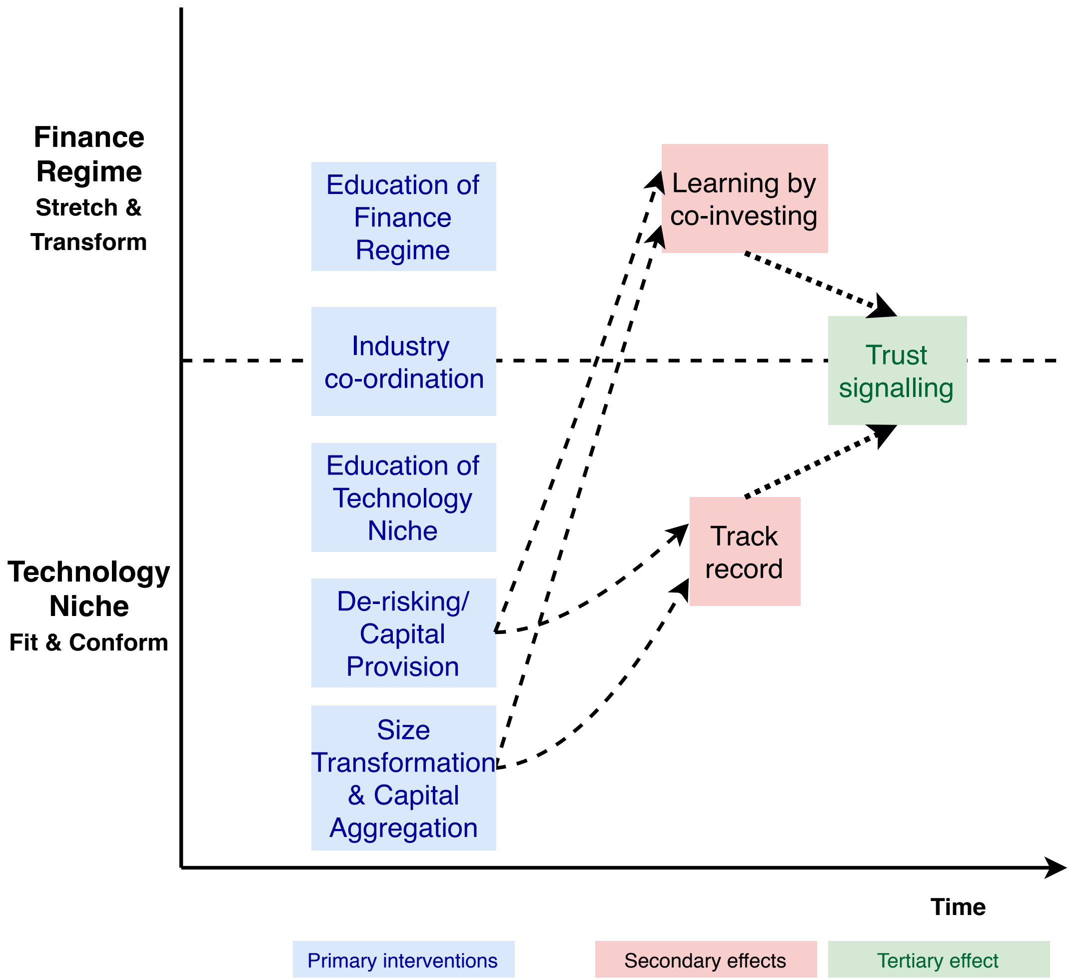

Figure 2: Primary policy interventions and effects

Three main points can be made from these results. First, SIB interventions do not just fit and conform the technology niche to the finance regime's pre-conceived expectations. SIB interventions also stretch and transform the financial regime, helping to overcome regime resistance (finance system stability) and helping to interrupt path-dependency within the financial regime. Second, the interventions that enable learning and co-ordination, and are considered to be evolutionary finance type interventions, are shown to be very important – these evolutionary interventions affect both the technology niche and the finance regime, even simultaneously enabling both 'fit and conform' and 'stretch and transform' interactions in the case of industry co-ordination. Finally, findings show that some interventions directly implemented by GIBs ('primary' interventions shown in blue), subsequently lead to 'secondary' and 'tertiary' effects on the niche-regime interaction, that occur later in time.

Notably, the track record and learning-by-co-investing effects enabled future subsequent projects to be independently financed without a direct SIB intervention.

Paper 2 derives both theoretical implications and implications for policymakers. The first of two theoretical implications is that evolutionary learning and adaptation processes can surmount finance regime stability and resistance. Most MLP analyses recommend that resistant regimes be destroyed and rebuilt (Geels, 2014) so perhaps future analyses could investigate whether other regimes' resistance could be overcome through learning and adaptation. Second MLP studies should consider whether subsequent 'secondary' and 'tertiary' effects on the niche-regime interaction occur as a result of interventions involving other (non-financial) parts of the regime.

Paper 2 derives three implications for policymakers. First, SIBs should be considered by policymakers who aim to support transitions. Paper 2 shows that such a policy tool has facilitated the low-carbon technology niche and finance regime interaction, accelerating the energy transition. Second, the observation that secondary and tertiary effects can occur after an SIB intervenes indicates that policymakers should consider considerably longer-term effects when judging the impact of such a policy. Finally, evolutionary processes are shown to be relevant for the finance regime, indicating that policies designed to enable evolutionary processes can help the finance regime undergo further learning and adaptation processes and overcome path dependency.

6.3 Paper 3: The politics of opportunity-oriented climate policy: an analysis of the political discourse behind establishing green investment banks

Findings from Paper 1 suggest that how a GIB is designed and set-up i.e. how it is financed, the financial tools and channels available for use, matters of risk and return, its target sectors and performance criteria etc., will impact upon how and how well it can mobilise finance and whether it can fulfil the five roles shown to be taken by effective GIBs presented in Paper 1. Additionally Paper 2 showed that if a policy institution such as a GIB is designed to intervene in both the finance sector (regime) and technology sector (niche) and facilitate interactions between the two, it can help accelerate the energy transition. Furthermore, given that a GIB is a national public policy instrument the decisions behind its creation and design may be subject to the national political and policymaking context. This raises questions regarding the political decisions and discourse behind their establishment and design.

Paper 1 explores these questions in two steps. First it investigates what was debated regarding whether to establish a GIB and how it should be designed. Second it investigates whether any existing political controversy regarding climate change is also reflected in this discourse. To do so it employs Discourse Network Analysis (DNA), a mixed-methods approach that merges quantitative social network analysis and qualitative content analysis (Leifeld, 2013, 2016) to study the parliamentary debates on the UK's Green Investment Bank (UKGIB) and Australia's Clean energy Finance Corporation (CEFC).

First the paper finds that arguments related to the role of the state and high level policy goals dominated the debate on GIB establishment and arguments related to technology target sectors, tasks and tools to be implemented and fulfilled, and organisational aspects dominated the debate on GIB design. Second, results show that the level of political conflict or consensus was reflected in the discourse behind both the establishment and design of a GIB. Australian climate change politics was noticeably more controversial than that in the UK at the time of GIB debates (Carter, 2014; Carter and Clements, 2015; Rootes, 2014; Warren et al., 2016). Australia's debates revealed distinct partisanship on all debated topics, whereas the UK displayed clear consensus in the majority of debates.

These findings have three implications. First, because the level of political controversy may be reflected in the GIB debates, a political consensus or government majority may be necessary in order to pass legislation that establishes a GIB. Second, the findings suggest that the level of political controversy may influence the focus of the debate: If a GIB is introduced during times of political consensus, debate may focus more on a GIB's design, allowing legislators to have greater influence over these features. This suggests a need to better understand the influence of partisanship on policy design processes, which is understudied in the policy design literature (Howlett, 2014; Howlett et al., 2015; Schneider and Ingram, 2008). Third, Paper 3 illustrates the shift of national level climate change mitigation politics towards an opportunity-oriented perspective where many arguments emphasised the opportunities of implementing a GIB rather than the costs. However it should be noted that political conflict can persist when new opportunities are seen as detrimental to incumbent sectors.

7 Conclusions

This dissertation aims to support policymakers considering GIBs as a policy instrument to mobilise finance and support energy transition. The key contributions of this thesis are summarised below, followed by a discussion of the most important implications for policy makers. Finally the dissertation's limitations and potential directions for future research are outlined.

7.1 Contributions to the literature

7.1.1 Empirical contributions

Papers 1 and 3 in this dissertation make empirical contributions to the existing literature on GIBs. First, the empirical literature on GIBs thus far has been limited to their general role in the economy, the various models in existence and their potential role in scaling up climate finance in emerging and developing countries (Berlin et al., 2012; D'Orazio and Valente, 2019; Macfarlane and Mazzucato, 2018; Mazzucato and Penna, 2015; Mazzucato and Penna, 2016; Mazzucato and Semieniuk, 2017; NRDC, 2016). This dissertation is the first to perform an empirical analysis of how and how well this policy instrument addresses barriers to financing faced by developers and to abstract the key roles taken by successful GIBs in order to mobilise finance and diffuse technologies. In addition the dissertation findings bring a focus onto previously overlooked and unrecognised roles of successful GIBs: the previously unrecognised *signalling role* and the previously underestimated *educational* and *first or early mover* roles (Cochran et al., 2014). Thus this dissertation makes a first empirical contribution by addressing various gaps on the detailed activities and high level roles of GIBs in successfully mobilising finance.

Second, Papers 1 and 2 of this dissertation indicate that the design of a GIB can influence its ability to effectively mobilise finance and accelerate the energy transition. However there is no empirical literature on why GIBs exist in their current form, or how or why they were established. There is no empirical literature on the political decisions and discourse behind the establishment and design of GIBs, and while there are studies on the politics of national climate change mitigation (Carter, 2014; Carter and Clements, 2015; Cheung and Davies, 2017; Hale, 2010; McCright et al., 2016; Young and Coutinho, 2013), there is none on the politics of GIBs specifically. Thus this dissertation makes a second empirical contribution towards addressing this gap in Paper 3.

7.1.2 Theoretical contributions

While transitions studies acknowledge the importance of finance (Perez, 2002, 2011) it rests on the periphery of many analyses and the literature remains limited. In particular, finance remains under-conceptualised within the MLP literature. This dissertation makes a step towards better integrating finance into the MLP. First this work argues that the finance sector is its own regime (with its own actors and institutions, set of norms, organisational and cognitive routines etc.) and that it overlaps with all other socio-technical regimes. Second it shows that evolutionary processes of learning and adaptation, catalysed by GIBs as a policy intervention, can help overcome financial regime resistance. More specifically this work shows that the financial sector can experience path dependency and that it can be surpassed by evolutionary processes in order to accelerate transitions. This improved conceptualisation may support future MLP transitions studies. Thus this dissertation has helped to address a theoretical gap in the literature.

7.2 Policy implications

In addition to making empirical and theoretical contributions to the literature this dissertation aims to provide insights for policymakers. While the work in this dissertation is based on three cases of GIBs in industrialised economies, some general implications for policymakers can still be derived. This section discusses the four most important implications for policymakers from this thesis.

First, this dissertation demonstrates that GIBs are an important and effective policy tool for mobilising finance for the development and diffusion of innovative low-carbon technology: GIBs can foster and diffuse innovation thereby enabling technological change. GIBs that successfully address barriers to financing faced by developers do so by performing a broad range of roles: de-risking, capital provision, educating (developers and financiers), signalling trust, and a taking first or early mover role. Accordingly, policymakers considering the introduction of a GIB should design it in such a way as to be able to fulfil these roles. A range of factors can influence how and how well an SIB can perform said roles including a GIB's approach to risk and return, allowed financial instruments, hiring practices, performance criteria, technology targets, source of finance etc. Policymakers can consider GIBs as an important feature of a country's overall policy mix. GIBs are able to address barriers to finance that other support schemes cannot – such as the lack of a track record or policy uncertainty as a country shifts between, or drops, other policy support schemes. If designed well, (and with inbuilt features to prevent crowding-out) GIBs can be a strong policy tool to mobilise finance and foster and diffuse innovation.

Second, this dissertation demonstrates that GIBs are an important and effective policy tool that can help accelerate the energy transition. GIBs successfully intervene in both the finance sector (regime) and technology sector (niche), facilitating the low-carbon technology niche and finance regime interaction, and accelerating the energy transition. Policymakers considering this tool should ensure it is designed to intervene and operate in both the technology and finance sectors, and that it fosters the expertise to do so by employing actors from both the finance and relevant technology sectors. In addition policymakers should consider longer-term effects when judging the impact of such a policy – findings show that effects can occur long after a GIB intervenes. This dissertation has demonstrated that, as a policy instrument, GIBs display the systemic features considered necessary for transition (Wieczorek and Hekkert, 2012).

Third, both neoclassical and evolutionary perspectives should be used to effectively design, monitor and assess GIBs and other (public finance) policy tools aiming to mobilise finance and accelerate transition. This dissertation demonstrates that GIBs are effective at mobilising finance and accelerating the energy transition because they implement and enable both neoclassical and evolutionary type policy interventions and processes. If a GIB implemented only neoclassical type interventions it would only perform de-risking and capital provision roles, helping to price risk and ensure the immediate risk-return profile of projects is desirable. Whereas this dissertation observed that GIBs do much more, developing deeper insights on the evolutionary processes that GIBs can promote. They enable processes of learning, adaptation and shaping, within both the technology and the finance sectors. In particular, financial system stability and path dependency can be overcome by a GIB's evolutionary interventions, demonstrating that policy designed to enable evolutionary processes is important for transition. Policy designed exclusively under the neoclassical lens may not be the most effective policy for accelerating transition: it may mean the finance sector remains resistant to change, slowing down transition. Similarly, policy that is monitored and assessed solely under a neoclassical lens will be underestimated and potentially be seen to underperform in terms of accelerating transition. Ultimately, if designed, monitored and assessed under both neoclassical and evolutionary perspectives, GIBs can be a powerful policy to mobilise finance, foster and diffuse innovation and ultimately support the energy transition.

Fourth, politics matters when it comes to the establishment and design of a GIB. This is important to note because GIBs are gaining popularity and are being considered by various governments (Green Bank Network, 2019), and because politics can influence and obstruct climate change mitigation policymaking (Meckling et al., 2015; Schmid et al., 2019; Stokes and Warshaw, 2017). First, this work demonstrated that GIBs may not be not immune to a country's existing level of political controversy regarding climate change mitigation: existing partisanship could be reflected in the debate around establishing and designing a GIB. Therefore policy makers should keep in mind that a political consensus or government majority may be required in order to establish a GIB. Second, in countries experiencing greater consensus towards climate change mitigation, political debate may centre more on the design aspects of a GIB. This would present an opportunity to policymakers to apply some of the recommendations made in this dissertation around how to design (and ultimately monitor and assess) an effective GIB (i.e. utilising both neoclassical and evolutionary perspectives).

7.3 Limitations and directions for future research

While this dissertation fills in some of the knowledge gaps related to the role of GIBs and their establishment and design, it has several limitations that could be addressed in future research.

First, this work would benefit from investigating the role of GIBs, or GIB like entities, in more countries, in particular in developing or emerging economies. Developers in these countries face additional barriers to financing stemming from, for example, increased political and currency exchange risks or the absence of an appropriate local banking and investment sector. Expanding this work to include developing country cases could bring insight into additional roles played by GIBs in mobilising finance.

Second, crowding out is often cited as a major concern and is used to argue against government intervention (via direct investment) into markets. Future work should therefore explore whether and how GIBs may have crowded out private finance, deriving specific implications for preventing this through policy design, monitoring and assessment processes.

Third, certain operational and design aspects of a GIB, such as how it is financed (e.g. via government budget allocations or access to capital markets) or it's performance criteria, may impact upon its approach towards taking risk, towards supporting innovative projects and its ability to mobilise private finance. Future work could therefore include an investigation into the extent and type of impact that certain key design and operational aspects could have upon a GIB's ability to address and bear risk, mobilise finance and support innovation.

Fourth, this dissertation utilised qualitative case studies to investigate the roles of GIBs in mobilising finance. A larger N quantitative analysis (using BNEF data or similar) could be performed to investigate to what extent GIBs fulfil some of these roles (e.g. to what extent GIBs act as first or early movers), whether any technology or finance trends exist and what factors may drive these roles. This could bring deeper insights to the qualitative findings in this dissertation.

Fifth, both neoclassical and evolutionary economics perspectives on finance and policy have been harnessed to derive insights about GIBs and their role in the transition. An additional perspective, the behavioural finance perspective (Shiller, 2003) could be employed to perform a deeper study on how GIBs address and impact upon investors' risk perceptions (Hall et al., 2015).

Finally there are several countries that are well placed to introduce a GIB. An exploration of the pre-parliamentary origins and history of GIBs, and an investigation of the groups or individuals that initially campaigned for the policy's introduction, could shed light on what might be required for a country to begin considering implementing such a tool.

Despite these limitations this dissertation has helped to fill a research gap by making contributions towards a better understanding of GIBs as a policy tool in mobilising finance for the energy transition. This contribution is relevant for policymakers of countries aiming to implement climate finance policies to operationalise the Paris Agreement.

8 Overview of the Papers

Table 2 lists the three papers that contribute to this dissertation including authors and the current journal publication or submission status. Full versions of these papers can be found at the end of this synopsis chapter. The submission status is relevant as of 12 September 2019 and all papers have either been published or submitted to a journal for peer review.

Table 2: Overview of authors and status of papers

No.	Title	Authors	Status
1	The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany	Anna Geddes, Tobias S. Schmidt, Bjarne Steffen	Published in *Energy Policy*, Volume 115, April 2018, Pages 158-170
2	Integrating finance into the Multi-Level Perspective: technology niche-finance regime interactions and financial policy interventions	Anna Geddes, Tobias S. Schmidt	Under review post resubmission to *Research Policy*
3	The politics of opportunity-oriented climate policy: an analysis of the political discourse behind establishing green investment banks	Anna Geddes, Nicolas Schmid, Tobias S. Schmidt, Bjarne Steffen	Submitted to *Energy Research & Social Science*

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Paper 1: The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany

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The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany

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ABSTRACT

Low-carbon energy technologies (renewable energy and energy efficiency) are considered essential to achieve climate change mitigation goals, so a rapid deployment is needed. However there is a significant financing gap and many policymakers are concerned that investment for the large-scale deployment of low-carbon technologies will not materialise quickly enough. State investment banks (SIBs) can play a key role in closing this finance gap and leverage additional private finance. Based on 52 interviews, this paper presents empirical evidence on the role of three SIBs in addressing the barriers to financing low-carbon energy projects; the Clean Energy Finance Corporation (CEFC) in Australia, the Kreditanstalt fuer Wiederaufbau (KfW) in Germany and the Green Investment Bank (GIB) in the UK. We investigate the activities and financial instruments offered by SIBs and compare these to the need for such from low-carbon developers when sourcing finance. Findings show that aside from capital provision and de-risking, SIBs take a much broader role in catalysing private investments into low-carbon investments, including enabling financial sector learning, creating trust for projects and taking a first or early mover role to help projects gain a track record.

1. Introduction

Mitigating climate change will require a rapid and significant transition of our energy system in order to reduce CO_2 emissions (IPCC, 2014). The development and deployment of new technology, especially of renewable energy and energy efficiency technology is considered key to this transition and so there is a need for policy to speed-up and redirect this technological change (Pizer and Popp, 2008; Schmidt et al., 2012). But there is a significant ‘financing gap’ for the low-carbon energy projects required to reduce global CO_2 emissions to target levels and many are concerned that investments for the large-scale diffusion of renewables will not materialise fast enough (IEA, 2014, 2016; IFC, 2010; SE4ALL, 2014). The International Energy Agency estimates annual global investments in low-carbon technologies will need to total USD 730 billion by 2035, more than doubling the 2015 figure of USD 290 billion, and will then need to reach over USD 1.6 trillion a year from 2030 to 2050 to meet global climate targets (IEA, 2014, 2016; Shlyakhtenko and La Rocca, 2012). However, public support and utilities’ balance sheets are currently constrained and, given the necessary scale of investment, new private finance is required (FS-UNEP and BNEF, 2016, 2017; GIBC, 2010; Mathews et al., 2010).

Although finance plays an important role along the entire innovation chain, it is especially downstream finance for commercialisation that is important for the rapid deployment of low-carbon technologies (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2015; Mazzucato and Semieniuk, 2017). While, due to innovation, the cost of low-carbon technologies has significantly fallen in recent years (Huenteler et al., 2015; Schmidt and Sewerin, 2017; Trancik et al., 2015), many projects are still perceived as risky by investors and are not financed (CPI, 2013; Hall et al., 2015; Jacobsson and Jacobsson, 2012; Jacobsson and Karltorp, 2013; Karltorp, 2015; Lang et al., 2015; Ondraczek et al., 2015; Sadorsky, 2012). The period post 2008 also saw a drop in low-carbon project investment activity in many countries due to the financial crisis and new reserve requirements for banks (IEA, 2009). Barriers to sourcing finance faced by developers differ by technology type, project size and context conditions (CPI, 2013; Hall et al., 2015; Kann, 2009; Polzin, 2017; Richards et al., 2012). Furthermore Waissbein et al. (2013) and Schmidt (2014) have shown that when the perceived investment risk is high the resulting increase in financing costs deteriorates the competitiveness of low-carbon vis-à-vis fossil fuel based projects. With many developers still facing barriers to sourcing finance the limited public finance that is available is being called on to leverage in private sector finance (Jacobsson and Jacobsson, 2012; Karltorp, 2015; Mathews et al., 2010; Schmidt, 2014; Steffen, 2017).

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In recognition of this issue, some governments have appointed state investment banks (SIBs) to close the financing gap and help green their economies. The UK's Green Investment Bank (GIB) and Australia's Clean Energy Finance Corporation (CEFC) were both founded in 2012 with government funding and a similar remit: to assist their country's transition towards a more sustainable economy by mobilising private sector capital into low-carbon energy projects (CEFC, 2016a; GIB, 2016b). Germany's Kreditanstalt fuer Wiederaufbau[1] (KfW), while originally established as the country's development bank, has also been very active in low-carbon energy financing (KfW, 2015a).

Recent work by the OECD reported that SIBs leverage private investment into green infrastructure (OECD, 2015, 2016, 2017). Other reports analysed models for the creation of green investment banks in light of receding government support (Berlin et al., 2012) and investigated the potential role of such banks in scaling up climate finance in emerging markets (NRDC, 2016). Mazzucato and Penna (2016) determined that SIBs 'shape and create' markets, rather than solely fix their failures and that KfW and BNDES[2] play a 'mission-oriented' role, making key investments in new sectors to address 'grand societal challenges', such as climate change (Mazzucato and Penna, 2015). More recently Mazzucato and Semieniuk (2017) found that public owned entities invested heavily in some high-risk renewable energy projects. However literature also discusses the concern that public financial intervention might crowd out private investment, which could lead to capital allocation inefficiencies[3] (Cumming and MacIntosh, 2006; Hall et al., 2015; Stiglitz, 1993).[4] More generally, Campiglio (2016) discusses the potential role of banking and monetary policy in expanding credit creation to finance the energy transition and Hall et al. (2016) examine how the industry structure of the banking sector can shape ownership structures and technology choices of energy transitions.

The literature to date falls under one of two categories; general public sector finance in energy transitions, or the general role of banking and finance in energy transitions. There is little empirical work on the role of SIBs specifically in overcoming barriers to mobilising finance. There is also an absence of detail on which instruments, channels and activities employed by SIBs have been effective and why, and little understanding of the mechanisms which allow SIBs to help mobilise private finance into the low-carbon energy sector. Our work in this paper aims to address this research gap by asking the research question: *What is the role of SIBs in addressing the barriers faced by low-carbon project developers in sourcing finance?*

To answer this question we investigate the instruments and activities supplied by SIBs and compare these to the actual demand for such from low-carbon energy developers in the context of the barriers they encounter in sourcing finance. We examine both how and how well SIBs address these barriers and in doing so we identify the roles taken by SIBs that successfully address developers' needs. We also investigate evidence for crowding-out and supply of inappropriate provisions. We present empirical evidence sourced from 52 interviews with 56 interviewees in Australia, Germany and the UK. With this work we aim to improve the understanding of the role of public finance in overcoming barriers to the energy transition.

The remainder of the paper is structured as follows: Section 2 introduces our cases, extending on the literature advanced in the introduction by presenting background to the three SIBs and their country contexts, and describes our method and data. In Section 3 we present and discuss our results, and we conclude with policy recommendations in Section 4.

2. Cases, methods and data

2.1. Case selection

Our study focuses on three cases from different industrialised countries with SIBs that are either primarily or heavily involved in financing low-carbon energy projects: Australia and the CEFC, Germany and the KfW Group and the UK and the GIB. The OECD (2015) reports on 13 'green' investment banks (GIBs) or GIB-like entities (such as funds) operating globally as of 2015. We selected the CEFC and GIB because they operate on a national level, perform more operations and activities than a fund and have a longer operating record (5 years). We excluded institutions from our study that operate solely as a fund, whose operating record is too short or that operate on a sub-national or regional level only. We include KfW in our study because, although not exclusively a 'green' state investment bank, it is mandated to support Germany's energy transition and was the biggest development bank investor in clean energy projects globally from 2007 to 2012 (Louw, 2013). Hence this case offers a large amount of empirical evidence to observe how SIBs address barriers to low-carbon finance.

In the following section we describe the policy context and financial sector background for each country and introduce background information to each bank. Table 1 provides renewable capacity and % total generation statistics for each country to indicate the relative level of development of each country's low-carbon sector. Table 2 summarizes each SIB's background information.

2.2. Australia and the Clean Energy Finance Corporation

2.2.1. Policy context

In contrast to the UK and Germany, Australia's low-carbon sector (beyond rooftop solar) remains in its infancy[5] (Table 1), with most technologies still considered to be new to the country and its actors, especially its financial system. Various context conditions have posed a challenge to sourcing finance for the deployment of low-carbon projects (Cheung and Davies, 2017; Kann, 2009; Nelson et al., 2013). Firstly electricity is generated in Australia under a fully commercial market-based system where historically developers have sourced power purchase agreements (PPAs) from commercial retailers (Kann, 2009). Secondly, apart from the Renewable Energy Target (RET) scheme,[6] there has been limited federal policy support for low-carbon technologies (Cheung and Davies, 2017; Talberg, 2013). Finally, long-term renewable energy and climate change policy uncertainty has been created through a lack of bipartisan support, on-going federal debate and policy change[7] (Cheung and Davies, 2017; Kann, 2009; Nelson et al., 2013, 2012). While policy uncertainty existed around Australia's RET, retailers were no longer prepared to enter into long-term PPAs. Financiers were then unwilling to fund such projects and investment in large-scale projects dropped 88 per cent in 2014 compared to the

[1] Translates to Reconstruction Credit Institute.

[2] The Brazilian Development Bank.

[3] Note there are various debates around public intervention in markets to support new technologies, including whether there is justification for any policy intervention at all, and around the level of specificity of such interventions in markets (Hall et al., 2015; Schmidt et al., 2016). Literature has extensively reported on a wide range of market failures (including structural barriers, information asymmetry, project finance markets differing to high frequency traded markets etc.) for low-carbon technology implementation and associated project finance markets, as well as co-ordination/ system failures, justifying policy intervention (Gillingham and Sweeney, 2010, 2012; Hall et al., 2015).

[4] In the context of SIBs 'crowding out' refers to public institutions investing in the place of private financiers, displacing and/or reducing private investment participation, and thus inhibiting the development of an effective and robust private sector market for financing (Cumming and MacIntosh, 2006).

[5] As of end 2014 there were only 5 operating large-scale (> 1 MW) solar PV plants, with a total installed capacity of 44 MW, well behind similar international markets (CEC, 2014, 2015).

[6] The Renewable Energy Target (RET) is a certificate-based scheme for large-scale renewables implemented in 2001.

[7] The country's carbon pricing scheme was repealed within 2 years of its launch by an incoming government (Taylor, 2014) and in 2012 and 2014 the same government reviewed and revised the RET scheme.

Table 1
Low-carbon energy statistics 2016[a].

	Australia		United Kingdom		Germany	
	Capacity GW	% total generation	Capacity GW	% total generation	Capacity GW	% total generation
Solar PV	5.6	3.2%	11.3	3.0%	41.0	6.0%
Offshore wind	0.0	0.0%	5.2	4.7%	4.1	1.9%
Onshore wind	4.3	5.3%	10.0	6.3%	45.6	10.0%
Waste-to-energy, bioenergy	0.8	1.5%	5.0	8.8%	9.3	7.0%
Total	10.7	10.0%	31.5	22.8%	100.0	24.9%

[a] Numbers based on AGEB (2017), BEIS (2017), CEC (2017) and IRENA (2017).

Table 2
SIB Background[a].

SIB Founding Year	CEFC 2012	GIB 2012	KfW 1948
Source of Capitalisation	AUD 10 billion (USD 7.9 bn) provided by Australian Government, the sole shareholder	GBP 3 billion (USD 3.9 bn) provided by UK Government, the sole shareholder (with a view to eventually giving the bank full access to capital markets in order to borrow freely)	EUR 3.75 billion equity (USD 4.4 bn) provided by German Federal (80%) & State (80%) shareholders EUR 72.8 billion (USD 85.9 bn) borrowed in 2016 from capital markets via government guaranteed bonds
Number of Staff as of end 2016	61	130	KfW Group: 4763 KfW IPEX: 657
Focus Sectors			
Solar PV	X		X
Onshore wind	X	X (from 2016)	X
Offshore wind		X	X
Waste-to-energy, bioenergy	X	X	X (until ca. 2014)
Energy efficiency	X	X	X
Small scale renewables	X	X	X
Financial instruments	• Debt (market rate, long-term) • Debt (concessional, limited to AUD 300 million (USD 237 mn) in NPV terms per year) • Equity (introduced after interviews) • Securitisation/ aggregation products • Guarantees (restricted to 5% uncommitted balance)	• Debt (market rate, long-term) • Debt (subordinated, mezzanine) • Equity (incl. bridging equity loans) • Securitisation/ aggregation products	• Debt (concessional, long-term) • Debt (market rate, long-term, for offshore wind, energy transition related R&D, SME & large corporate projects) • Equity (limited amount) • Grants • Guarantees/ insurance
Major finance channels	• Direct lending via co-investment/ syndication • On-lending via local intermediaries • 3rd party & own managed investment funds • Climate bond investment	• Direct lending/ investing via co-investment/ syndication • 3rd party & own managed equity and debt investment funds • Joint Venture	• On-lending via local intermediaries • Limited direct lending to municipalities and some large corporations • KfW IPEX: Direct lending/ investing via co-investment/ syndication
Example programs and funds	• Commercial on-bill financing program • Clean Energy Innovation Fund • Australian Bioenergy Fund (cornerstone investor)	• UK GIB Operating Offshore Wind Fund • Foresight UKWREI (UK Waste Resources and Energy Investments) Fund • Societe Generale Equipment Finance (SGEF) Partnership for energy efficiency	• Renewable Energy Program - Standard (Renewable electricity and small scale heat) • Energy Efficiency for the Housing Sector - Energy Efficient Construction and Rehabilitation program (EECR) • KfW Offshore Wind Energy Program • Energy Advice program for SMEs

[a] Data based on CEFC (2016a, 2016b), GIB (2016a, 2016b) and KfW (2015a, 2016b, 2017a, 2017b).

previous year (CEC, 2016; Talberg, 2013). Most low-carbon energy developers, OEMs and investors exited the Australian market entirely, only to start returning in late 2015.

2.2.2. Financial sector background

Australia's market-based financial system is mostly privately owned and is dominated by 4 main banks[8] with significant market power (RBA, 2006, 2017). Moreover, Australia's banking system is primarily funded by short-term deposits and short-term funding (Atkin and Cheung, 2017). Local lenders tend to offer short to mid-term loans of around 5 years that are unsuited to low-carbon projects with longer lifetimes. Developers have more successfully sourced finance from Europe and Asia where financiers display more comfort with low-carbon projects and are willing to offer longer-term finance.

2.2.3. CEFC background

CEFC was established in 2012 under a mandate to "mobilise and leverage the flow of funds for commercialisation and deployment of renewable energy, low-emissions and energy efficiency technologies necessary for Australia's transition to a lower carbon economy" (CEFC,

[8] Australia and New Zealand Banking Group, Commonwealth Bank, National Australia Bank and Westpac.

2016b). An independently operated government institution, it has a mandate to invest its AUD 10 billion[9] (USD 8.6 billion) on commercial terms similar to commercial banks and must compare its financial performance to a portfolio benchmark return based on the five-year Australian Government bond rate plus 4–5% (CEFC, 2016b). The CEFC provides capital to low-carbon projects and funds where it deems sufficient capital is not available and simultaneously aims to crowd-in private finance, targeting institutional investors, commercial banks and individuals for co-investment (Act104, 2012; CEFC, 2016a, 2016b). Since its launch an incoming government has twice tried to abolish the CEFC, both attempts of which were halted in the parliament (Taylor, 2014).

The CEFC focuses on large-scale solar PV, onshore wind, waste-to-energy, bioenergy, energy efficiency, small-scale renewables and low emissions vehicles[10] (see Table 2 for further SIB features). Fig. 1a shows a breakdown of the CEFC's investments by sector and technology type. As the CEFC is committed to investing on commercial terms, its main financing instrument is the provision of long-term fixed market rate debt. The CEFC supplies its financing through four main channels: direct investment in mostly large-scale projects, co-financing programs with credit intermediaries, own and third-party investment funds and green bond investment. As of end 2016 the CEFC has been involved in over 60 direct investments and is currently involved in 9 co-finance and aggregation programs (GBN, 2017). The CEFC has made AUD 3 billion (USD 2.6 billion) of cumulative investment commitments in a total of AUD 7 billion total (USD 6 billion) project value and, as of end 2016, every AUD 1 from the existing portfolio had helped catalyse AUD 2 from the private sector (GBN, 2017).

2.3. The UK and the Green Investment Bank

2.3.1. Policy context

Although more mature than the Australian low-carbon sector, the UK was considered more of a mid- to late-comer, until more recently catching up to Germany (see Table 1). In 2008 the UK became the first country to set a legally binding carbon reduction target into law agreeing to an ambitious 80% reduction in emissions by 2050, with an interim cut of 34% by 2020, from 1990 levels (CCA, 2008). The country has seen an increase in renewable energy support over the years, from certificate based schemes to feed-in tariffs and the more recent contracts for difference (CfD) auction scheme (DECC, 2011; Lilliestam et al., 2014). Changes in government and support policy[11] have seen many boom-bust cycles for renewables in the last 10–15 years as developers rush to connect plants before subsidy scheme deadlines are imposed (Bolton et al., 2016).

2.3.2. Financial sector background

The UK financial system is market-based, like Australia's, however it's banking sector is less concentrated and consists of a more diverse range of participants (Hall et al., 2016; Wójcik and MacDonald-Korth, 2015). Capital markets in the UK struggled to provide liquidity during and just after the global financial crisis of 2008, which, along with new reserve requirements on banks, contributed to the financing gap for projects. Markets didn't see capital availability improve again until 2011–2012[12] and by 2015 investors showed substantially more interest

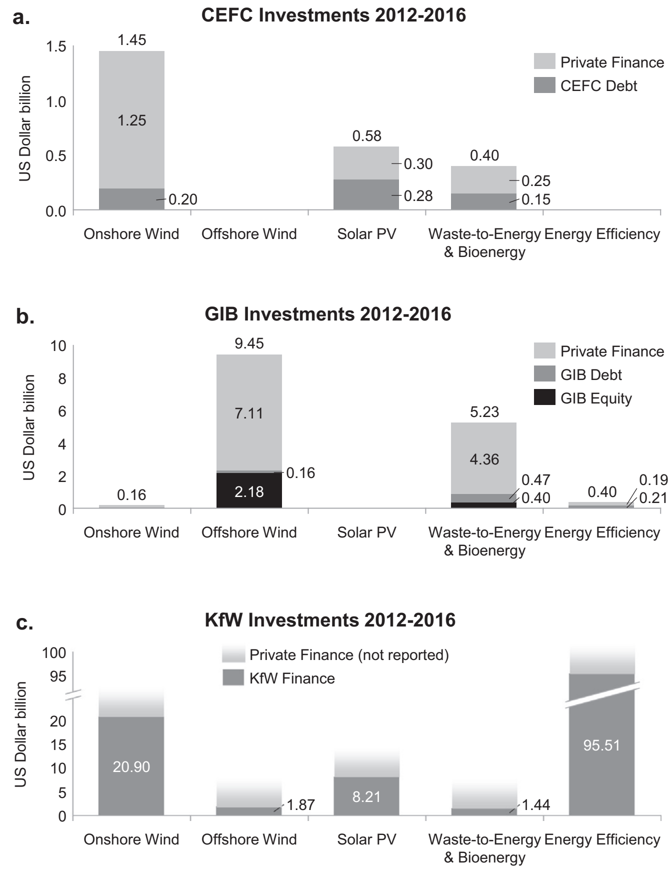

Fig. 1. *SIB Investments.* CEFC figure excludes low emission vehicles, community housing, green bonds and commitments not yet resulting in disbursement of funds, including energy efficiency funds. KfW figure excludes KfW IPEX offshore wind commitments and private finance leveraged not reported. Data based on CEFC (2013, 2014, 2015a, 2016a), summary of transactions in GIB (2016b) and KfW promotions reports KfW (2013, 2014, 2016a).

in low-carbon projects. Developers' and investors' biggest concern is that policy uncertainty is stalling investment.

2.3.3. GIB background

The UK's GIB was founded in 2012 to help the UK meet its emissions targets cost effectively by mobilising private finance into low-carbon projects (CCA, 2008; EAC, 2011; Holmes, 2013). The GIB is an independent, government owned[13] entity capitalised with GBP 3 billion (USD 4.6 billion). The GIB only invests on terms equivalent to those of commercial banks and must meet a minimum 3.5% annual return on investments before tax (EAC, 2011; OECD, 2015). In-line with EU state aid rules, EU commission approval of the GIB's establishment was made subject to it providing capital only to those projects and sectors where there is not considered sufficient private or commercial funding (EAC, 2011). Where possible the GIB aims to simultaneously crowd-in private finance to projects (EAC, 2011; GIB, 2016b).

The GIB's target sectors are offshore wind, waste-to-energy, bioenergy, energy efficiency and more recently onshore wind (see Fig. 1b). The bank provides a wider range of financial instruments than the

[9] Government supplied equity with AUD 2bn (USD 1.7bn) disbursed annually for 5 years.

[10] Out of scope for this study.

[11] Regular policy changes are often cited as a significant source of uncertainty for investors, contributing to the lack of required investment in renewables (Foxon et al., 2005).

[12] The two traditional lenders to UK project finance for medium to large-scale renewable projects (Lloyds and RBS) backed away from lending in response to the recession and then in 2014 many other European banks stopped providing 15-year commitments to renewable projects in response to the new reserve obligations via the Basel III requirements (Blyth et al., 2015). Developers and deal arrangers have observed Japanese banks, such as BTMU and SMBC, and French banks, such as Société Générale, become more actively re-engaged in the market and institutional investors are starting to invest in large scale solar PV and wind.

[13] The UK Government announced its intention to privatise the GIB in 2015 and in April 2017 its sale to a Macquarie Bank-led consortium was given approval under the condition the Government maintains a minority 'special share' in order to monitor the banks' green performance (Pickard, 2017).

CEFC, including long-term fixed market rate debt, mezzanine and subordinated debt, equity and bridging equity loans.[14] It disburses its finance through three main supply channels, including direct financing, co-financing partnership programs and own and third-party managed funds, financing 69 projects between 2012 and 2016 (GIB, 2016b). The GIB has committed GBP 2.1 billion (USD 3.2 billion) cumulative investment towards a total of GBP 8.5 billion (USD 13 billion) worth of project value, leveraging GBP 3 from the private sector for every GBP 1 invested by the GIB (GIB, 2016b).

2.4. Germany and the KfW group

2.4.1. Policy context

The German energy industry has been heavily shaped in recent decades by the Federal Government's Energiewende (energy transition), an initiative that aims to reduce the use of high-carbon and nuclear energy, and transition to a renewable and sustainable energy system (Lauber and Jacobsson, 2016; Morris and Pehnt, 2016). As of end 2016 Germany has a mature and established low-carbon energy sector (Table 1). Like the UK, Germany also has ambitious carbon reduction targets, aiming to reduce emissions by 40% by 2020 and by 80% by 2050 compared with 1990 levels. In order to reach these targets Germany's government has provided a very supportive environment for renewables and energy efficiency via technology specific feed-in-tariffs, priority feed-in and other complimentary support schemes (EEG, 2000; Lauber and Jacobsson, 2016; Lauber and Mez, 2006).

2.4.2. Financial sector background

Compared to the market-based financial sectors in the UK and Australia, Germany has a more bank-based sector characterised by an extensive network of over 1600 local banking institutions (compared to the UK's 162) (Hall et al., 2016; Wójcik and MacDonald-Korth, 2015). German developers experienced an investment gap when the capital sector struggled to provide liquidity for low-carbon projects during and just after the global financial recession of 2008 and with banks' subsequent new reserve requirements (Blyth et al., 2015). Developers described improvements around 2011–2012 and could access plenty of finance in the marketplace from early 2014. They also report that investors have become very knowledgeable and comfortable with low-carbon technology and its financing and that German banks in particular have become very competitive within all low-carbon sectors.

2.4.3. KfW background

KfW[15] was founded in 1948 as Germany's reconstruction and development bank and has supported the country's development in various ways since. Originally established with Marshall Funds, it is a AAA-rated institution and currently raises over 90% of its funds in capital markets through government-guaranteed bonds (KfW, 2015b, 2016b; Kraft, 2003; Mazzucato and Penna, 2015). Its shareholders, the Federal Government (80% share) and German States (20% share) together hold EUR 3.75 billion (USD 4.6 billion) of equity capital and it raised EUR 72.8 billion (USD 89 billion) from capital markets in 2016 (KfW, 2015b). KfW has most recently supported Germany's energy transition directly through its 'KfW Energy Turnaround Action Plan', implemented in 2012. However the bank has been active in environmental protection for many decades and invested heavily from 2005 to 2011 in renewables and energy efficiency (KfW, 2015a; Kraft, 2003; Louw, 2013).

KfW's low-carbon focus areas are energy efficiency, renewable energy (solar PV, wind, waste-to-energy & bioenergy) and energy-related innovation projects (see Fig. 1c and Table 2). Unlike the CEFC and GIB, KfW mostly provides standardised, fixed-rate concessional debt[16] through its domestic programs, which it channels through Germany's extensive network of local banks via on-lending (Carrington, 2012; Kraft, 2003).[17] It also offers guarantees, grants, up-front repayment-free periods, and a limited amount of equity and long-term market rate debt for large corporate projects. Domestically KfW IPEX[18] focuses on large-scale offshore and onshore wind and specialises in project finance offering a dedicated fixed market rate, long-term debt product. In the years 2012–2016, KfW launched EUR 103 billion (USD 126 billion) under the Energy Turnaround Action Plan (Poethig, 2017).

2.5. Methods and data

We undertook a qualitative case study design following the procedure of Eisenhardt (1989), iteratively collecting and analysing data on the three SIBs. Primary qualitative data has been collected through in-depth semi-structured interviews with low-carbon energy project developers, equity and debt providers, bankers (SIBs and commercial banks), and industry experts. To prevent bias we interviewed both developers who had and had not successfully engaged with SIBs. In total we performed 52 semi-structured interviews with a total of 56 interviewees from late 2015 to mid 2016, listed in Table 3. Interviewees[19] were found through searches of SIB websites, renewable energy associations, Internet searches and snowball sampling. All interviews were conducted under the "Chatham House Rule"[20] and hence no references to interviewees or their affiliations are made. Secondary qualitative data was sourced from publicly available literature on each bank and the projects they have undertaken.

Key themes within the data set were identified via a qualitative content analysis. To enable the analysis, interviews were recorded and transcribed. The primary and secondary data was then coded using the qualitative data analysis software MAXQDA12 and categorized into conceptual groups using a bottom-up iterative procedure. These categories were then abstracted to generate key themes. We then iteratively tested these themes with each successive interview, sourcing additional data when contradictions were encountered. We continued holding interviews until no additional thematic insights were observed (Eisenhardt, 1989). We then 'mapped' developers' demand for risk mitigation instruments or barrier removal against the supply of instruments and activities from SIBs. In this way we were able to determine how well SIBs addressed the needs of developers.

3. Results and discussion

The results of our evaluation on how and how well each SIB addresses the barriers faced by low-carbon developers are summarised in Fig. 2, Section 3.2. This figure shows the entirety of our results whereas we only describe below in detail the technology sectors that best illustrate the types of results seen in each country: Large-scale solar PV in Australia, wind and waste-to-energy and bioenergy in the UK and wind, solar PV, energy efficiency & small-scale renewables in Germany

[14] Short-term financing to allow completion of deals before longer-term financing is secured.

[15] For this work we investigated those business units and subsidiaries of the KfW Group that are active in the low-carbon energy sector domestically: KfW Mittelstandsbank, KfW Kommunal-und Privatkundenbank/ Kreditinstitute and KfW IPEX.

[16] KfW offers low lending rates (1–2% in 2012) due to KfW's top credit rating plus further government subsidy of the interest rate.

[17] Rather than investing directly, KfW mostly channels its standardised financial products through Germany's extensive network of local banks via on-lending. KfW IPEX however does lend directly to its large-scale projects, usually acting as the lead investor in a syndicate. KfW has a wide range of programs that are part of KfW's Energy Turnaround Action Plan, under which it provides finance to the low-carbon sector (see examples in Table 2).

[18] We refer to KfW IPEX when specifically discussing the subsidiary's activities. KfW IPEX occasionally disburses equity on behalf of KfW.

[19] All interviewees were initially contacted via e-mail. Approximately 85% of interviews were conducted via Skype or telephone and 15% conducted in-person. Interviews lasted from between 30 min and 90 min with the average interview taking 60 min.

[20] When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.

Table 3
Interview Sample.

Category		Organisation[a]	Technology Focus[b]	Country[c]	Interviewee's Role
Developer	**1**	Project Developer	Wind, Solar PV	AU	Head of Business Development
	2	Project Developer	WtE	AU	Chief Executive Officer
	3	Project Developer	WtE	AU	Managing Director
	4	Project Developer	WtE	AU	Managing Director
	5	Project Developer	Bioenergy, WtE	GB	Independent developer
	6	Project Developer	Wind, Bioenergy	GB	Managing Director
	7	Project Developer	WtE	GB	Managing Director
	8	EPC, OEM	Wind, Solar PV	AU	Business Development Manager
	9	IPP	Wind	AU	Executive General Manager
	10	IPP	Wind, Hydro	AU	Executive Manager, Development
	11	IPP	Renewables	AU, GB, DE	Chief Financial Officer
	12	IPP	Solar PV	DE	Project Developer
	13	IPP	Bioenergy	GB, DE	Independent developer
	14	IPP	Wind, Solar PV	GB, DE	Manager, ESG
	15	IPP	Wind, Solar PV	GB, DE	Executive General Manager
	16	IPP	WtE, Bioenergy	GB, DE	Head of Origination
	17	OEM	Wind, Solar PV	AU	Head Structured Finance
	18	OEM	Small-scale wind	AU, GB, DE	General Manager
	19	OEM	Renewables	AU, GB, DE	Sales Manager, Renewables
	20	OEM	Renewables	AU, GB, DE	Senior VP Project Development
	21	OEM	Wind	GB, DE	Senior Investment Manager
	22	Utility	Renewables, FFs	DE	Managing Director
	23	Utility	Renewables, FFs	DE	Head Business Development
	24	Utility	Wind, Solar PV	GB, DE	Business Development Manager
	25	Utility	Wind, Solar PV	GB, DE	Managing Director
Investor	**26**	Commercial Bank	Renewables, FFs	AU	Executive General Manager
	27	Commercial Bank	Renewables, FFs	AU	Senior Consultant
	28	Commercial Bank	Renewables, FFs	AU, GB, DE	Director Corporate Clients
	29	Commercial Bank	Renewables, FFs	AU, GB, DE	Consultant, Green Banking Expert
	30	Commercial Bank	Renewables, FFs	GB, DE	Consultant, Innovative Finance
	31	Gov't funding entity	Renewables	AU	Transactions and Development
	32	Green Bank	Renewables	GB, DE	Relationship Manager, Arranger
	33	Invest. Advisors	Renewables	AU	Principal Financial Advisor
	34	OEM investors	Renewables, FFs	AU, GB, DE	Managing Director
	35	Invest. platform	Renewables	GB	Managing Director
	36	SIB	Renewables, EE	AU	Division Director
	37	SIB	Renewables, EE	AU	Researcher
	38	SIB	Renewables, EE	AU	Department Director
	39	SIB	Renewables, EE	AU	Associate Director
	40	SIB	Renewables, FFs	DE	Department Director
	41	SIB	Renewables, EE	GB	Department Head
	42	SIB	Renewables, FFs	GB, DE	Investment Officer
	43	SIB	Renewables, FFs	GB, DE	Project Assessor
	44	SIB	Wind, Renewables	GB, DE	Team Head, Wind Power
	45	Sustainable Bank	Renewables	GB, DE	Chief Financial Officer
	46	VC Investor	Renewables, FFs	AU, GB, DE	Director
Expert[d]	**47**	Consultancy	Renewables	AU, GB, DE	Arranger, Due Diligence
	48	Consultancy	Renewables, FFs	GB, DE	Associate Principal, Energy
	49	Consultancy	Wind	GB, DE	Senior Consultant, Power Market
	50	Consultancy	Wind	GB, DE	Partner, Energy and Resources
	51	Energy Think-tank	Renewables	GB	Director, Finance, Energy Policy
	52	Envir. Consultancy	Renewables, FFs	GB, DE	Principal Consultant
	53	Envir. NGO	Renewables, FFs	AU, GB, DE	Director of Strategy and Finance
	54	Legal Consultancy	Renewables	AU	Partner, Project Finance, Energy
	55	Legal Consultancy	Renewables	AU	Senior Associate, Project Finance
	56	Legal Consultancy	Renewables	AU, GB, DE	Partner, Arranger

[a] IPP: Independent Power Producer, OEM: Original Equipment Manufacturer, EPC: Engineering, Procurement and Construction.
[b] WtE: Waste-to-energy, EE: Energy Efficiency, FFs: Fossil Fuel based power generation.
[c] AU: Australia, GB: The United Kingdom, DE: Germany.
[d] Experts include deal arrangers, due diligence experts and expert consultants. These are interviewees who work closely with SIBs or are heavily involved in the development process.

(remaining technologies can be found in the Appendix). A summary of the results is followed by a discussion of SIBs' key roles.

3.1. How do SIBs address barriers to finance?

3.1.1. Australian large-scale solar PV developers and the CEFC

Australian large-scale solar PV project developers identified four main barriers to sourcing finance. Firstly, in recent years, revenue uncertainty due to a lack of long-term power purchase agreements (PPAs) has been an issue. This is a result of policy uncertainty that occurred during the reset of the RET such that projects now face full or part merchant exposure: that is, they must sell their generated electricity onto a merchant power market at uncertain prices rather than deliver via pre-agreed prices under PPAs. As one developer reported *'in Australia it is very, very tough to get a PPA, and without a long-term PPA the commercial banks won't fund your project'*. The CEFC has provided long-term market rate debt to projects that have part or full merchant exposure to both address the debt gap and to create a track record for the

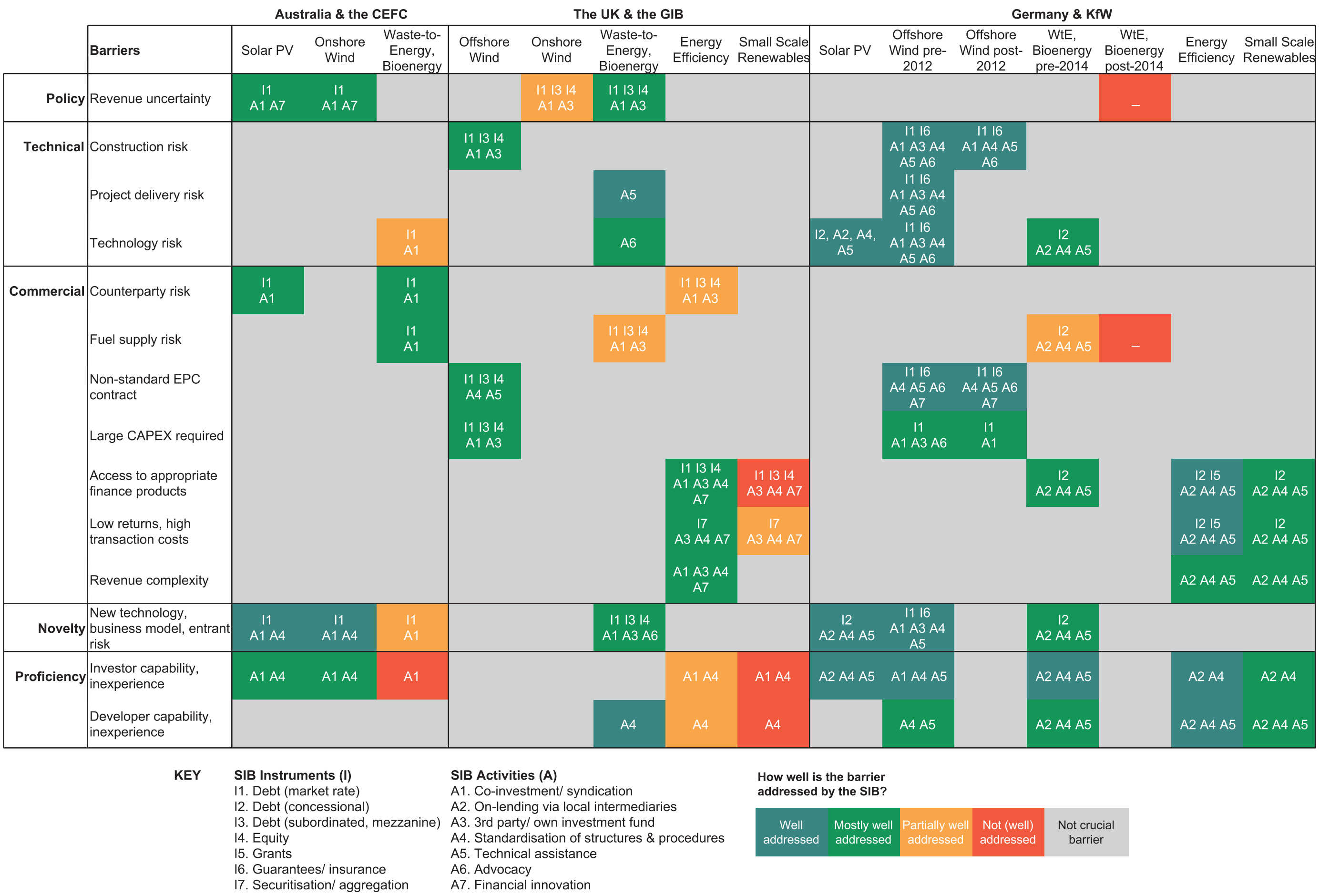

Fig. 2. *Summary of Results.* The crucial barriers to sourcing finance for developers are listed on the left-hand side of the figure, grouped into categories. The letters and numbers denote the instruments and activities supplied by the SIBs and the colour scheme represents how well the barrier is addressed by the SIB.

industry, showing banks and investors that projects displaying this risk can be successfully developed. The CEFC has also been working with developers and investors on an innovative loan product that would reduce the merchant exposure to a project, taking advantage of high power prices by charging higher interest rates into a reserve account and then lower rates if prices dropped. This is a direct result of the CEFC having developed specialist internal capabilities, having a good understanding of the risks involved in developing projects, and then leveraging these strengths to create innovative financial products.

Secondly there are other issues unique to Australian projects that increase the off-take counterparty risk, even for projects with long term PPAs. For instance, one solar PV-diesel hybrid plant developer was unable to arrange debt funding even while holding a long-term PPA, because the counterparty, a long-life mine, was located in a very remote location. The developer reported that *'if our counterparty fails, we can't evacuate our electricity to someone else. We would literally have to pick up our panels and move them thousands of kilometres to find another customer. The banks were not interested'*. This project, the first of its kind in Australia, was successfully developed with CEFC debt funding and now other remote businesses are initiating projects with similar settings.

Thirdly projects displaying new technologies, new business or income models and new entrants, such as first-time developers or equipment suppliers, have been unable to source finance in Australia due to the lack of a track record, something investors require. The CEFC has repeatedly taken the first or early mover role for new project settings. The CEFC agreed to debt fund one of the very first large-scale PV plants, which was also unable to source a long-term PPA, hence acting as an early mover both in terms of technology type and scale as well as in terms of project business model.[21] The CEFC also generates trust and increases legitimacy for new project settings. The bank announced its intention to provide debt to a world-first project featuring new technology combinations[22] in a remote desert location and developed by a family-owned company with little full-scale development experience. Having unsuccessfully tried to source bank debt for over a year, the CEFC announcement enabled the developer to attract equity and in turn an oversubscription of debt on even better terms than those offered by the CEFC. The CEFC funding was no longer required and the project was successfully developed without government funding. The mere announcement of the presence of the CEFC in a project 'signals' trust in a project and previously disinterested investors crowd-in.

Finally, due to the immaturity of the sector, Australia's investors are less experienced. By financing these projects and ensuring they are successfully developed, the CEFC is educating investors and helping them to become familiar with risks so they are more likely to fund projects in the future.

3.1.2. UK offshore wind developers and the GIB

UK offshore wind developers identified three main barriers to sourcing finance. The first concerns difficulty in sourcing enough funding, given the sheer scale of investment required. Secondly,

[21] New business model in this case refers to a business model that displays partial merchant market exposure. Previously business models featured no merchant market exposure due to having PPAs for the entire life of the project.

[22] Concentrated solar panels to desalinate water with cooling and heating systems for hydroponic agricultural greenhouses.

sourcing early stage finance from investors willing to accept higher construction risks is also a challenge. These construction risks arise from the technological and logistical challenges faced during construction in a hostile deep-water marine environment. A third barrier is the non-standard engineering, procurement and construction (EPC) contracting structures, compared to other infrastructure projects. The GIB has directly financed the construction of wind farms via equity and debt, simultaneously helping to fill the funding gap while showing a willingness to accept higher construction stage risks and non-standard EPC structures. Secondly, by providing equity,[23] the GIB has been able to attract cheaper private debt into the earlier construction stage of a wind farm project. This was the first of its kind in terms of the project financing structure and two other wind farms have since been financed in a similar fashion.

Developers also reported that the activities of the GIB Offshore Wind Fund were valuable in indirectly addressing the above issues. The Fund is the first of its kind to provide refinancing for operating offshore wind projects. Long-term institutional investors have a larger appetite to lend to operational projects, rather than to the higher-risk construction phase. The GIB Offshore Wind Fund crowds-in these investors to refinance operational wind farms, in turn freeing up capital from project developers and other early-stage investors with greater risk appetites so they can re-invest in the higher risk development and construction stage of projects. As one expert said, *'that fund really helps the (high risk) investors to recycle their capital…and there are lots of big pension funds… that really want to take a piece of that (operating wind projects)'*. Developers would like to see the GIB address construction risks more directly by supplying guarantees to help address the constant technological and logistical innovation that still occurs during the construction phase.

3.1.3. UK waste-to-energy and bioenergy developers and the GIB

Waste-to-energy (WtE) and bioenergy developers reported six major barriers to sourcing finance. Firstly, revenue uncertainty is a great issue with the sector experiencing changes to support level and scheme design.[24] Two additional issues exacerbate this policy-induced revenue uncertainty. Interviewees agree that many developers in this sector do not have the capabilities and experience required, also re-enforcing a third barrier, an increased risk in delivering projects successfully, especially under the tight deadlines imposed due to scheme changes. There can be a mismatch between what a smaller, inexperienced developer thinks is *'construction-ready'* versus what an investor thinks, and many developers do not achieve the due diligence level needed before a financier will commit funds. This is where the GIB played a key role, with the bank bringing its expertise to help developers meet their due diligence requirements in order to reach financial close, addressing the three barriers simultaneously. Interviewees reported that the GIB hired people with extensive experience from within the industry who are very familiar with project risks, engaged specialist funds, and put more manhours into each deal than private institutions. As one developer put it *'the Green Investment Bank helps to come in and close these projects. I cannot emphasize how important it was for a lot of biomass and waste projects, because of the support deadlines…they were so strong'*.

Fourthly, many technologies, and developers, need to gain a better track record in the sector before they can attract finance. The GIB has taken a role as a first mover, investing in a successful biomass gasification project developed by a new, inexperienced developer who also utilised a new type of fuel. Once the first project was implemented, the developer was able to attract capital with ease for subsequent projects. As with the CEFC, biomass gasification developers found that when the GIB announced (signalled) they would finance a project, banks were soon competing to provide debt. As one investor reported, *'banking is about perception and perceived comfort with risks and if the Green Investment Bank has said that it's good then it's good. It is a huge deal'*.

Fifthly, investors still perceive certain technology risks as being too high. Some original equipment manufacturers (OEMs) in the waste-to-energy gasification sector were not providing guarantees on their specialised feed processing equipment; something that investors had indicated was necessary in order to more readily provide finance. The GIB actively lobbied these OEMs, who now provide such guarantees, essentially de-risking projects and making them more attractive to investors. Interviewees reported that the bank was instrumental in ensuring the guarantees were provided as a standard. Finally, developers report that investors still show concern around fuel supply risks and would like to see the GIB provide insurance or guarantees for fuel supplies. Developers cannot get feedstock contracts from forestry or farms for more than a few years and need longer contracts to source finance.

Finally although developers appreciated the general flexibility of the GIB in being able to offer both equity and debt type products, some biomass developers and sponsors reported that the GIB was willing to offer only equity in certain projects where they preferred debt. The developers and sponsors wanted to maintain ownership of such projects and saw this as crowding-out, given that they already had the capacity to maintain equity in such projects.

3.1.4. German wind developers and KfW

In the early days of Germany's offshore wind industry (prior to 2012), projects displayed a wide range of high risks and barriers to financing.[25] Projects exhibited high technology risks, and a lack of technical expertise and experience intensified construction and project delivery risks. High upfront capital costs and non-standard EPC contracts also proved to be barriers to sourcing finance. It was difficult to identify, assess and mitigate risks and developers found it very challenging to source finance. KfW IPEX recognised the expertise gap in the industry early and addressed this in several ways. It provided technical and risk advisory services in the industry as far back as 2004, having engaged its own internal engineers specialising in offshore wind projects to become familiar with the associated risks. KfW IPEX[26] invested in Germany's very first offshore wind farm commissioned in 2010 and has invested in every project since, working closely with developers and insurers to develop better contingency structures around the unique project delivery conditions. The bank requested early stage due diligence processes that helped developers, and investors, to better understand risks. OEMs report that KfW staff actively visit sites and investigate innovative technology to develop their expertise. As one developer said *'KfW know renewable energy inside out…they have a real technical grounding in understanding how renewable energy works'*.

It was not just developers who benefited from KfW IPEX's technical expertise. Banks especially had a lack of knowledge and KfW IPEX regularly took the lead role in syndicates, helping to educate participating banks on the risks involved. Interviewees described KfW IPEX as 'a real opinion leader' where they are known to be *'the technical bank'* in any consortium. IPEX's due diligence processes, risk assessments and registers are considered throughout the industry to be *'technically*

[23] Many investors and developers state that providing equity or other higher risk capital (mezzanine, sub-ordinated debt) sends a stronger de-risking signal to the market and helps crowd-in additional finance.

[24] For example in moving from ROCs to CfDs.

[25] Early projects saw vast delays and budget overruns due to the myriad construction and project delivery risks not being adequately addressed, such as wave heights causing delays, insolvencies during construction and inexperience with the non-standard EPC contracting setups.

[26] Before banks had become comfortable with the risks around offshore wind and developers were struggling to source the necessarily large volumes of finance, KfW IPEX recognised the huge funding gap at that time (2004–2012) and submitted a proposal to the KfW Group, requesting assistance to provide the additional funds. KfW responded by creating the KfW Offshore Wind Energy Programme, which supplied market rate debt for filling the financing gap in offshore wind projects. This in turn helped to bring in new private investors who saw this as a further de-risking signal for offshore wind projects.

excellent and accurate'. They then bring these processes and knowledge to other investors, helping them to become familiar with the risks.

Today Germany's offshore wind developers face similar issues as UK developers[27] however they report that they no longer struggle to source finance as they once did. Many developers said that KfW was no longer essential[28] in their industry with one saying *'are they even needed anyway to finance these projects now? Haven't they done their job already by sending those early signals?'*.

3.1.5. German large-scale solar PV developers and KfW

Germany's large-scale solar PV industry was still seen as an innovative prior to 2005, displaying higher technology risk and much higher costs than those seen today and investors, especially banks, were not familiar with the risks nor willing to invest. To address these barriers, KfW offered developers concessional fixed-rate, long-term debt via on-lending programs through local banks. The local bank is awarded a fee for 'originating' the deal and can choose to take a portion of the loan onto its own books, essentially risk-sharing the project with KfW. In addition, KfW provides standardised project risk assessment profiles and due diligence processes for the local banks to follow when considering whether to lend to a project. This simultaneously allows KfW to access local banks clients more easily, developers to receive cheaper debt while local banks familiarise themselves with the risks of projects. Developers reported that the concessional debt combined with the fixed-rate gave more favourable terms than the variable rates offered by banks and helped keep down capital costs. They report that from 2013 to 2016 there has been no lack of either debt or equity in the market and the costs for both have dropped. They also report that German banks are now so experienced at investing in solar PV that the market place has become very competitive. However they concede that concessional rates are no longer essential for the industry and may in fact start to crowd-out private finance.

3.1.6. German energy efficiency and small-scale renewables developers and KfW

Developers of both energy efficiency and small-scale renewables face similar barriers to sourcing finance.[29] Projects display low returns and high transaction costs compared to larger scale projects. Both investors and developers can lack experience and capability in terms of understanding project benefits and there can be some complexity in accurately pricing projects and their revenue streams. In addition there is usually a lack of appropriate fit-for-purpose finance products in the market. KfW addressed these barriers by harnessing the local banking network to channel its concessional debt products, and by providing grants for homeowners that were easily accessible on-line. These provisions allowed a very wide range of smaller to mid-sized beneficiaries, including individuals, co-operatives, SMEs and public authorities, to easily access a local supply of affordable and appropriately sized and structured finance. Utilising these local banks and an on-line portal to undertake transactions reduces transaction costs for KfW and standardised risk assessments and due diligence processes reduce transaction costs for the local bank, whilst they simultaneously become familiar with the risks involved. Inexperienced energy efficiency developers were also aided by KfW's advisory and technical support programs including the Energy Advice program that supports SMEs to work with external independently accredited experts for advice.

[27] They require large scales of finance especially for the riskier construction phase displaying non-standard EPC contracts.

[28] Developers report that private investors offer them better and more flexible terms and that dealing with a syndicate involving a state investment bank like KfW often *'takes too long'*.

[29] We have grouped these sectors together here because they face some similar barriers in sourcing finance although we recognise that from both a technology and financing point of view they are different.

3.2. How well do SIBs address barriers to finance?

A summary of our results showing how and how well the three SIBs address the barriers faced by low-carbon energy developers in sourcing finance is shown in Fig. 2.

For large-scale solar PV and onshore wind the CEFC has addressed barriers to financing projects well by providing long-term debt financing to projects displaying revenue uncertainty, counterparty risk (solar PV) and risks involved with introducing novelty to projects.[30] But developers agree that provision of equity or higher risk debt by the CEFC would better assist in addressing revenue uncertainty, something the CEFC does not (yet) supply. Waste-to-energy and biomass developers' needs are not as well met, with smaller developers calling for better access to a wider range of capital products including equity and subordinated debt. Although the CEFC has provided long-term debt finance to projects displaying various risks that commercial banks have declined to finance (counterparty and fuel supply risks), the CEFC isn't addressing technology risk well. Some developers also felt that the CEFC wasn't as experienced or as capable of assessing risks around waste-to-energy & biomass projects as the UK's GIB who is considered to be excellent in this field[31] and that greater education of the investment sector is needed.[32]

The GIB's provision of market-rate and subordinated debt and equity for wind farm construction in conjunction with the finance recycling activities[33] of the GIB Offshore Wind Fund have addressed the range of risks and barriers to financing (construction and new technology risks, non-standard EPC and large capital expenditure barriers) for UK offshore wind farm development mostly well. Developers would like to see the GIB address construction risks more directly by supplying guarantees. Biomass and waste-to-energy project barriers and risks have been addressed well by the GIB, via technical support, the provision of a wide range of financial instruments and successful lobbying for technology guarantees. Provision of an insurance or guarantee type product would help address the remaining fuel supply risks. For energy efficiency, the GIB has managed to address a range of barriers and risks mostly well by using its highly skilled personnel and specialist funds to help set up, package and standardise structurally complex deals and aggregation and securitisation products. However developers are calling for a counterparty risk guarantee product and greater technical assistance to address the lack of capabilities. While the GIB has partially met some of the needs of small-scale waste-to-energy and bioenergy projects it has not had a significant impact on addressing barriers to finance among other small-scale projects.

As Fig. 2 shows KfW has supported a wider range of technology sectors than the CEFC and GIB and has addressed many of the barriers well or mostly well. The bank addressed a wide range of high risks and barriers faced by offshore wind developers in the early days of the industry well, leveraging on its technical expertise. Solar PV and early stage waste-to-energy and bioenergy project risks and barriers were also well addressed by KfW, thanks to its provision of concessional, fixed rate, long-term debt via on-lending programs through local banks. However today's waste-to-energy and biomass developers face revenue uncertainty (due to reducing policy support) and fuel supply risks and,

[30] Novelty risk can refer to new technology, new business model and new entrant risks.

[31] While we were completing interviews for this work the CEFC announced the formation of the Australian Bioenergy Fund with the specialist fund manager, Foresight, who has had previous success in this sector in the UK with the GIB (CEFC, 2015b).

[32] At the time we performed this investigation the CEFC had not been very active in the energy efficiency and small-scale renewables sectors. It has since launched a range of funds and programs that involve co-lending with local credit institutions in order to make the funding more accessible to a wider range of beneficiaries as well as providing aggregation and securitisation products to help overcome investors' aversion to the low income, high transaction costs of these projects.

[33] The Fund crowds-in investors to refinance operational wind farms, in turn freeing up capital from project developers and other early-stage investors with greater risk appetites, so they can re-invest in the higher risk development and construction stage of projects.

because the German Government sees these sectors as less sustainable methods for energy production, developers receive much reduced KfW support. Finally, providing concessional finance via on-lending through local banks, offering grants via an on-line portal, and advisory and technical support allowed KfW to address barriers around sourcing finance for energy efficiency and small-scale renewable projects well.

3.3. Synthesis: the roles SIBs take to successfully address barriers to finance

By iteratively analysing and classifying key emergent 'themes' from our interviews, and systematically comparing these across each case and interview, we abstracted five pre-dominant roles taken by SIBs who successfully address barriers faced by developers sourcing finance.[34] We define a role as the function (based on observations of its activities in the market) an SIB assumes in order to catalyse finance for low-carbon projects.

3.3.1. Capital provision role

By taking a capital provision role, SIBs have successfully addressed investment gaps for projects with very large upfront capital costs as well as gaps that arose owing to reduced global and local investment activity due to the financial crisis (see 3.1.2 and 3.1.4). This finding substantiates work by Mazzucato and Penna (2016) that SIBs can successfully take a countercyclical role during times of economic downturn and supports the concept that public finance can help address structural barriers such as those around very high capital cost projects (Hall et al., 2015).

3.3.2. De-risking role

SIBs use their limited capital to also perform a de-risking role to mobilise private capital into low-carbon projects. Risk has a significant impact on financing costs and also plays an important role in determining whether a project is financed. There are distinct differences in the de-risking instruments these three SIBs have at their disposal. Whereas Germany's KfW maintains that a combination of concessional finance (e.g. 1–2% interest rates for energy efficiency improvements to households) and guarantees are the pillar of de-risking projects and mobilising private finance (Enting, 2013), the CEFC and GIB take a different route, where it is argued that providing de-risking instruments and capital at commercial terms sends a greater de-risking signal to investors that the projects they invest in are 'commercial' ready and bankable (see 3.1.1, 3.1.5 and 3.1.6. In addition, the wider range of instruments provided by GIB and the flexibility it shows in offering them is well suited to different developer types and their changing needs. Although the instruments on offer differ, all three SIBs have had major impacts through de-risking while taking on higher risk projects, indicating that the observations of Schmidt (2014) in developing countries also apply to OECD countries for new technologies.

3.3.3. Educational role

A third key role of SIBs relates to education, both internal to the SIB itself and external, of developers and financiers (see 3.1.3 and 3.1.4). SIBs foster specialist internal expertise, in order to better assess risks, create and standardise innovative de-risking instruments and then diffuse this new knowledge throughout the industry. Developers and investors repeatedly reported that SIBs actively employ highly qualified people so that they are specialists both financially (bankers and financiers) and technically (technology specialists and in-house engineers). SIBs also actively develop their internal capabilities[35] in areas where they may lack experience and knowledge. SIBs then harness their specialist internal capabilities to achieve several outcomes. Firstly they can focus on more accurately assessing the risks of (especially new and unproven) low-carbon energy projects and are known to spend more man-hours on transactions than commercial banks in order to do so. They apply their expertise to structuring investment deals in order to ensure the division of risk is spread in such a way that those involved are comfortable and ensuring risk is priced correctly, reducing the cost of capital. Secondly the SIBs and their specialist teams also innovate and standardise, creating new de-risking products, contractual structures and procedures in order to help projects become bankable. Then, in conjunction with technical assistance, SIBs can educate and support investors and developers by diffusing knowledge throughout the sector; helping investors better assess risk and become familiar with new projects while supporting developers with due diligence in order to reach financial close. The various activities captured under this education role heavily overlap and are interdependent.[36] Although the value of technical assistance provided by SIBs has been mentioned in the literature (Cochran et al., 2014) our findings highlight that an SIB's educational role takes many forms and that its importance and impacts have been previously underestimated.

3.3.4. Signalling role

SIBs have mandates to co-finance the majority of their larger-scale projects, ensuring they are not the sole debt or equity provider; they must directly 'crowd-in' additional finance. Where an SIB has successfully developed a reputation for expertise, there is an understanding within the investment community that the SIB's decisions to invest are worthy of trust. Hence when SIBs 'signal' they will participate in a project, soon after previously disinterested investors commit funding, sometimes even leading to an oversubscription of finance to that project that can lead to the exclusion of the SIB itself (see 3.1.1). An SIB's signalling role to directly crowd-in investors (based on its expertise and ability to create trust) has not been recognised in the previous literature. This trust generating and signalling role is especially powerful when an SIB also acts as a first or early mover in a project and is then able to bring private finance to projects containing novelty or innovation.

3.3.5. First or early mover role

Finally, SIBs are seen taking the risky role of 'first or early mover', investing in projects that in some way are among the first of their kind or contain some sort of novelty or innovation that is new to a country or its actors, such as a new technology, business model or a new entrant, such as a first-time developer or equipment supplier (see Sections 3.1.1 and 3.1.3 for examples). Debt providers in particular are risk averse and rarely adopt the role of first mover, preferring to see ample evidence of a track record before they will invest with one developer saying *'investment doesn't usually lead, it follows'*. When SIBs are a first or early mover in these projects, they do so to demonstrate a track record that shows the project can be developed successfully. As opposed to the signalling role, which crowds-in *directly* to a project, the first or early mover role only crowds-in private investment to *subsequent future projects*, having already established a track record. A demonstration role taken by some SIBs has been mentioned by Cochran et al. (2014) but in general the tendency of SIBs to take a first or early mover role, the subsequent crowding-in effect and the positive impact upon innovation diffusion has not been well acknowledged in previous work.

[34] This analysis and abstraction process compares to the Shaping Hypotheses step of Eisenhardt (1989).

[35] SIBs visit project sites to inspect new technologies, regularly interact with key stakeholders, join informal collaborations, such as the Green Bank Network and take part in SIB staff exchanges to share knowledge.

[36] SIBs work to diffuse both explicit and tacit knowledge to investors and developers. Standardisation allows the diffusion of explicit or codified knowledge (knowledge that can be precisely articulated and is easily communicated via written or verbal format) whereas technical assistance and other more demonstrative assistance allows the diffusion of tacit knowledge (knowledge that is more intuitive and experience based and is difficult to communicate via written or even verbal methods; it is more based on action and involvement) (Smith, 2001).

4. Conclusions and policy implications

As the study clearly shows SIBs are important actors in addressing the low-carbon financing gap in Australia, the UK and Germany. They *provide capital* and perform *de-risking*, but also go far beyond these activities. They take an *educational role*, building and developing their own capabilities in order to better identify, assess and mitigate risk. In doing this they create and standardise new knowledge with the dual aims to enable financial sector learning and support developers. Drawing on their reputation for expertise, SIBs also perform a *trust creation and signalling role* where their decision to support a project has a labelling effect and their presence directly crowds-in additional finance. Finally, leveraging on their capabilities and de-risking instruments to assess, take and manage risks, SIBs perform a *first or early mover role* by supporting risky innovative projects to create a track record which indirectly crowds-in private finance to future projects. In particular this work brings a spotlight onto the previously unrecognised *trust generation and signalling role* and emphasises the importance and impact of the *educational* and *first or early mover* roles, which are too often overlooked in previous work on SIBs.

Those policymakers considering following Australia, the UK and Germany in appointing a ‘green’ SIB to catalyse finance into low-carbon energy projects would need to consider a range of factors that can impact upon the roles an SIB performs. An SIB's mandate (e.g. technology focus areas, performance criteria, allowed de-risking instruments, conservatism of investment mandate etc.) has an impact, directing where an SIB provides its capital and how well it is able to perform de-risking. The set-up of a country's financial and banking system and how an SIB interacts with it affects both the type and size of project that can be financed, and how an SIB can diffuse new knowledge and educate its finance sector. Finally the source and amount by which an SIB is capitalised may limit the impact it can have in terms of mobilising capital, the width of its investment scope, and may impact upon its approach to risk.

Policy makers also need to consider the balance between public and private investment. Our work generally showed that KfW's provisions have played a part in making domestic wind and solar PV mature, to the point where private investors provide capital at low cost. Hence there is a question as to whether KfW is still necessary given the more mature stage of these markets and that it may be crowding-out[37] private finance. Offering inappropriate provisions, such as in the case of GIB offering equity to certain biomass developers and sponsors, who wanted to maintain equity ownership control of projects but needed debt, can also be seen as a type of crowding out (if the offerings are accepted). Our empirical evidence suggests that at earlier phases of a low-carbon technology's deployment, SIB provisions have not led to major crowding-out. However, to prevent this, if an SIB is deemed successful, such as KfW in Germany's solar PV and wind sectors, then its interventions need to be well designed in order to trigger an appropriate phase-out strategy (compare Rodrik (2014); Stiglitz (1993)).

Policymakers can think of SIBs as a key policy component within a country's overall energy policy mix. The German case indicates that KfW's widespread financing, in conjunction with policy support, was influential for the country's advanced stage of low-carbon sector development. Support schemes for renewables do not necessarily address all the barriers to financing projects. In the early phase of a technology's development in a country, feed-in tariffs for example provide revenue certainty but do not necessarily address novelty risk and the need for a track record. A first or early mover is required to produce a track record and this is one way SIBs prove useful as part of the policy mix. When a country later transitions between policy support schemes, such as moving from a feed-in-tariff to an auction scheme (onshore wind in the UK) or when renewable energy targets are being revised (the Australian case) SIBs can help address policy uncertainty. Ultimately, if designed carefully, SIBs can be a powerful tool to foster and diffuse innovation. To have mandates focusing on capital provision and de-risking is too narrow and innovation guidelines are needed in order to more broadly support the deployment and diffusion of innovation. Finally a policy mix that affects both the financial sector (e.g. Basel or national reforms, policies to mainstream green investment etc.) and the low-carbon energy technology system is needed to properly support energy system transformation; an SIB can be seen as a systemic instrument that effectively contributes to this policy mix (Wieczorek and Hekkert, 2012).

[37] KfW may be crowding out private finance in more mature markets, particularly with its concessional rates. Note that KfW also offers cheaper concessional finance to other countries including the UK, and that the GIB intends to eventually invest outside the UK. Although not investigated as part of this work, policy makers should consider the impact of cross-border SIB interventions in terms of crowding-out.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.enpol.2018.01.009.

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Appendix A: Additional Results

This appendix presents the results of all remaining technologies per country not discussed in detail in the main article. These results, also shown in Figure 2, include onshore wind and waste-to-energy and bioenergy in Australia, onshore wind and energy efficiency and small-scale renewables in the UK and waste-to-energy and bioenergy in Germany.

Australian onshore wind developers and the CEFC

Large-scale onshore wind developers have faced many of the same issues as solar PV in terms of being unable to source bank debt for projects with merchant exposure, and in turn the CEFC has supported these projects in similar ways. As one wind developer said, *'the CEFC has been much more open and amendable to looking at financing for projects that have an element of merchant exposure'*. The CEFC has also acted as a first mover by financing the first large-scale wind farms to be developed with full and partial merchant exposure. Wind developers agreed with solar PV developers that equity provision could play a stronger role in fostering the merchant renewable market and in general saw the CEFC's first mover role as valuable in providing track records in order to address risks, both actual and perceived.

The CEFC leveraged their internal capabilities to try and introduce similar innovative debt products for wind as for solar PV. When one wind developer announced it was putting a wind farm up for sale the CEFC and developer collaborated to try and develop a way to introduce retail investors, via an innovative investment product, where investors could take an equity share in the farm while the CEFC provided debt. Developers have been impressed with the innovative approach of the CEFC, commenting that *'they have been extremely imaginative and committed in trying to think of ways in which they could usefully deploy their capital'*. Wind developers also reported similar effects to solar PV around the generation of trust and crowding-in of private finance to their projects when the CEFC announced their intention to invest.

Australian waste-to-energy & bioenergy developers and the GIB

Waste-to-energy (WtE) and biomass are underdeveloped sectors in Australia and both the perceived and actual technology risk is considered to be one of the biggest barriers to sourcing capital, especially debt financing. Developers we interviewed found that commercial banks had little experience with these projects and automatically put an additional 2 points of IRR (internal rate of return) on top of any project compared to what they would see in similar projects in the UK. As one developer put it *'the banking system is all about confidence and you need someone to walk them through it…right back to "What is a waste-to-energy plant?"'*. Of the projects that have been financed by the CEFC, some new technology has been introduced into the Australian market. But in general the CEFC isn't addressing new technology risk in the sector when deciding where to make its investments. Developers agree they would also need the CEFC to provide equity in order to take on greater technology risk rather than just providing long-term, fixed rate debt. Some developers also felt that the CEFC wasn't as capable of assessing risk as the UK's Green Investment Bank who is considered to be excellent in this field and that the investment sector in general requires greater experience and capability with these projects.

Of the projects that have been developed with the CEFC, off-take counterparty and fuel-supply risks were also barriers to sourcing finance. Banks especially regard these risks, both of which increase for projects in remote locations, as being too high, and the CEFC has attempted to fill this financing gap. As seen for solar PV and onshore wind, having the CEFC on board a project automatically generates trust and brings in additional financing with one developer stating *"they make an announcement that they are going to fund this project and then all of a sudden the banks start ringing and saying 'well if it's good enough for them, we want a piece of that'"*.

UK onshore wind developers and the GIB

Onshore wind developers reported that they are struggling to source finance due to the lack of future revenue certainty (due to recent regulatory changes that removed all subsidy) with one developer saying that *'no one is willing to take a 15 year price risk on new onshore wind'*. Although not initially a target sector for the GIB, it recognised the shortage of capital for onshore wind projects and in 2016 proceeded to supply much needed debt to its first onshore wind farm.

UK energy efficiency and small-scale renewable developers and the GIB

Some energy efficiency project barriers and risks have been mostly well addressed by the GIB and others only partially well addressed. The GIB has managed to address revenue complexity, low return, high transaction cost issues and accessibility issues by using its highly skilled personnel and specialist funds to help set up, package and standardise structurally complex energy efficiency deals, as well as some aggregation and securitisation products. Offering the range of equity and loan products has also better addressed needs as some developers have a greater demand for higher risk capital over debt. However developers are calling for a counterparty risk guarantee product and there remains a gap around both developer and investor capabilities and greater technical assistance is required. Small-scale renewable projects face very similar barriers to energy efficiency projects and while the GIB has been successful in meeting some of the needs of small-scale waste-to-energy and bioenergy projects (via its specialist funds and flexible range of finance products from debt to mezzanine debt to equity) it has not had a significant impact on addressing remaining barriers to finance among other small and community-scale renewables.

German waste-to-energy and bioenergy developers and KfW

During the early phase of Germany's bioenergy and waste-to-energy sectors (2007-2014) developers faced many of the same barriers to sourcing finance as the German solar PV industry and KfW addressed these in much the same way. The one key difference however was around fuel supply where banks required long-term fuel supply contracts. Developers reported that KfW have shown more flexibility and were willing to finance projects with shorter or less certain fuel contracts, partially addressing barriers associated with fuel supply risk. In addition, given that many developers were local farmers or businesses, they felt they greatly benefited from the ease of being able to access KfW's finance from their local banking institution where they had pre-existing relationships.

However the recent situation for financing bioenergy projects has changed. The German Government has become concerned about the sources of fuel for bioenergy projects from outside Germany, particularly from developing countries. It is no longer seen as a sustainable method for energy production and KfW support is greatly reduced. Commercial local banks are asking for 10-year fuel supply contracts however local farmers and fuel suppliers cannot and will not commit to more than 2-5 year contracts. As one developer stated *'the biomass sector in Germany is dead. You see, everybody is going bankrupt there. It is basically (due to) political uncertainty and the feedstock issue*'.

Paper 2: Integrating finance into the Multi-Level Perspective: technology niche-finance regime interactions and financial policy interventions

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Abstract

Any major socio-technical transition requires a fundamental re-direction of financial capital from incumbent to new technologies and practices. While the transitions literature conceptually covers financial markets, the role of finance is marginalized and has scarcely been analysed empirically. To address this gap, here we build on the multi-level perspective (MLP), which considers financial markets as part of the existing regime. We argue that the role of finance is highly relevant for the niche-regime interaction: Redirecting finance towards new niche technologies requires that either the niche is fit for and conforms to the financial regime's expectations or the financial regime is stretched and transformed in order to accept and finance niche technologies. Based on 56 interviews, we identify factors that determine interactions between the financial regime and technology niches: these include acceptable risk and transaction size, an abundance of knowledge and heuristics in both the regime and niche, and an extensive, existing industry network. We further analyse how State Investment Bank (SIB) interventions in Germany, the UK and Australia, aimed to mobilise private finance into low-carbon project development, affect the interaction between the technology niche and financial regime, i.e. whether they resulted in fitting-and-conforming the technological niche for the financial regime or stretching-and-transforming the financial regime. Our results point to several important effects of SIB interventions, with most effects fitting the niche to the regime. However, we also detect effects that stretch and transform the financial regime – through evolutionary processes. Importantly, some effects occur as a consequence of the primary effects. Based on our findings we discuss policy implications on how to accelerate transitions through policies aiming at finance as well as theoretical insights gained through our analysis.

1 Introduction

The grand challenges faced by society, such as inequality or environmental degradation, call for major socio-technical transitions towards sustainability (Geels et al., 2017; Markard et al., 2012). These transitions require a fundamental redirection of financial capital away from incumbent towards new technologies and practices (Mazzucato, 2011; Mazzucato and Penna, 2015; Perez, 2002, 2010, 2011; Schmidt, 2014).[1] In the field of evolutionary (or neo-Schumpeterian) economics, Mazzucato analysed the role of finance in innovation, finding that

[1] Financial systems can also undergo transitions (e.g. through block chain technology) but this is not the focus of this paper.

different companies (new innovative firms versus established incumbents) face different ability to access finance for innovative activities (Mazzucato, 2013) and Perez observed that groups of risk-taking financiers that support innovation accompany periods of radical change (Perez, 2002, 2011). In addition, Dosi (1990) has described the selection function of capital markets: when investors[2] finance a project or firm, they select which technologies and/or designs, and consequently which innovations, are deployed into the system. These technologies can then further improve due to learning feedbacks (Huenteler et al., 2016a; Huenteler et al., 2016b; Malerba, 1992; Rosenberg, 1982).

However, while finance is considered an important enabler to any transition and is generally present in key transitions frameworks, it is largely marginalised by the transitions literature. Key exceptions include Perez who showed that finance is fundamental to stimulate much needed transitions (Perez, 2002, 2011) and Karltorp who uses the Technological Innovation Systems (TIS) approach to analyse the role of finance in more depth, assessing the finance sector's perspective on, and its interactions with, the TIS (Karltorp, 2016; Karltorp et al., 2017). The multi-level perspective (MLP) looking at regimes (selection environments, such as the financial system) and niches (in which technological innovations occur) and their interactions has a wide perspective on transitions and generally covers financial markets as part of the existing regime (Geels, 2002). However, apart from one paper that examines the impact of the financial crisis on sustainability transitions in terms of MLP concepts (Geels, 2013), to date no studies exist that conceptualise and explicitly analyse the role of finance for transitions in detail, using the MLP perspective.

Here, we want to address this gap by analysing the interaction between the financial regime and niches in low-carbon energy technologies (renewable energy and energy efficiency technologies). We argue that the role of finance is highly relevant for the niche-regime interaction as discussed by Smith and Raven (2012): Redirecting finance towards new niche technologies may require that either the niche is fit for the financial regime or the financial regime is stretched. More specifically, we want to understand how this interaction evolves through the use of a specific systemic policy institution; State investment banks (SIBs) (Geddes et al., 2018) can affect the technological niche - financial regime interaction and thereby answer the question:

What are the factors that determine the interactions between the finance regime and technology niches and how are these interactions affected by policy interventions?

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[2] We will refer to both equity and debt providers as 'investors'.

With this work we aim to provide a first empirical study that takes a step towards theorising about finance in MLP.

The remainder of the paper is structured as follows. Section 2 introduces the theoretical background to the topic (indicating where our work sits within the literature) and presents our approach to analysing the research question. Section 3 describes our research case, research method and data. We present our results and observations in section 4, discuss them in section 5 and conclude in section 6.

2 Theoretical Perspectives

2.1 The Multi-level perspective on transitions

A Socio-technical system is composed of actors (individuals, firms etc.), institutions (norms, regulations etc.), and artifacts and knowledge (Geels, 2004; Markard, 2011; Markard et al., 2012). A socio-technical transition is a series of developments that results in a fundamental transformation of such a socio-technical system (Kemp, 1994). During such a transition fundamental technological, institutional, socio-cultural, political and economic change can be expected (Markard et al., 2012).

Various approaches have made great contributions to our understanding of socio-technical transitions (for a review see Markard et al. (2012)). Whereas other frameworks focus predominantly on the niche in which innovation occurs (such as in the TIS or Strategic Niche Management (SNM) approaches) the multi-level perspective (MLP) includes analysis of new technology (*niches,* defined as protective spaces where path-breaking, radical innovations, such as low-carbon technologies, are produced and developed), the existing context conditions (in the form of *regimes,* also known as the selection environment, defined as the arrangement of established practices, sets of rules and organisational and cognitive routines that affect incumbent actors' resistance to or compliance with system change and the *landscape,* defined as a set of deep structural trends and technology-external factors), as well as interactions between each (Geels, 2002, 2012, 2013; Geels, 2014; Geels and Schot, 2007; Smith et al., 2005). Knowledge and capability progressions, price/ performance improvements, support from, and protection by key actors and groups allow niches to develop internal momentum with a view to successfully entering mainstream markets, and the regime. However, the success of a new technology (niche-innovation) is also determined by changes at the existing regime and landscape levels. Landscape changes can pressure regimes and/ or the destabilisation and reconfiguration of the regime can create openings for the diffusion of niche-innovations. It is the alignment and interaction of all of these processes that can allow for innovations to compete with mainstream technologies and sectors within the existing regime (Geels, 2002; Geels, 2014; Geels and Schot, 2007).

The MLP literature has established concepts for observing niche-regime interactions, and for potentially overcoming regime resistance. These are the 'stretch & transform' (S&T) and 'fit and conform' (F&C) processes (Smith and Raven, 2012). Fit and conform processes allow niche-innovations to be competitive in unaltered, existing mainstream selection environments (i.e. the existing financial regime) by ensuring niches develop in order to fit existing rules and institutions. F&C empowerment includes processes that result in improved alignment with existing industrial norms or structures such as with economic, financial, technological, organisational and other conventional regime selection criteria of existing markets (e.g. improved cost-efficiency/performance). Stretch and transform (S&T) processes alter existing, mainstream selection environments, adjusting the rules and institutions of these conventional regimes, in ways that benefit the niche. S&T empowerment includes processes that restructure, and even undermine, incumbent regimes, transferring some features of the niche such as new norms and routines, and institutional reforms into a transformed regime (Lauber and Jacobsson, 2016; Smith and Raven, 2012). Thus far empirical analyses of niche-regime interactions have largely ignored the role of finance such that no scholars have specifically analysed technological niche-financial regime interactions in terms of the F&C and S&T concepts.[3] This might be caused by the general under-representation and lack of conceptual clarity of finance in the MLP.

The majority of the existing MLP work focuses on supporting and promoting niche innovations, focussing less on existing incumbent regimes and actors (such as the finance sector), with scholars usually regarding regimes as "monolithic barriers to be overcome" (Geels, 2014). Understanding regimes is important in order to understand and affect niche-regime interactions, to "enact the destabilization and decline" of incumbent regimes (Geels, 2014) and to enable transition. However, those scholars that have focused on regimes, have not focused on finance, observing instead other incumbent regimes such as utilities, infrastructure, institutions etc. (Geels, 2014). Furthermore, whereas for these parts of the regime there are calls to "enact their destabilization and decline" in order to transition from unsustainable to sustainable sectors (Geels, 2014), finance is and will still be considered a

[3] Note that a recent critique by Sorrell (2018) points to several potential weaknesses of the MLP approach including that it is rarely used to provide causal explanations, i.e., it does not provide any testable hypotheses and is only used in ex-post rationalisation. We argue that this criticism does not account for Smith and Raven's (2012) F&C and S&T concepts which could provide causal explanations: one could formulate and test propositions. E.g. the greater the fit of the niche with the regime heuristics, the more likely the niche will be taken up. One could then find proxy data to test these. We do not formulate and test propositions in this paper but we argue that this would be possible using these MLP concepts. Sorrell (2018) also concludes that MLP features the flexibility to allow for improvements: which we have endeavoured to do in this work.

necessary part of the regime in any transition. Hence, the existing analysis and policy recommendations for such parts of the regime may not be appropriate for the financial regime. Only Geels (2013) uses the MLP concept to focus on finance. However, his paper examines the impact of the financial-economic crisis on sustainability transitions in general, using the MLP concept to conceptualise this impact. It does not focus on interactions involving the finance regime and technology niche specifically (Geels, 2013). Despite acknowledging the relevance and importance of the financial sector, analysis of finance in the MLP literature remains under-represented

2.2 Finance in evolutionary economics

Any major socio-technical transition requires a fundamental redirection of financial capital away from incumbents and towards new technologies and practices: finance is considered an important enabler to the innovation process, and hence to any transition (Mazzucato, 2011; Mazzucato and Penna, 2015; Perez, 2002, 2010, 2011; Schmidt, 2014). The dominant theory on financial markets is the efficient market hypothesis (EMH) which is underpinned by the neo-classical school of economics (Fama, 1970; Sharif, 2006). This theory states that markets are efficient in that prices always ‘fully reflect’ available information (Fama, 1970). Accordingly, under mainstream finance theory, markets always price risk (and return expectations) perfectly, instantaneously and rationally (Fama, 1970). Under the efficient market hypothesis, when new information or investment opportunities arrive (e.g. in the form of new technologies), at any point in time it is instantly incorporated into asset prices, with markets instantly reaching a new equilibrium (Hiremath and Kumari, 2014). It also assumes that finance is technology neutral and hence if the risk-return profile of an innovation (e.g., a new technology) is favourable, investors will invest.

In contrast, evolutionary economics points to path dependencies[4] and risk aversion within the finance sector that inhibit the ability of entrepreneurs to access appropriate finance required for innovative activities. Given that the MLP framework is based on evolutionary economic theory, any work that aims to better conceptualise finance in the MLP framework should reflect on evolutionary economists views on finance.

Schumpeter’s work first linked an economy’s credit and capital markets to its innovation performance indicating that credit/finance is essential for on-going innovation (Schumpeter 1912). Schumpeter coined the banker as the ‘ephor’ of capitalism, producing ‘the commodity “purchasing power”’ (Schumpeter, 1912, 74) and he claimed that in capitalism the ultimate

[4] Learning and network effects (in combination with increasing economies of scale) can push a system facing various potential outcomes (e.g. technologies) towards one particular outcome, even if that outcome is considered to be socially sub-optimal in the long run. Seemingly small historical events can matter. Thus we can say that some systems are ‘path dependent’ and subject to eventual ‘lock-in’ (Arthur, 1989).

aim was to transfer this purchasing power to the entrepreneur, in turn allowing innovation to occur (Mazzucato, 2013; Schumpeter, 1912, 107). Also in the field of evolutionary (or neo-Schumpeterian) economics, Dosi (1990) has described the selection function of capital markets and their role in creating techno-economic path dependencies: when investors finance a project, they select which technologies and/or designs, and consequently which innovations, are deployed into the system. In turn, finance can leave new projects and their technologies un-selected (say if they are considered too innovative and/or risky) and accordingly investors can de-select existing projects and technologies.

Mazzucato further develops Schumpeter's ideas for the modern economy, discussing issues around the concept of finance and innovation (Mazzucato, 2013). She discusses the different role in innovation of new innovative start-up companies versus established (often larger) incumbents and their different ability to access finance for innovation (Mazzucato, 2013, 2015; Mazzucato and Semieniuk, 2017). In general, traditional commercial banks see the uncertainty associated with innovation as too risky and decline to provide the finance required by firms for exploratory work: Small innovative firms that perform more 'exploratory' activities have been unable to source finance apart from equity markets, especially venture capital (Mazzucato, 2013). Venture capital is not necessarily able or willing to provide the longer term patient capital that is appropriate for may innovative firms, especially in for example, the energy sector (Mazzucato, 2013; Mazzucato and Semieniuk, 2017; Nanda and Ghosh, 2014). Larger, more established companies however, are able to fall back on their existing balance sheets to finance their activities, innovative or otherwise, and are also able to source finance via debt from banks and other investors (Mazzucato, 2013; Steffen, 2018). This is important because new start-up companies involved in innovative activities (niches) are needed for transitions (Geels, 2002, 2013; Schumpeter, 1912, 2010/1942). Therefore, with traditional banks, and capital markets, unwilling to finance such innovative activities, firms have needed to turn to other sources of finance; such as venture capital or public finance sources, such as via state investment banks. Indeed public finance has been shown to support socio-technical transitions when it plays a 'mission oriented' role where it addresses such issues as climate change by making key, directed investments in higher-risk and new sectors (Mazzucato and Penna, 2015; Mazzucato and Penna, 2016; Mazzucato and Semieniuk, 2017).

This supports Perez who determines that 'courageous and bold' finance is required in order to instigate much needed transitions, especially when finance is too attached to established markets and incumbents (Perez, 2002). She observes that historically periods of radical change see groups of risk-taking investors that support entrepreneurs and innovation and that finance plays a fundamental role in supporting transitions (Mazzucato, 2013; Perez, 2002, 2011).

In particular, evolutionary perspectives acknowledge that the concept of path dependency, resulting in potential lock-in, can be used to describe financial system stability (Foxon, 2011; Hall et al., 2015; Markard, 2011; Unruh, 2000). Hall et al. (2015) describe financial markets as adaptive and Egli et al. (2018) found empirical proof that the financial sector undergoes a learning process when faced with investments in new projects and technologies: path dependency can be created within the finance sector. This contradicts the EMH view on financial markets.

Different types of finance perform different functions along a technology's innovation chain as it moves from research and development to early stage commercialisation through to commercialisation and large-scale diffusion (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2016). Public finance often plays a key role in the earlier stages with venture capital and private equity financing early commercialisation and banks and institutional investors financing the later commercialisation and diffusion stages (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2016). However there are several financing gaps along the innovation chain known as valleys of death (Grubb, 2004; Nemet et al., 2018); the first occurs upstream of the innovation chain as a technology tries to move from the demonstration phase to early stage commercialisation, and the second occurs when the technology moves from commercialisation to large-scale diffusion (Karltorp, 2016).

2.3 Integrating finance into MLP

Geels (2013) indicates that the finance sector itself sits at the regime level. We support this concept because the financial sector has a selection function and can be thought of as a selection environment: when investors invest in a firm or project, the technologies and/or designs in that project, are selected into the system (Dosi, 1990). We also argue that Finance is its own regime (see Figure 1a) with its own actors and institutions, set of norms, rules and heuristics and organisational and cognitive routines that affect incumbent actors' resistance to or compliance with system change and that it can be seen as overlapping and interacting with all other socio-technical regimes. Finance regime actors and institutions encompass the investors, financial intermediaries (such as banks and insurers), financial transactions, heuristics (such as investing according to the risk-return trade-off principle) services and markets that enable the exchange of capital so that firms can produce, operate and innovate. Incumbent technology firms in differing socio-technical regimes also typically source finance, and other services (including risk management, size transformation, maturity transformation and risk pricing), from financial markets and/ or intermediaries (e.g. banks), resulting in a strong interaction (or even overlap) between the financial and socio-technical regimes. In fact the finance regime can be seen as the centre of innovation and affects all other socio-technical regimes. There is no substitute for finance, at least within capitalist systems, which seem to be highly conducive to innovation (Rosenberg, 1982; Schumpeter, 2010/1942). Yet, the degree of interaction of the finance regime with other regimes is determined by landscape developments. E.g., the varieties of capitalism (Hall and Soskice, 2001) at the landscape level impact upon the interactions between the finance and the real economy regimes and thus determines the importance of the finance regime (see Figure 1b).. For example, the increasing financialisation of the economy (Lazonick, 2007, 2013) indicates that more of the real economy, and regimes, overlap and interact with the finance regime with the finance regime becoming more dominant.

We also argue that the financial regime – technology niche interaction is particularly important for overcoming the 2nd valley of death. Observing how finance works in the second valley of death is important for several reasons. Upstream finance, supporting research and development, and early stage commercialisation helps to create the technology niche. Downstream finance, supporting the commercialisation and widespread, large-scale diffusion of a technology helps move the technology niche into the socio-technical regime. When technologies are deployed into the system they can then further improve due to learning feedbacks i.e. feedbacks from learning-by-doing and learning-by-using (Huenteler et al., 2016a; Huenteler et al., 2016b; Malerba, 1992; Rosenberg, 1982). Hence, rather than solely focussing on upstream research and development and venture capital finance in what is referred to as the 1st valley of death, addressing the selection function of downstream finance (and financial actors) for commercialisation, in what is referred to as the 2nd valley of death, is also required (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2016).

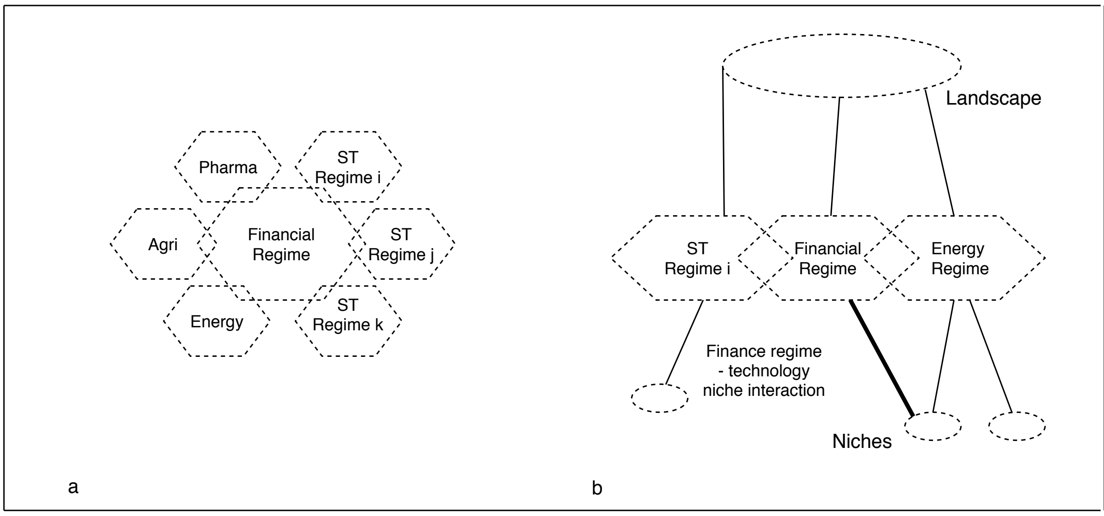

Figure 1: Finance regime a) overlapping with other socio-technical regimes and b) within the MLP

We address the research gap by empirically analysing the factors that determine the interaction between the finance regime and technology niche i.e. factors that determine financing. We then analyse the policy interventions implemented by a public finance institution with the aim to catalyse finance. We want to increase our understanding of how the use of these specific policy interventions aimed to mobilise finance can affect niche-financial regime interactions (Figure 2 shows two cases. On the left hand side, a niche innovation is unable to enter the regime as the regime resistance is too high. On the right hand side financial policy interventions help to either 'fit and conform' the niche or 'stretch and transform' the regime, allowing it to enter the technology regime). We determine the effect of the policy intervention on the niche-regime interaction, analysing whether it "fits and conforms" (low-carbon technology) niches, or "stretches and transforms" the regime (financial sector) enabling financial interactions that allow finance to flow to the niche and for the niche to enter the regime. With this work we make a step towards theorising about finance in the MLP perspective on transitions.

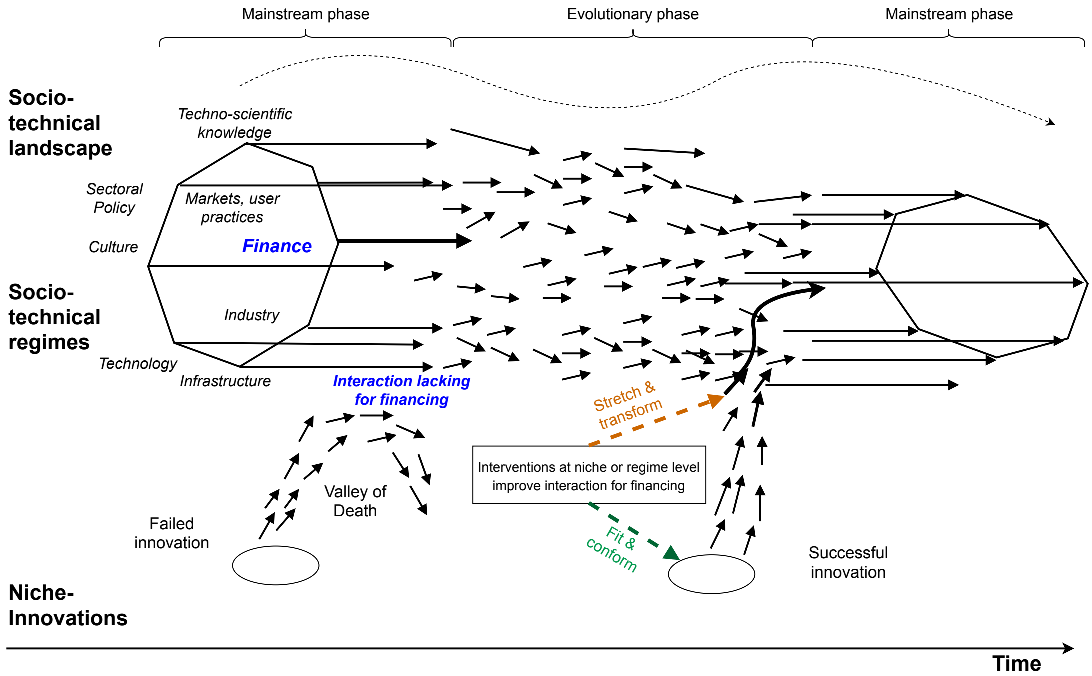

Figure 2: Multi-level perspective on transitions. Adapted from Geels (2002) and Geels and Schot (2007). Left hand niche-innovation: Failed niche innovation where factors that determine the interaction (and financing) are lacking. Right-hand niche-innovation: Niche successfully entering regime with finance policy intervention. Policy interventions are shown at the niche and regime levels. The interventions enable the financial regime to Stretch and Transform or the niche to Fit and Conform, allowing finance to flow to the niche and for it to enter the regime

3 Research Case, Method and Data

3.1 Research Case

We chose the energy transition as our research case as it is considered necessary in order to mitigate climate change, and hence is anticipated to be one of the largest and most challenging sustainability transitions facing humankind (Geels et al., 2017; IPCC, 2014). An energy transition describes the shift from one energy system to another that is dependent on a significantly changed set of technologies, fuels, sectors, carriers etc. rather than a change in one technology or fuel source (Fouquet and Pearson, 2012; Grubler et al., 2016). In addition, the new technologies required for this transition, such as renewables and energy efficiency, can be capital intensive and display various different risk and cost structures compared to incumbent technologies within the regime (Schmidt, 2014; Waissbein et al., 2013). Given these unique features and the importance of finance for transitions in general, examining the role of finance in the energy transition with a focus on renewables and energy efficiency, should divulge a wide range of data for study.

Finance in the traditional energy regime plays a role that suits and supports, in particular, incumbent energy companies and technologies. Larger incumbents (often listed companies issuing bonds) in the energy regime have traditionally used mostly corporate finance (on their balance sheet) to raise funds in order to develop projects (Steffen, 2018). Banks and other intermediaries also play a role by providing traditional and well-known de-risking instruments (mostly financial instruments and some insurance) to cover any financing gaps encountered by incumbents. Traditionally new technologies have not been supported or developed by incumbent companies and/or investors (Geels, 2014). Many new independent developers of new (low-carbon) technologies started out as smaller companies, often without access to appropriately sized balance sheets to develop projects (Steffen, 2018). This has been exacerbated by the fact that many low-carbon technology projects are capital[5] intensive (meaning even some larger companies have been unable to develop projects on their balance sheets). Non-recourse project finance[6] has often been used in lieu of balance sheet investment for such developments (Steffen, 2018). Hence often niche technologies need to rely on additional investors and intermediaries in order to raise funds and develop projects (Polzin et al., 2016; Steffen, 2018). SIBs can be effective in this space.

We will help conceptualise finance by examining the niche-regime interaction within a specific part of the energy sector. The energy transition requires new low-carbon technologies that are most often developed in niches. Hence the 'low-carbon technological' niche - 'financial' regime interaction is particularly important when studying the energy transition. In addition, given the important role of knowledge feedbacks (learning-by-doing and -using) in the design, production and use phases for complex technologies such as low-carbon technologies (Huenteler et al., 2016a; Huenteler et al., 2016b; Lewis and Wiser, 2007; Malerba, 1992; Rosenberg, 1982; Schmidt et al., 2016) the selection function of financial actors can result in lower rates of innovation and the lock-out of (presently) more risky technologies (Dosi, 1990; McKelvey, 1997). For example, low-carbon technologies have very high up-front capital costs and can display high risks for investors. Hence interactions with the financial regime are especially important to the success of these niches, perhaps more so than to the incumbent energy system (Geddes et al., 2018; Schmidt, 2014).

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[5] Capital intensive projects are those that have very high up-front capital costs (investment) compared to their operational (variable) costs. Therefore they need a very high volume of production in order to produce an acceptable return on investment.

6 Developers either develop projects on their balance sheet (i.e. using corporate finance), or draw on project finance. When using corporate finance all assets and cash flows from the company (developer) is used to guarantee any credit required. When using project finance, a new entity (i.e. a special purpose vehicle) is created to incorporate the project; credit required is then guaranteed against the cash flows of the new project only, with no or very limited claim (recourse) on the developer's (company's) assets (Steffen, 2018).

We selected SIBs and their policy interventions as our empirical policy case for examining finance in the energy transition for various reasons. More generally, state intervention in financial markets has been widespread (Stiglitz, 1993) and SIBs have been applied across a wide range of countries. SIBs are a public finance institution that intervene in investment markets and are simultaneously thought of as part of a country's policy mix (Geddes et al., 2018; Mazzucato, 2011; Mazzucato and Penna, 2015; Mazzucato and Penna, 2016; Stiglitz, 1993). SIBs may be mandated to help drive a country's energy transition via the mobilisation of private finance and can offer many different types of interventions. It has also been argued by other scholars that SIBs are a potential catalyser of niche-regime interaction, something we wish to understand in detail (Mazzucato and Penna, 2016; Mazzucato and Semieniuk, 2017). Note that we did not look at overarching financial regulation type interventions, such as Basel III interventions, because typically these regulations are not designed to foster socio-technical transitions and may also be considered part of the landscape.

We selected three SIBs[7] for our study that are primarily or heavily active in financing low-carbon projects: Australia's CEFC, the UK's GIB and Germany's KfW. The GIB and CEFC were set up specifically to help their countries transition to a greener more sustainable economy, and KfW has played a key role in supporting Germany's Energiewende (energy transition) (Geddes et al., 2018). We wanted to cover a breadth of investment grade, well-developed financial systems/ markets (e.g. UK's market based financial system, Australia's more concentrated market based financial system with stronger short-term money market activity, and Germany's bank-based financial system with its extensive network of local banks). In addition these three countries display low-carbon energy sectors at various different stages in terms of technology diffusion and local financial system experience and expertise, as well as variance around the level of energy policy support, type and stability. Hence we want to observe some variance on the niche (low-carbon sector stage variance) and the regime levels (financial system variance) in order to capture a wide range of observations, but not too strong a variance on the regime (financial market) itself that we observe interventions that 'replace' or 'build' non-functioning or non-existent markets (hence the exclusion of SIBs in developing countries).

3.2 Method and data

[7] We selected our SIBs only from developed countries because we wanted our observations to emerge from well developed and functioning financial and investment markets. In order to focus on the energy transition we didn't want to focus on additional barriers to finance that can accompany developing country markets such as political risk or even a complete absence of an operating banking sector/ investment market. In fact in many developing countries SIBs, development banks and MDBs are part of the regime as there is no fully developed private financial sector. Additional future work would be needed to analyse finance in transitions in developing countries.

Following the procedure of (Eisenhardt, 1989), we undertook a qualitative case study design. Primary data[8] was collected via in-depth semi-structured interviews with project developers, equity and debt providers, bankers, and industry experts. Secondary data was sourced from publicly available literature on each SIB and their low-carbon projects. We interviewed 56 participants in total, both niche and regime actors, from late 2015 to mid 2016, listed in Table 1. Interviewees[9] were found through searches of project websites, renewable energy associations, Internet searches and snowball sampling. All interviews were conducted under the "Chatham House Rule". In accordance with (Eisenhardt, 1989) we continued performing interviews until no new insights were observed.

Interviews were recorded, transcribed and then coded along with the secondary data using the qualitative data analysis software MAXQDA12. A first researcher coded the interview data and a second coder was recruited to 'control' this coding in order to improve the accuracy and reliability of the coding process (Eisenhardt, 1989).

As a first step in this work we observed how incumbents[10] source finance from the regime and identified the factors that determine whether finance will flow to niche technologies and projects. We then observed the specific SIB interventions and coded for these. Finally we examined the effect of the SIB's intervention in terms of its impact on technology niche-financial regime interactions. Specifically we analysed and then categorised (coded) an SIB intervention based on the Smith and Raven (2012) MLP literature concepts: whether it "stretches and transforms" (S&T) the financial sector (regime) or whether it "fits and conforms" (F&C) the low-carbon project (niche) to the expectations and rules of the existing financial sector (regime). Finally we determined whether there were any other additional subsequent niche-regime effects that occurred over time as a result of the SIB interventions and categorised (coded) them using the same logic described above.

[8] The collected dataset was also used for an additional project and publication (Geddes et al., 2018) however for each project the data was coded differently for separate analysis.

[9] All interviewees were initially contacted via e-mail. Approximately 85% of interviews were conducted via Skype or telephone and 15% conducted in-person Interviews lasted from between 30 min and 90 min with the average interview taking 60 min.

[10] A detailed analysis of how finance supports the existing energy incumbents and regime is not the focus of this paper. We are more interested in the niche-regime interactions between finance in the regime and low-carbon niches, and in particular how finance can be made to flow to the niche and allow niches to become part of the technology regime.

Table 1: Interview Sample

Category	Organisation[a]	Technology Focus[b]	Country[c]	Interviewee's Role
Niche	Project Developer	Wind, Solar PV	AU	Head of Business Development
	Project Developer	WtE	AU	Chief Executive Officer
	Project Developer	WtE	AU	Managing Director
	Project Developer	WtE	AU	Managing Director
	Project Developer	Bioenergy, WtE	GB	Independent developer
	Project Developer	Wind, Bioenergy	GB	Managing Director
	Project Developer	WtE	GB	Managing Director
	EPC, OEM	Wind, Solar PV	AU	Business Development Manager
	IPP	Wind	AU	Executive General Manager
	IPP	Wind, Hydro	AU	Executive Manager, Development
	IPP	Renewables	AU, GB, DE	Chief Financial Officer
	IPP	Solar PV	DE	Project Developer
	IPP	Bioenergy	GB, DE	Independent developer
	IPP	Wind, Solar PV	GB, DE	Manager, ESG
	IPP	Wind, Solar PV	GB, DE	Executive General Manager
	IPP	WtE, Bioenergy	GB, DE	Head of Origination
	OEM	Wind, Solar PV	AU	Head Structured Finance
	OEM	Small-scale wind	AU, GB, DE	General Manager
	OEM	Renewables	AU, GB, DE	Sales Manager, Renewables
	OEM	Renewables	AU, GB, DE	Senior VP Project Development
	OEM	Wind	GB, DE	Senior Investment Manager
	Utility	Renewables, FFs	DE	Managing Director
	Utility	Renewables, FFs	DE	Head Business Development
	Utility	Wind, Solar PV	GB, DE	Business Development Manager
	Utility	Wind, Solar PV	GB, DE	Managing Director
Regime	Commercial Bank	Renewables, FFs	AU	Executive General Manager
	Commercial Bank	Renewables, FFs	AU	Senior Consultant
	Commercial Bank	Renewables, FFs	AU, GB, DE	Director Corporate Clients
	Commercial Bank	Renewables, FFs	AU, GB, DE	Consultant, Green Banking Expert
	Commercial Bank	Renewables, FFs	GB, DE	Consultant, Innovative Finance
	Gov't funding entity	Renewables	AU	Transactions and Development
	Green Bank	Renewables	GB, DE	Relationship Manager, Arranger
	Invest. Advisors	Renewables	AU	Principal Financial Advisor
	OEM investors	Renewables, FFs	AU, GB, DE	Managing Director
	Invest. platform	Renewables	GB	Managing Director
	SIB	Renewables, EE	AU	Division Director
	SIB	Renewables, EE	AU	Researcher
	SIB	Renewables, EE	AU	Department Director
	SIB	Renewables, EE	AU	Associate Director
	SIB	Renewables, FFs	DE	Department Director
	SIB	Renewables, EE	GB	Department Head
	SIB	Renewables, FFs	GB, DE	Investment Officer
	SIB	Renewables, FFs	GB, DE	Project Assessor
	SIB	Wind, Renewables	GB, DE	Team Head, Wind Power
	Sustainable Bank	Renewables	GB, DE	Chief Financial Officer
	VC Investor	Renewables, FFs	AU, GB, DE	Director
Intermediary[d]	Consultancy	Renewables	AU, GB, DE	Arranger, Due Diligence
	Consultancy	Renewables, FFs	GB, DE	Associate Principal, Energy
	Consultancy	Wind	GB, DE	Senior Consultant, Power Market
	Consultancy	Wind	GB, DE	Partner, Energy and Resources
	Energy Think-tank	Renewables	GB	Director, Finance, Energy Policy
	Envir. Consultancy	Renewables, FFs	GB, DE	Principal Consultant
	Envir. NGO	Renewables, FFs	AU, GB, DE	Director of Strategy and Finance
	Legal Consultancy	Renewables	AU	Partner, Project Finance, Energy
	Legal Consultancy	Renewables	AU	Senior Associate, Project Finance
	Legal Consultancy	Renewables	AU, GB, DE	Partner, Arranger
Policy Institution	SIB	Renewables, EE	AU	Division Director
	SIB	Renewables, EE	AU	Researcher
	SIB	Renewables, EE	AU	Department Director
	SIB	Renewables, EE	AU	Associate Director
	SIB	Renewables, FFs	DE	Department Director
	SIB	Renewables, EE	GB	Department Head
	SIB	Renewables, FFs	GB, DE	Investment Officer
	SIB	Renewables, FFs	GB, DE	Project Assessor
	SIB	Wind, Renewables	GB, DE	Team Head, Wind Power

[a] IPP: Independent Power Producer, OEM: Original Equipment Manufacturer, EPC: Engineering, Procurement and Construction
[b] WtE: Waste-to-energy, EE: Energy Efficiency, FFs: Fossil Fuel based power generation
[c] AU: Australia, GB: The United Kingdom, DE: Germany
[d] Intermediaries include deal arrangers, due diligence experts and expert consultants.

4 Results

4.1 Factors determining niche-regime interactions

The following section describes how incumbents access finance from the regime and describes the factors that determine financing for niche uptake.

4.1.1 Acceptable Risk

Risk and its management (via risk transfer, reduction, diversification, delegated monitoring activities) are key factors when deciding whether to invest in a project. Investors decide whether to invest or not according to the risk-return trade-off principle: the principle that potential return rises only by accepting an increase in risk (possible losses) (Brealey et al., 2017). That is, an investor will consider if an investment displays too much risk or too little potential for return as compared to their pre-determined desired limits, to decide whether to take action and invest. For incumbent technologies (that exist within the regime, not the niche) risk-return profiles are well known and well within acceptable (usually pre-determined) limits, and intermediaries, investors and lenders are willing to finance such projects and technologies[11]. However many low-carbon energy projects display, or are perceived to display, high risks (especially in the early market stage), and given that there is too little risk-taking by financial markets, particularly by banks (investors and lenders have risk limits), projects are not always financed. That is, the financial regime is not willing to finance the niche and let it enter the regime. Conforming to these risk-return profiles is an important rule within the financial regime and if niche projects don't conform they are not financed.

4.1.2 Transaction size

Investors usually have limits, upper or lower, on the amount of capital per project they are willing or able to invest. Many incumbent technology projects fall within what are considered to be acceptable project size limits and hence the financial regime is willing to finance these. Large scale low-carbon investments, such as for offshore wind projects, can require very large up-front capital expenditure (they are capital intensive), and even if structured as a syndicate to bring in several investors, smaller investors (and some larger ones) are unable to invest due to their upper capital limits. In addition many energy efficiency (EE) and small-scale low-carbon projects are considered too small for most investors, considering that transaction costs usually remain the same whether the project is large or small (transaction costs need to be

[11] This is starting to change as low-carbon technologies emerge and divestment and carbon bubble movements against incumbent fossil fuel technologies grow. This is an example of regime decline and destabilisation and, while not the focus of this paper, is a promising area for future research.

acceptable to investors). There is a mismatch between the amount of capital investors are able or willing to invest/ lend and the amount of capital required for many low-carbon projects.

4.1.3 Knowledge and heuristics

In incumbent energy sectors, financiers and developers have an abundance of experience and knowledge relating to financing and developing projects.

In new or underdeveloped sectors (such as low-carbon energy sectors) financiers and other relevant stakeholders have not yet developed the knowledge and heuristics for assessing new asset classes (the tools and processes needed in order to identify project opportunities and identify, assess and mitigate project investment risks) or the knowledge to sufficiently design and perform new due diligence processes. That is, the financial regime displays a lack of technical (and sometimes financial) knowledge needed to make fully informed investment decisions.

In new or underdeveloped technologies, developers and other relevant project stakeholders in the niche, such as OEMs, do not necessarily yet have the financial (and sometimes technical) experience and expertise to successfully attract finance to reach financial close and develop a project. For example, investors have pre-determined expectations around due diligence requirements and processes that developers may not meet.

4.1.4 Industry network

For incumbent energy sectors, an extensive industry network exists that supports project development (minimising unforeseen project delivery issues), which better enables financing of projects.

For early stage technologies, different parts of both the niche sector and financial regime are either inexperienced and do not provide well for the needs of the niche (or finance sector) or do not yet exist. This can prevent finance flowing to niche projects. Industry network stakeholders include partners along the logistics and supply chain, original equipment manufacturers (OEMs), operation and maintenance (O&M) companies, insurers etc. A lack of co-ordination within an innovation system or niche can be thought of as a system failure (Wieczorek and Hekkert, 2012).

4.2 Policy interventions & effects on niche-regime interaction

Here we detail the interventions implemented by SIBs to better meet the determinants of financing and enable finance to flow to the niche, including examples. We describe each SIB intervention's observed effect upon the technological niche-financial regime interaction, graphically displaying the results in Figure 3.

In addition to the interventions (and their effects) that were directly implemented by the SIBs, we also observed subsequent additional or 'secondary' and 'tertiary' effects upon the niche-regime interactions. These additional effects generally occurred at a later time to the original intervention and usually as a direct result of one or more of the initial 'primary' interventions. We describe these additional effects in sections 4.3 and also display them graphically in Figure 3.

4.2.1 De-risking & capital provision

All three SIBs in our sample deployed various de-risking approaches to manage and mitigate risks to projects and leverage in private finance. De-risking interventions are designed to reduce, share or transfer risk. Examples of pure de-risking tools include guarantees, insurance, off-take and counterparty risk guarantees, technology guarantees etc. However SIBs also commonly deploy instruments that combine both capital provision and de-risking elements. Examples include concessional debt (lower than market rate), grants, mezzanine products, taking a sub-ordinated role in a syndicate, providing market rate or concessional capital featuring long tenures and/ or fixed-rates, co-investing and on-lending (both risk sharing tools) etc. All of these interventions, or some combination of them, act in order to redistribute and/ or reduce the risk, improving the overall risk/ return profile of the project. Our interviews showed that these de-risking instruments have had an important effect on the niche-regime interaction.

For example, our interviews showed that in the early phase of Germany's wind industry when construction risks were very high and development and construction teams were inexperienced, developers were unable to source finance. To address this KfW IPEX were able to provide construction guarantees, improving the projects' risk/ return profile, lowering the risk to investors and bringing the projects more in line with the existing expectations and performance requirements of the finance sector. This led to the eventual leveraging-in of additional finance and the development of projects. Today construction cost overrun risks are still high, particularly for offshore wind. KfW now guarantee these overruns by offering to finance them if they occur. This guarantee reduces the risk of financial failure and maximises the chance of successful project completion, again lowering the risk to be aligned with existing investor expectations and attracting private finance. The CEFC has provided a fixed market rate, long-term debt financing product for solar PV and onshore wind projects displaying high revenue uncertainty with the stipulation that co-investors must also participate. The long-term and fixed-rate features of the debt ensured longer-term certainty for projects, which was seen a risk reduction by investors and consequently attracted co-investment. This intervention aligned the projects with current finance sector expectations and led to private investment. KfW also provided a concessional debt-financing product for mid to large-scale solar PV developers in the early days of the industry when both the technology costs and risks, and the cost of capital, were still high, and in general investors were not willing to invest. In addition to providing the necessary capital, the concessional interest rate lowered the cost of capital to projects, simultaneously reducing the risk that the borrower could not make repayments. This intervention allowed many solar PV developments to attract finance via co- and on-lending programs.

Investors will not participate in a project unless the project's risk/ return profile is within desirable (usually pre-determined) limits. So de-risking a project to improve its risk/ return profile aligns it with the current expectations and performance requirements of the existing finance sector and also allows the project to compete on a more equal footing with others vying for investment in the regime. As these examples illustrate, de-risking interventions (both pure and in combination with capital provision) have the effect of *fitting and conforming* the low-carbon niche to the requirements of the existing financial sector regime, allowing finance to flow to the niche without changing the financial sector and ensuring niche projects are successfully developed and can enter an unaltered regime.

4.2.2 Size transformation & capital aggregation

SIBs provide interventions including tools that aggregate small-scale projects or allow smaller investors to participate in large capital expenditure projects. These interventions perform a size transformation role and change the pattern around how capital can be aggregated or moved around the market, and reducing transaction costs. In doing so they allow other investors who previously could not invest in such projects to now do so (e.g. by allowing 50 smaller investors to purchase bonds in projects they could not have accessed previously).

For example, the GIB provided market rate debt and/or equity capital to offshore wind projects that were unable to fully mobilise sufficient finance due to projects' large upfront capital expenditure requirements and capital limitations on investors' overall portfolios. Our interviewees explained that in these cases private and institutional investors had shown interest in the projects, and often already committed funding, but were unable to provide the full amounts of capital required. The GIB's intervention to fill the remaining gaps allowed the attracted private finance to be utilised and the projects to reach financial close. KfW also created a wind fund to provide market rate debt to fill such gaps for Germany's wind projects facing the same issues. KfW also issues Project and Climate bonds based on its own low-carbon projects. These issuances have allowed a greater number of smaller investors to purchase bonds in low-carbon projects they could not have accessed previously. The CEFC and GIB create funds and tools to aggregate/ securitise small-scale projects, especially for energy efficiency projects. This has reduced transaction costs for investors and enabled investors with lower limits on capital provision to invest in EE and small-scale low-carbon projects that they could/ would not have accessed previously.

These capital aggregation style interventions have allowed smaller EE and low-carbon energy investments and very large capital expenditure projects to become more aligned with existing investment products and investors' expectations. These interventions *fit and conform* the niche to access finance from an unchanged market.

4.2.3 Education of finance regime

SIBs have greatly contributed to the development, standardisation and diffusion of new knowledge to help the finance sector adapt to the new technologies and to low-carbon sector projects. SIBs have created and provided standards, in the form of codified knowledge[12], tools, paperwork and processes. These standards can be thought of as an intervention that allows investors and other relevant stakeholders, including due diligence (DD) intermediaries, to easily and efficiently bypass their lack of knowledge by following the standardised forms and processes provided. Standards help financial actors adjust to technological change by reducing the time, costs and barriers associated with acquiring and developing the knowledge from scratch. SIBs' standards bring down costs of DD and arranging.

Developers and investors reported that many of the standards created and deployed by SIBs have been successfully taken up by the finance sector. KfW provide many of its financial products (capital and de-risking tools) via an on-lending process through Germany's extensive local banking network. This on-lending process includes supply of standardised risk registers, assessment tools, documentation, training etc. The local commercial banks disbursed KfW's provisions, using its standard risk registers and assessment tools and in the meantime have now became familiar with low-carbon projects and their associated risks. Our results have shown that investors and banks are now very competitive. KfW IPEX produced technical and risk standards during the early phase of the wind industry that it shared with fellow investors in project syndicates. The CEFC and GIB create standards for projects containing new and early stage technology or other innovative features. CEFC also provides standards for EE projects, a particularly underdeveloped sector in Australia, and disburses them via on-lending through various EE funds run by local banks.

The development and diffusion of knowledge (via these standards) provided by SIBs have changed the way the financial sector perceives and approaches these projects and

[12] Codified knowledge is usually knowledge that can be precisely articulated and is easy to communicate via written or verbal format (e.g. formulae, instructions etc. (Smith, 2001). Standards are important for imparting codified knowledge.

technologies, allowing the financial sector to *stretch and transform*, and finance to flow to the niches.

4.2.4 Education of technology niche

SIBs commonly intervene with non-financial support for projects, often referred to as technical assistance, in order to help developers (and other associated stakeholders in the niche) fulfil their requirements, attract the required finance and ensure projects reach financial close.

Our interviewees provided many examples of SIBs providing non-financial assistance that resulted in the successful leveraging of finance and completion of projects. The GIB offered extensive technical support to the biomass and WtE sectors in order that they meet due diligence requirements for investors early enough to also meet subsidy deadlines. Developers claimed that they were themselves somewhat inexperienced and this support was invaluable to them in sourcing private finance, making deadlines and reaching financial close. The GIB's assistance ensured that the developer had met all investors' requirements, conforming to what the investors expected from a viable investment project. KfW assisted wind developers in performing early stage due diligence, and helped to develop standards, to ensure they had considered and mitigated all project risks at an early enough stage and considered all requirements in order to source subsequent private finance. Wind developers claimed that this support ensured they were able to better assess and mitigate project risks in line with the finance sector's expectations and were then able to attract the required private finance, allowing the projects to go ahead.

The technical assistance and standards provided by these SIBs better ensured projects would *fit and conform* with financiers' expectations and requirements around investments allowing developers to attract finance from an unchanged financial regime.

4.2.5 Industry co-ordination

SIBs actively intervene in the sector, identifying gaps, weaknesses, a lack of knowledge and expertise, absences of services and products etc. and use their position and involvement to co-ordinate what is required either internally or externally to the sector. Often in this case the SIB does not directly provide an instrument or capital but instead uses their expertise and 'reputation' to co-ordinate and negotiate between relevant stakeholders to ensure the required services or products are eventually implemented.

When the GIB entered the WtE sector it recognised that some developers were struggling to source finance because part of their project equipment did not feature guarantees from the OEMs. Developers state that the GIB played a key role petitioning WtE OEMs, helping to convince them to provide technology guarantees. Technology guarantees are seen as familiar de-risking instruments by the financial sector, which subsequently ensured that investors were more comfortable with the technology risks displayed by the project. Developers reported that the entry of the technology guarantee then helped leverage in private finance. This effect helped the niche *fit and conform* to the finance sector's existing expectations around technology guarantees.

German wind developers reported that KfW worked extensively with insurance firms, developing and sharing their own technical expertise, to encourage them to provide project specific insurance products for wind projects displaying project-unique and high risks, particularly during construction. Developers say the supply of appropriate wind project insurance products and the subsequent further development of the insurance industry around wind in general was key to helping them eventually attract private finance; the intervention allowed the niche to *fit and conform*. However, the insurance sector is part of the finance sector, so KfW's intervention to encourage and support the insurers to provide products for new projects, simultaneously had a *stretch and transform* effect on the insurance part of the financial regime.

Hence we see industry co-ordination interventions as having effects on both the regime and the niche. Industry co-ordination type interventions have helped the sector (niche) to *fit and conform* to investors' expectations and attract subsequent finance and to alter the finance sector (insurers for example) to *stretch and transform*.

4.3 Follow-on Effects on Niche-Regime Interactions

4.3.1 Learning-by-co-investing (Secondary Effect)

When an SIB ensures other investors participate in a project, such as via part of a syndicate or another type of co-investment environment, we have observed this lead to learning-by-doing or in this case, learning-by-co-investing. In this way co-investors became familiar with 'new' projects, the technology and business models and the risks involved, learned how to better assess and mitigate them and how to reach financial close in new and unfamiliar project settings. The private co-investors benefit from knowledge diffusion, or an exchange of information and ideas with the other participants, as well as from learning-by-co-investing. These knowledge processes and learning-by-co-investing are very important for imparting tacit knowledge. Tacit knowledge is usually knowledge that is intuitive and experienced based, is hard to communicate via written or verbal methods, and is based on action, involvement and experimentation (e.g. norms, cognition etc.) (Nelson, 2011; Nonaka, 1991; Smith, 2001). This learning-by-co-investing process changed investors' usual investment decisions (heuristics) and activities, enabling them to invest in future low-carbon projects.

For example, the CEFC's mandate states that it cannot be the lone investor or financial participant in a project: it should ensure that co-investors also participate. By implementing de-risking and capital provision interventions the CEFC has attracted private, often inexperienced, co-investors to new and innovative projects. Many investors co-invested with the CEFC (who provided market rate debt, a capital provision intervention) in various commercial grade solar PV projects featuring innovative leasing business models. Developers and investors report that these co-investors subsequently went on to initiate and invest in similar projects without the CEFC's involvement. Developers and investors working with the GIB and KfW have made similar reports, having seen investors continue to invest in low-carbon projects after their initial SIB co-investment experience.

When investors learn by co-investing, there is a *stretching and transforming* effect upon the finance sector, ensuring the financial regime changes in a way that is beneficial to the niche, allowing finance to flow to low-carbon projects. Figure 3 shows how some primary interventions can lead to this secondary learning-by-co-investing effect.

4.3.2 Establishing a Track Record (Secondary Effect)

We have observed another secondary effect that an SIB's primary interventions can lead to: the demonstration one or more projects successfully, also known as the creation of a track record. Demonstrating a project (or projects) successfully creates a track record for the unproven elements of the project. Track records are very important because investors in the financial regime require them before they will invest. Track records allow investors to observe what risks exist and how they can be assessed and mitigated. We have witnessed this effect across all low-carbon technologies where SIBs have taken the first/ early-mover or demonstration role to establish a track record for a project. Our results show that time and again, once a track record has been established, investors start showing interest in similar projects, and private finance is leveraged in.

For example the GIB provided a primary intervention of fixed, market rate, long-term debt to a first-time biomass developer who was using a new, unproven processing technology and utilising a new feedstock. Thanks to the original intervention the project reached financial close and was successfully developed. Once this 'unproven' project had been shown to be successfully implemented, the developer reported that they had no problems sourcing private finance for subsequent similar projects from financiers who were inexperienced with the technology.

The finance sector's expectations around requiring track records for unproven projects remain unchanged, and the SIB's effect is to help the project (niche) *fit and conform* into these expectations. The successful development of a project, or the establishment of a track record, has the effect of allowing finance to flow to the niche, eventually allowing the niche to enter the unchanged financial regime.

4.3.3 Trust Signalling (Tertiary Effect)

We have witnessed a final additional effect of SIB interventions relating to the creation and signalling of trust for projects. Developers and investors reported that the SIBs have developed a reputation for expertise around viable, bankable project identification and development as well as expertise for accurate risk assessment and mitigation. SIBs have in fact created their own successful investment profile and other financiers have learnt to trust their decisions. SIBs have created trust both for themselves as an investor as well as for the projects that they choose to invest in; that is, there is a 'signalling effect' on those projects. This effect has developed over time as each SIB gained experience and legitimacy, rather than as a direct result of a single or several primary interventions. Hence when an experienced SIB 'signals' a project by announcing its intention to invest, previously disinterested investors crowd-in. It seems that SIBs are able to harness existing herd mentality[13] within the financial sector. We observed this 'signalling effect' for projects announced by all of our SIBs, regardless of the technological niche analysed.

For instance the GIB announced its intention to provide market rate debt to several biomass and WtE projects, many of which comprised of something unproven or innovative, such as new technology or a first-time developer. Prior to the GIB's involvement, these projects were unable to source the debt finance they required from private investors. However, once the GIB's announcements were made public, equity and debt providers immediately crowded-in, sometimes offering even better terms than those offered by the GIB, and often resulting in an oversubscription of finance that eventually excluded the GIB from the project.

[13] Herd mentality of financial actors has been described in the literature for a long time (Buttonwood, 2015; Keynes, 1936; Scharfstein and Stein, 1990). Buttonwood (2015) summarizes this mentality: "Markets display a herd mentality in which assets … become fashionable. Investors pile in…encouraging more investors to take part".

This effect, the SIB's signal, indicates to the financial regime that the project niche is worth investing in, that it *fits and conforms*. However, one could also argue that the finance sector has learned to trust the SIB and thus altered its heuristics to include "follow the SIB". This clearly evolutionary process is a *stretching and transforming* of the financial regime. Importantly, the reputation of the SIB that enabled this effect, could only be built because of secondary effects described above (see Figure 3)

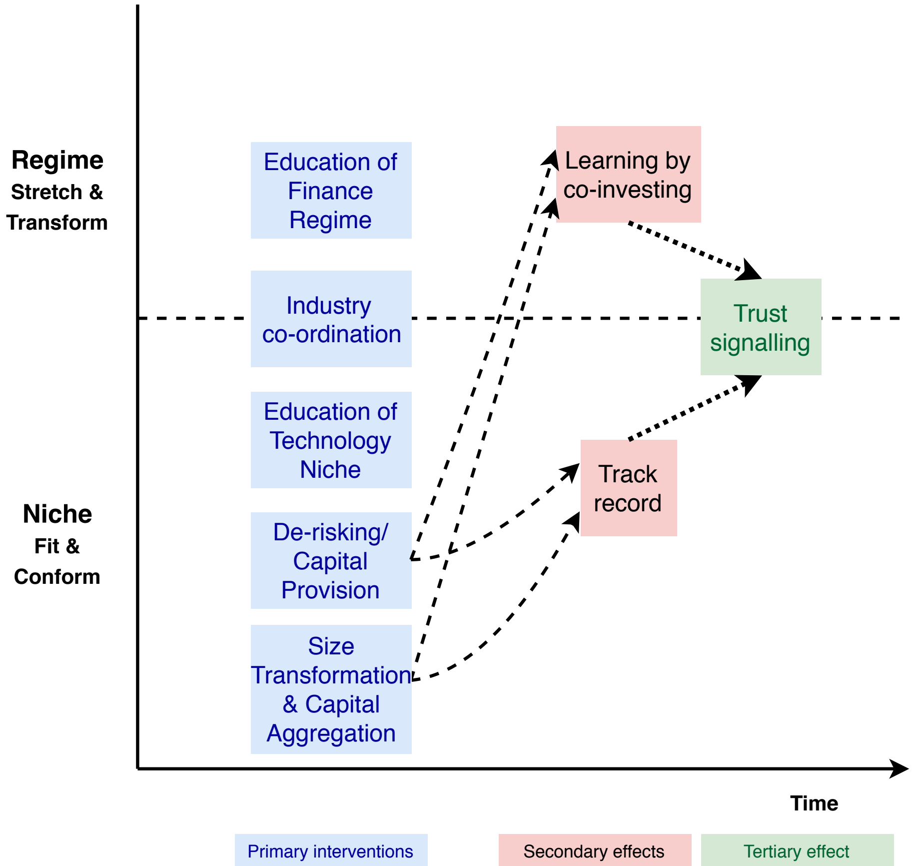

Figure 3: Primary interventions and subsequent effects

5 Discussion

5.1 Analysing the finance niche – technology regime interaction

Our work identified various factors that determine whether finance will to flow from the finance regime to technological niches, allowing these niches to enter the regime. Many new technology projects display high risks and unless a project's risk-return profile is within desirable (usually pre-determined) limits, finance will not flow to the niche. We also found that there can be a mismatch between the amount that investors are willing or able to invest and the project size of many new technology projects. Policy interventions (in our case via

SIBs) can help meet these determinants by *fitting and conforming* the niche (through de-risking and size transformation or capital aggregation) and enable finance to flow to niches. These interventions have had the effect of allowing low-carbon niches to fit and conform to existing financial regime requirements; however this is only one perspective of how the niche-regime interaction has been improved by SIB interventions.

We also see determinants related to learning and co-ordination. Developers and other niche stakeholders can display a lack of knowledge needed to attract investment and - notably - investors have not yet developed the knowledge and experience for assessing new asset classes in order to make fully informed investment decisions. Interventions enabling learning in both the niche and regime, as well as coordinating between them, are shown to be highly important and are considered to be evolutionary type interventions. These interventions have had a more diverse effect by impacting both the niche and the regime, with industry co-ordination type interventions especially having the effect of simultaneously stretching and transforming the regime whilst fitting and conforming the niche in order to catalyse finance.

Importantly, we also observe that some interventions lead over time to subsequent secondary and tertiary effects. In particular, the learning-by-co-investing (resulting in stretching and transforming of the financial regime) and the track record effects (resulting in fitting and confirming of the technological niche) allowed for private finance to flow to future subsequent projects independently and in the absence of an intervention. The observed tertiary effect of trust signalling affects both the niche and the regime. Our empirical observations of these follow-up effects show that it is not enough to look only at the immediate effect of an intervention but to also consider longer-term effects on the niche-regime interaction.

Overall although most SIB interventions and effects predominantly fit and conform the niche, we do also see SIB interventions stretching and transforming the financial regime. Those interventions that help to stretch and transform the financial regime help to overcome regime resistance. These interventions are learning, knowledge and co-ordination type interventions that would fall under evolutionary finance concepts. In fact by stretching and transforming the regime, these SIBs and their interventions are helping to break/ shift path-dependency within the financial regime. SIBs do much more than just provide patient capital provision and de-risking, something that is often called for in order to help finance flow to more innovative sectors.

5.2 Implications for transitions scholars and policy makers

Our first scholarly implication is that transition researchers should focus more on finance in their analyses. Geels (personal communcation) suspects that many transitions scholars ignore finance because they assume financial markets to be fully rational and thus not requiring intervention. Our findings support the idea that financial markets are path dependent and not technology-neutral and hence indeed require intervention.

Second, while much previous MLP-regime focused work implies that regime resistance should be overcome via destruction and rebuilding some part of it (utilities, infrastructure etc.) (Geels, 2014), our results show that financial regime resistance can be overcome via learning and adaptation. In this respect, finance might differ from other parts of the regime. Future MLP analyses could analyse the extent to which different components of the regime could be stretched and transformed through learning and adaptation vis-à-vis destruction and rebuilding. This also has implications for studies modelling transitions (Safarzyńska et al., 2012; Walrave and Raven, 2016), as these regime components have to be represented differently.

Third, we observe secondary (and tertiary) niche-regime interaction effects as a consequence of primary interventions. Interestingly, it seems that a primary intervention fitting-and-conforming the niche can result in a subsequent stretch-and-transformation of the regime. To our knowledge, this has not been detected before. However, it is possible that such secondary effects can also occur in other interactions of the niche with (non-financial) parts of the regime. Further transitions studies should consider such follow-up effects.

Fourth we have better conceptualised finance in the MLP by arguing that it is its own regime (with its own actors and institutions, set of norms, organisational and cognitive routines etc.) that interacts and partly overlaps with all the socio-technical regimes. In particular we have also shown that the financial sector can be path dependent and that this can be addressed and overcome in order to accelerate transitions.

Finally we have also demonstrated that in the specific case of SIBs, they have indeed helped accelerate the energy transition by facilitating the low-carbon technology niche and finance regime interaction. Policy makers aiming to support transitions should strongly consider finance-related policy interventions, e.g. via the use of SIBs. This work shows that designing, implementing and assessing finance policy interventions that have an effect on both the technology niche and finance regime is essential for understanding and accelerating successful socio-technical transitions. Our findings imply that, in the short term, some types of interventions only fit and conform the niches to unchanged financial regime expectations. Hence exclusively focusing on such policy interventions may mean the finance sector remains static and resistant to change, slowing down transitions. Some form of finance intervention to help stretch and transform the finance sector should be added to the policy mix in order to increase policy effectiveness. Also in the longer term, it should be noted that initial finance interventions, if implemented in ways that support innovation, can lead to secondary effects over time. This implies that assessments of interventions should consider such follow-on effects, in order to avoid an underestimation of the transformational effectiveness of the analysed interventions.

The institutions aiming to improve technological niche – financial regime interactions can be powerful if designed to operate as part of the finance regime while also utilising actors from both the finance regime and technology niche. This way the institution can design and implement policy interventions that both successfully fit and conform the niche as well as stretch and transform the finance sector.

6 Conclusions

The work makes both conceptual and empirical contributions. Conceptually, this paper makes an attempt to integrate finance into the multi-level perspective on socio-technical transitions, highlighting the validity of a finance-focussed regime paper. We provided an empirical analysis based on a dataset of 56 interviews collected from 3 countries with SIBs active in energy finance. First we identified that acceptable risk and transaction size, an abundance of knowledge in both the regime and niche and extensive industry networks are factors that determine interactions between the financial regime and technology niches. Then we analysed the SIBs' interventions in terms of their effect upon niche-regime interactions i.e. whether they resulted in fitting-and-conforming the low-carbon technological niche for the financial regime or stretching-and-transforming the financial regime, (in both cases allowing finance to flow to the niche). Finally, based on our findings, we derived insights and implications on how to accelerate transitions through policies aiming at finance as well as theoretical insights gained through our analysis. One important insight is that evolutionary processes are also relevant for the finance regime; we show that the interaction between the finance regime and technology niche can be affected in order to overcome path dependency as the finance regime undergoes learning processes.

As this is a first attempt to bring finance into the MLP literature it is not free from limitations that should be addressed in future research. The work would benefit from incorporating more countries; additional future work would be needed to analyse finance in transitions in developing countries that face additional barriers, such as political risk or even a complete absence of an operating banking sector and investment market. Models of transitions are being developed and these would benefit from including the finance sector and evolutionary approaches. This work would also benefit from an attempt to quantify the niche-regime interaction effects (compare to Egli et al. (2018) who were the first to discover the learning rate for financing using quantitative data). Future work should also examine other types of policy interventions designed to catalyse finance apart from those deployed by SIBs (e.g. feed-in tariffs) (Polzin et al., 2016). In addition work should analyse the divestment and re-direction of investment away from high carbon technologies in the regime and analyse regime-landscape interactions and changes. The role of MLP landscape changes affecting the financial regime, such as drastic changes in monetary policy, and the effect on niche-regime interactions should be analysed. For example, the quantitative easing policy of the European Central Bank resulted in additional financial flows to incumbent (highly emitting) sectors (Matikainen et al., 2017), but also technological niches. Finally, alternate sectors undergoing sustainability transitions rather than just the energy sector should be analysed. Such future work would help to improve the generalisability of findings. Notwithstanding these limitations our approach has helped to fill a research gap and can lead to a better understanding of the role of finance in MLP.

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Paper 3: The politics of opportunity-oriented climate policy: an analysis of the political discourse behind establishing green state investment banks

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Abstract

The Paris Agreement will require national level mitigation action that takes advantage of economic and technological opportunities while redirecting finance towards low-carbon alternatives. However climate change has been politicized in many countries, potentially blocking the introduction of climate change and low-carbon policies. Green investment banks (GIBs) are one policy instrument that mobilizes private finance into national opportunities. It can be hypothesized that a GIB is potentially more 'immune' to national partisanship regarding climate change. However very little is known about the political decisions behind the establishment and design of these banks and there is no account of whether the political controversy that surrounds other climate change mitigation policies also surrounds GIBs. We analyze the parliamentary discourse behind the establishment and design of the UK's Green Investment Bank and Australia's Clean Energy Finance Corporation, examining what is debated and the extent to which the political controversy level surrounding climate change is reflected in each country's GIB debate. We also investigate whether and how political controversy may shape the focus of this discourse. We find that the country's existing partisanship or consensus level was mirrored in each country's debate, indicating that a GIB as a policy instrument is not 'immune' to political controversy. We also find that the political controversy level may have influenced the focus of the debate. We discuss how these findings could inform future research.

1 Introduction

On 12 December 2015 the Paris Agreement, a global treaty on climate action, was agreed to by the world's governments (United Nations, 2015). This agreement marks a shift away from the burden-sharing mind-set of the Kyoto agreement to focus on nationally driven mitigation action, and therefore national level policy instruments, and on benefiting from seizing economic and technological opportunities (Schmidt and Sewerin, 2017). Moreover, the UNFCCC process has acknowledged the critical role of finance in addressing climate change, with parties having committed to 'making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development' (Article 2.1c of the Paris Agreement) (United Nations, 2015; Whitley et al., 2018).

However, the issue of climate change mitigation has been politicized in many countries, including the United States, Canada, Australia and the UK, and partisanship and ideological divides persist[1] (Carter, 2014; Carter and Clements, 2015; Cheung and Davies, 2017; Hale, 2010; Lockwood, 2018; McCright et al., 2016; Young and Coutinho, 2013), which can obstruct the introduction of national climate policies (Meckling et al., 2015; Schmid et al., 2019; Stokes and Warshaw, 2017). In the energy sector in particular, mitigation action is pertinent because a technological transition from high to low greenhouse gas emitting energy technologies is required in order to meet climate change goals (Bataille et al., 2016; Geels et al., 2017). Substantial investment is required for this energy sector transition (Schmidt, 2014; Steffen, 2018) and, hence, it is also important that the finance sector is brought in line with Article 2.1c of the Paris Agreement (Egli et al., 2018; Geddes et al., 2018; Knuth, 2018). Green state investment banks (GIBs) are a policy instrument that focuses on national economic and low-carbon energy technological opportunities, using public finance to mobilize the private finance needed for the energy transition. Importantly, these banks may be less politically controversial than other policy instruments, such as carbon pricing: it could be hypothesized that a GIB may be associated less with 'direct government support' and 'market distorting state intervention' activities and more with market shaping and opportunity-seizing activities (Eggleton, 2015; Geddes et al., 2018; Mazzucato and Penna, 2016). This implies that, as a policy instrument, a GIB is potentially more 'immune' to national partisanship and controversy.

GIBs have already been established by several countries (e.g. UK, Australia) and are being considered by others[2] (e.g. US, France and Indonesia) to help develop their low-carbon energy sector and green their economies (Geddes et al., 2018; Green Bank Network, 2018; OECD, 2015, 2016, 2017). While there exists literature on the various ways to design and fund GIBs (Berlin et al., 2012; NRDC, 2016), as well as on their roles in, and impacts on, the economy (Geddes et al., 2018; Hall et al., 2016; Mazzucato and Penna, 2015; Mazzucato and Penna, 2016; Mazzucato and Semieniuk, 2017), there is no empirical account on the political decisions behind, and discourse around, the establishment and design of these banks. In other words, there is no literature on how they came to exist and why they look the way they look. Similarly, while there is literature on the politics of climate change mitigation on a national level (e.g. Carter, 2014; Carter and Clements, 2015; Cheung and Davies, 2017; Jotzo, 2012; McCright et al., 2016), there is none that focuses on this new instrument and there is no

[1] This is in part due to efforts to downplay the importance of climate change by conservative actors (Dunlap and McCright, 2015; Hamilton, 2007; McCright and Dunlap, 2011; McCright et al., 2016; McKewon, 2012).

[2] In May 2019 US Senator Chris Murphy (D-CT) and several other Senators introduced the "Green Bank Act of 2019" to the US Senate, France's President Emmanuel Macron has recently called for a "Climate Bank" (Green Bank Network, 2019) and Indonesia is actively exploring the suitability of applying the green investment bank model to its economy (Climate Policy Initiative, 2019).

account of whether the political controversy and partisanship that surrounds other climate change mitigation policies also surrounds GIBs.

We aim to address this research gap by asking the research question: *What core arguments and conflict patterns can be observed in the political discourse behind the (i) establishment and (ii) design of a GIB?*

We address the research question using Discourse Network Analysis to analyze the parliamentary debates of two countries that have established GIBs: The UK and its Green Investment Bank (UKGIB), and Australia and its Clean Energy Finance Corporation (CEFC). First, we present the overall discourse networks for each country based on all the debated topics. These networks indicate that the existing political controversy level may be reflected in each country's debate. Next we examine what is debated in the discourse on whether to establish a GIB and the extent to which political controversy regarding climate change is reflected in this discourse. We find that the debate on GIB establishment focused on arguments related to high-level policy goals and the role of the state. We also find that the existing partisanship or consensus level was mirrored in each country's debate, indicating that a GIB as a policy instrument is not 'immune' to political controversy. Second, we examine what is debated during the discourse on the design of a GIB and find that debate focused on technology target sectors, tasks and tools to be implemented, and organizational aspects. Again we see the political controversy level reflected in the design discourse. Our findings also indicate that the political controversy level may have influenced the focus of the debate. In Australia where political conflict existed, members of parliament (MPs) were more inclined to debate on higher-level concepts, whereas in the UK, where political consensus existed, there was greater discussion of more detailed design issues.

The remainder of the paper is structured as follows: Section 2 describes our case selection and background of GIBs and in section 3 we discuss the method and data. In section 4 we present and discuss our results, and in section 5 we conclude with policy implications and future research.

2 Case selection and background

2.1 Case Selection

The OECD reports that 13 countries or sub-national governments have established GIBs[3] or GIB-like entities since 2015 (Green Bank Network, 2018; OECD, 2015). In order to observe the politics and political discourse behind the establishment of a GIB we chose countries that have similar political systems, display similar varieties of capitalism (Hall and Soskice, 2001) and that established their GIB at approximately the same time. Finally, we selected countries whose level of political controversy and partisanship regarding climate change and energy policy were different at the time the GIB's establishment was under debate. Thus we selected "most similar cases", where cases are similar on important variables other than the main exploratory and/or dependent variable (Seawright and Gerring, 2008). We maintained similar political systems (Westminster-style democracy), varieties of capitalism (liberal-market economy) and GIB establishment timing (2012) in our selection in order to control for these features so that we can observe whether a variation in political controversy towards climate change and energy policy is then reflected in the GIB debate. In our case the dependent variable (the establishment and design of a GIB) is similar whereas the key explanatory variable (political controversy towards climate change) differs. The cases selected for final study were the UK and its UKGIB and Australia and its CEFC, both GIBs established in 2012. A description of each country's parliament and political parties can be found in Appendix 1.

2.2 Background & political history of the UKGIB

The UK has a long history of dependency on fossil fuel generation, however it has made progress in terms of its low-carbon sector, having achieved a share of installed renewables of 8% in 2012 at the time of the GIB's establishment (Figure A2 in Appendix 2) (BEIS, 2018). From 2006 the issue of climate change rapidly climbed the political agenda, underpinned by growing public concern over climate change (Carter, 2014; Carter and Clements, 2015). This saw the major political parties start to compete over who was the most environmentally progressive (Carter, 2014). The Labour Government (Tony Blair 1997-2007, Gordon Brown 2007-2010) implemented a spate of climate change and energy policies from 2006 amid this consensus-building phase and the UK became the first country to legally commit to an ambitious emissions reduction target in 2008 (Carter, 2014; Carter and Clements, 2015; CCA, 2008). After the 2010 election, the new Conservative-Liberal Democrat coalition Government

[3] The OECD defines a GIB or GIB-like entity as a "public, quasi-public or non-profit entity established specifically to facilitate private investment into domestic low-carbon, climate-resilient infrastructure" (Green Bank Network, 2018).

(2010-2015), led by Prime Minister David Cameron, initially maintained this non-partisan momentum towards climate and energy policy making (Carter, 2014; Carter and Clements, 2015).

The idea of a green bank was first raised by various advocacy groups, think-tanks and NGOs, including e3g, Climate Change Capital and the Friends of the Earth, wherein a grassroots campaign was run until the Liberal-Democrats proposed a UK Infrastructure bank in 2009 (Holmes, 2013; OECD, 2016). Soon after all three main parties had included plans to establish a GIB in their party manifestoes, reflecting the competitive 'one-upmanship' between parties around climate change policy (Carter, 2014). The UKGIB's establishment debate occurred towards the end of this politically non-partisan phase, and soon after the 2008 financial crisis, amid strong calls to stimulate, diversify and 'green' economic growth. The Enterprise and Regulatory Reform Bill 2012, containing legislation pertaining to the UKGIB's establishment and mandate, was introduced by the Conservative-Liberal Democrat coalition to the House of Commons on 23 May 2012, passed to the House of Lords on 18 October 2012 and eventually received Royal Assent on 25 April 2013 (Enterprise and Regulatory Reform Act 2013, 2013; UK Parliament, 2013).

2.3 Background & political history of the CEFC

The fossil fuel sector has historically dominated Australia's economy, both export-wise and via domestic generation and consumption (Crowley, 2017). Its energy mix reflects an incumbent fossil fuel industry heavily dependent on coal and, more recently, natural gas with a share of installed renewables of 6% in 2012 at the time of the CEFC's establishment (Figure A2, Appendix 2) (AER, 2012). There have been a range of impediments to the financing and deployment of low carbon projects, many related to "entrenched political and economic interests of the fossil fuel industry" (Cheung and Davies, 2017; Hamilton, 2007) and on-going policy uncertainty (Cheung and Davies, 2017; Geddes et al., 2018; Jotzo et al., 2012; Kann, 2009; Nelson et al., 2013; Nelson et al., 2012; Simshauser, 2018). In contrast to the UK, both climate change and associated energy policy have been heavily politicized in Australia (Hamilton, 2007; Jotzo, 2012; Rootes, 2014; Warren et al., 2016). The electricity sector has faced increasing levels of political conflict and policy uncertainty since the 1980s when climate change first arrived on the political agenda (Warren et al., 2016). This has also been complicated by the ever-changing positions on climate change and energy policy of the two major political parties, Labor and Liberals, as they undergo internal conflict and division (Cheung and Davies, 2017; Crowley, 2013; Warren et al., 2016). Cheung and Davies (2017) found that "energy policy is primarily a political and ideological issue rather than one driven by underlying economic conditions" (Cheung and Davies, 2017, p96).

Prime Minister Julia Gillard's minority Labor Government (2010-2013), supported by Green and Independent MPs who held the balance of power in both houses, announced the CEFC in July 2011 as part of its Clean Energy Future Package (DCCEE, 2011; Jotzo, 2012; Jotzo et al., 2012). But it was the Green party that originally pushed for the establishment of the CEFC and made other climate policies, such as carbon pricing, conditional in return for their on-going support for the minority government (Jotzo, 2012; Rootes, 2014). The opposition leader at the time, Tony Abbott (Liberal party), maintained an unrelenting attack on the Government throughout its term, focusing in particular on denouncing its climate change policies and declaring the carbon price to be "a great big tax on everything" (Rootes, 2014). It was against this political backdrop that the Clean Energy Finance Corporation Bill 2012 was introduced to the House of Representatives on 23 May 2012, then the Senate on 18 June 2012 before eventually passing both houses as of 25th June 2012 (Clean Energy Finance Corporation Act 2012, 2012).

3 Data and Method

3.1 Data

We collected primary data in the form of parliamentary debate documents from each country's official online Hansard[4] archive (Parliament of Australia, 2019; UK Parliament, 2019b). For each country we performed a word search in both chambers of parliament for documents containing the exact phrase "green investment bank" for the UK and "clean energy finance corporation" for Australia, filtering until 11/10/2018. This returned 1255 UK documents and 820 Australian documents. We then identified the key bill that was debated in each parliament in order to establish a GIB and identified the date at which each bill was passed into law. In the UK this was the "Enterprise and Regulatory Reform Bill 2012", which passed through both houses as of 17 October 2012. In Australia this was the "Clean Energy Finance Corporation Bill 2012", which passed both houses as of 25th June 2012. We then removed debates that occurred after these dates in each country, removed any duplicate debate documents and any documents that did not contain public debate (daily programs, notice papers, orders of business, journals and procedures etc.). We were left with 308 debate documents in total (189 UK, 119 Australia).

[4] A Hansard is a transcribed report of what is said in Parliament and includes decisions taken and how Members vote during a parliamentary sitting (Parliament of Australia, 2019, UK Parliament, 2019b).

3.2 Method

Our overall analytical approach is based on Discourse Network Analysis, a mixed-methods technique combining qualitative content analysis and quantitative social network analysis (Leifeld, 2013, 2016). We proceeded in four steps. First the transcriptions of the parliamentary debates were uploaded into the Discourse Network Analyzer (DNA) software to allow analysis of the qualitative content (Leifeld, 2013, 2016). Second, the data was coded within the DNA software. A codebook was built using a bottom-up iterative process where conceptual groups were categorized and then abstracted into meta-categories to answer the research questions. The codebook can be found in Appendix 3 and contains 46 categories that were aggregated into five meta-categories. From the 308 documents, we coded 2811 statements (arguments) by 197 Members of Parliament (a list of MPs can be found in Appendix 4). Three researchers were involved in the coding process, with two researchers coding material and a third acting as a control check on the original coders, in order to improve reliability of the coding (Eisenhardt, 1989).

Third, to explore the politics behind the establishment of GIBs, we analyzed the coded parliamentary debates using Discourse Network Analysis (Leifeld 2013, 2016). With this method, we were able to distil political networks from the parliamentary debates. By coding text data, we linked actors, i.e. individual MPs, to concepts, i.e. arguments for or against GIB establishment and design (see Appendix 5 for an overview of the model). Based on this coding, we can project one-node networks of MPs. In such networks, we can visualize clusters of MPs that share a common set of arguments related to GIBs. Hence, on an abstract level the method allowed us to explore differences in partisanship in our two cases. Fourth, we zoomed into different topics debated about GIB establishment and design. To do so, we plotted the relative frequency of both negative and positive argument categories across the two cases, and differentiated by political party. These descriptive statistics allow us to give exploratory insights into the saliency and partisanship around various argument categories related to the establishment and design of GIBs.

4 Results

The results and discussion are structured as follows: In Section 4.1 we present the general overview of the discourse in each country, investigating the discourse networks and the distribution of the overall categories debated in each country. In Section 4.2 we then investigate the categories debated during the discourse on whether a GIB should be established, namely high level policy goals and role of the state. Finally in Section 4.3 we examine the categories debated during the discourse on a GIB's design, namely a GIB's target sectors, tasks and tools and organisational aspects.

4.1 General characterization of the discourse

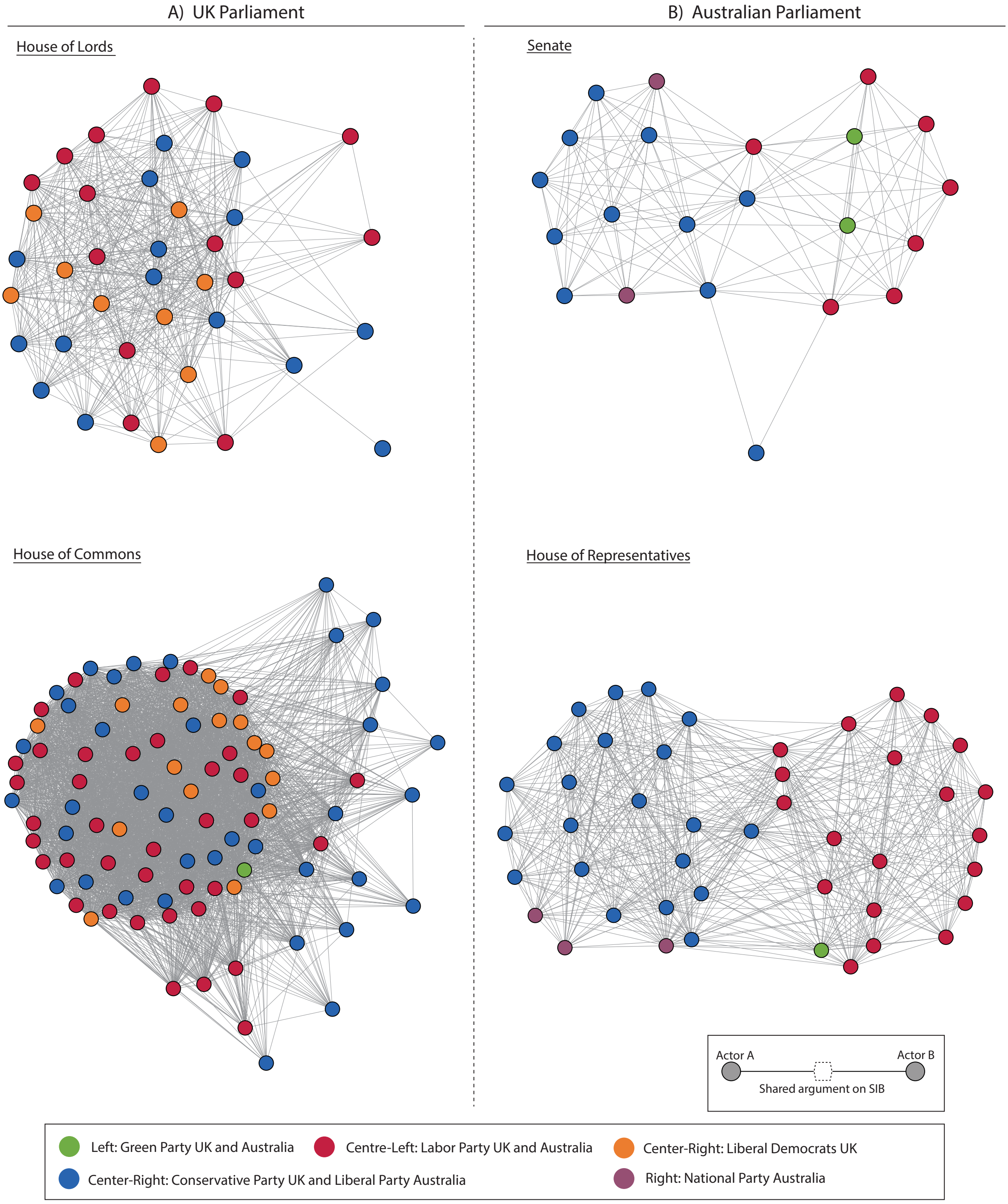

Figure 1: Discourse networks during parliamentary debates in the UK and Australian parliaments regarding the establishment and design of a green investment bank (GIB). In the one-node support affiliation networks, nodes are members of parliament (MPs) that coalesce around arguments on GIBs. Two actors (MPs) are linked if they share an argument about GIBs (see legend). Networks are based on all arguments on GIBs (for the codebook see Appendix 3). Colors indicate MPs' individual party affiliation (see legend). Refer to Appendix 4 for the list of MPs. Networks are based on 2811 coded statements from 308 parliamentary debate documents (from all four chambers) on the establishment and design of GIBs, from 2010 to 2013. The graph layout is based on stress minimization.

Figure 1 shows the discourse networks observed during parliamentary debates in the UK and Australian parliaments regarding the establishment and design of a green investment bank (GIB). The key observation here is that while the UK parliament consists of one large network cluster with few outliers, the Australian parliament is composed of two clearly separate clusters. In other words, our analysis reveals broad consensus between MPs of all party-colors in the UK parliamentary discourse whereas we see strong polarisation between left-wing and right-wing parties in the Australian parliamentary discourse. On a high level, this indicates that the partisanship around climate change in Australia also affected the discourse around the establishment of its GIB. We see similar clustering in both legislative chambers for each country. In order to better understand the (non-)partisanship patterns seen in Figure 1, below we examine the types of arguments voiced in the debates, delineating by political party, before zooming into the details behind individual argument categories.

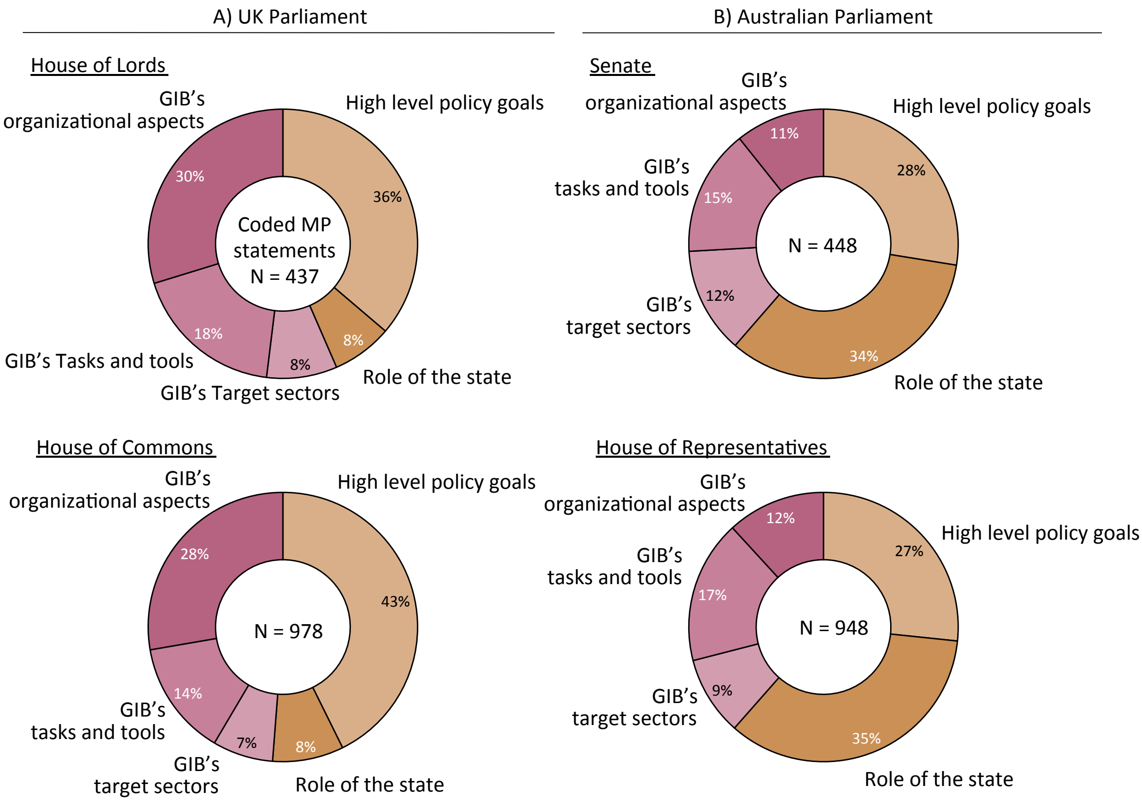

Figure 2: Overall distribution of debated topics in both legislative chambers in Australia and the UK. N represents the number of arguments made per chamber. Role of the state and high level policy goals are categories debating the higher level question as to whether a GIB should be established. GIB's organisational aspects, tasks and tools and target sectors are categories concerned with debate around a GIB's design.

Figure 2 shows the overall distribution of debated statements by category, separated into each country's two legislative chambers. There are two important findings. First, categories that are concerned with the a GIB ‘s design (GIB’s target sectors, tasks and tools and organizational aspects) received more attention in the UK than in Australia, where debate on categories concerned with whether to establish a GIB (high level policy goals and the role of the state) were of greater focus. Second, there is little difference in the distribution of debate topics between the two houses in the UK and likewise for the two houses in Australia.

Because for each country the network clustering is similar in both houses (Figure 1), and the overall distribution of categories discussed do not significantly differ between houses (Figure 2), in the following analyses, we aggregate the data in both houses for each country. Given the large proportion of arguments on the role of the state and high level policy goals linked to establishing a GIB in both countries, we next take a more detailed look at this category.

4.2 Discourse on whether to establish a GIB

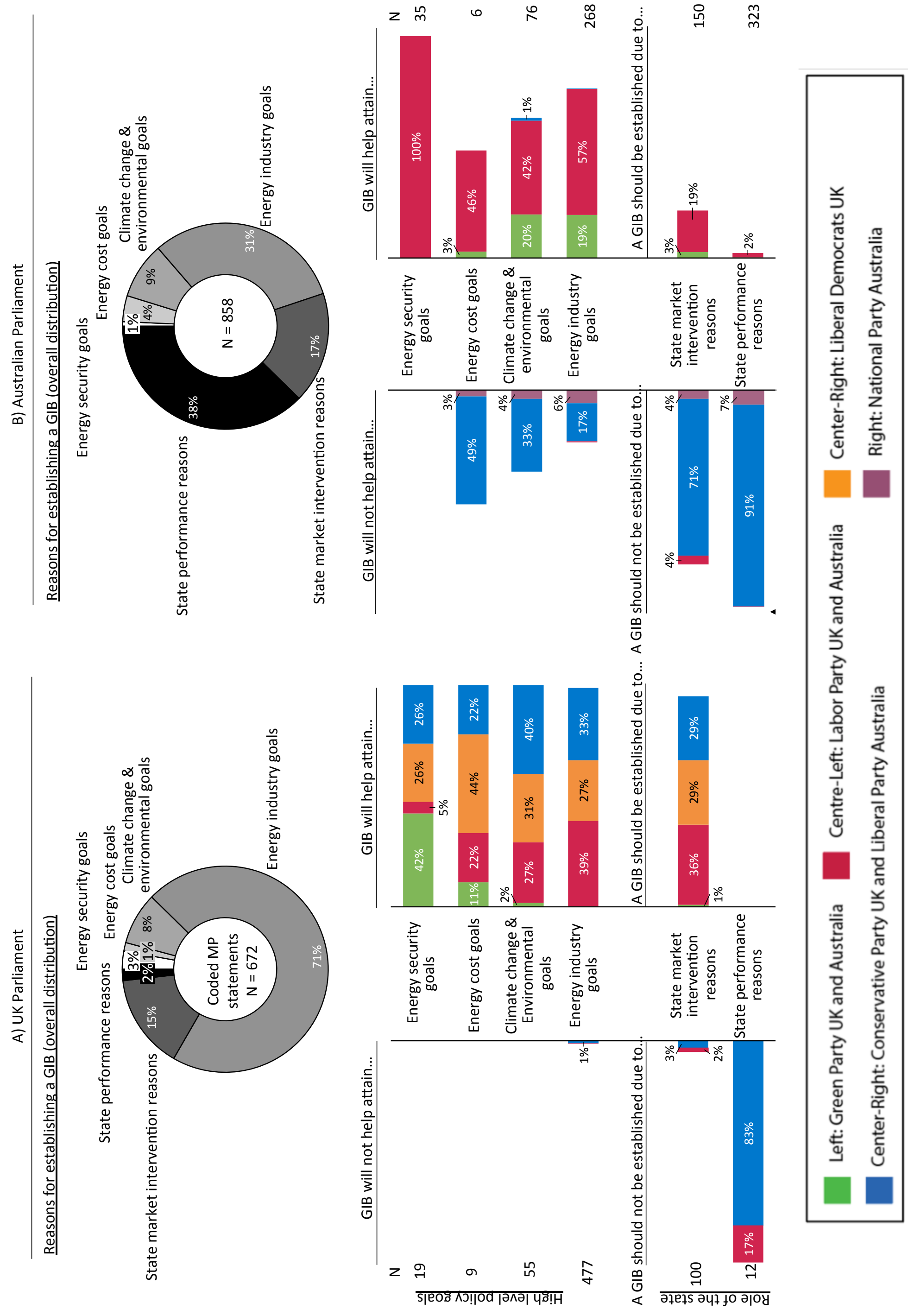

Figure 3: Reasons for establishing a GIB: Attaining high level policy goals and the role of the state. The doughnut charts show the overall distribution of disaggregated argument categories. Here N represents the total number of arguments made regarding the high level policy goals and the role of the state. The bar charts show the distribution of arguments either in support of establishing a GIB (right side for each country) or in opposition to it (left side for each country). Here N represents the total number of arguments made for each argument category. The breakdown of each argument category by an MP's political party affiliation can also be seen by color and per cent.

When debating whether the country should or should not establish a GIB, MPs' arguments fell into two broad categories: Whether establishing a GIB will help to attain high-level policy goals and reasons relating to the role of the state. In Figure 3 we disaggregate these argument categories and the following four main observations can be made. Firstly, there is a difference in the emphasis of the high level debates for each country (doughnut charts). The UK debates centered on whether establishing a GIB would help meet energy industry goals (to be discussed in detail next) whereas in Australia the debate focused on role of the state type arguments, in particular state performance. One Australian MP opposed to establishing the CEFC argued, "We have seen first hand the problems created when a government backs a so-called winner…the monumental collapse of the Queensland government's ZeroGen project, costing taxpayers well over $100 million of losses". Secondly, and somewhat surprisingly, in both countries there were very few arguments around whether establishing a GIB would help meet energy cost goals, despite energy poverty being considered a very important issue in the UK (Becker et al., 2019; Middlemiss, 2017; NEA, 2019) and Australia paying some of the highest retail energy prices in the world (Mountain, 2012). Thirdly it is also interesting that there wasn't more debate in either country regarding whether a GIB would help or hinder the attainment of climate change and environmental goals, given that this could be considered one of the main motivations for establishing such a bank.

Finally our analysis in the bar charts of Figure 3 also allows us to gain new insights on the partisanship of the debated topics: the UK shows clear consensus for most of the argument categories whereas the Australian data indicates strong partisanship, with debate occurring along clear party lines: we see support for the CEFC's establishment coming almost exclusively from the left leaning parties and opposition arguments predominantly from the right leaning parties. It is interesting that center-right and right parties in the UK showed almost no opposition to the bank for reasons regarding the role of the state regardless of the fact that the center-right Conservative party has historically been against 'unwarranted' government intervention in markets, being more supportive of liberalized market ideology (Carter, 2014; Carter and Clements, 2015).

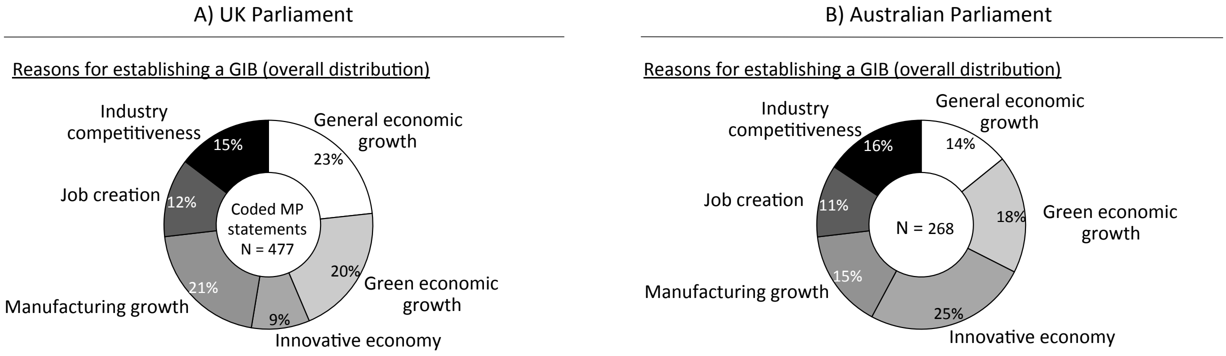

Figure 4: Reasons for establishing a GIB: Disaggregation of energy industry goals. The doughnut charts show the overall distribution of the disaggregated argument categories. Here N represents the total number of arguments made regarding the energy industry goals category.

In Figure 4 we zoom into the energy industry goals category for each country because this category featured a large number of statements and included a wide variety of sub-arguments. In the charts we observe a somewhat similar distribution of debated topics for each country. However the UK was more focused on whether a GIB's establishment would help support manufacturing growth and general and green economic growth, whereas in Australia the debates focused more on whether a GIB will help foster an innovative economy. A UK MP argued that "A GIB will support the growth, industrial transformation and greening of the UK economy" and an Australian MP asserted that "[…] the CEFC [will] generate innovation and get behind the research, development and exploitation that have so often been missing in creating a more diverse economy than we have at this point."

The focus in both countries on energy industry goals shows that economic opportunity arguments were central to discussions in both countries. Importantly, many of the energy industry goals that were debated, such as the green economic growth and innovative economy arguments, are beyond the traditional industry policy arguments indicating that 'green' industrial policy (Rodrik, 2014) was considered relevant within these countries' political debates. This, however, did not make GIBs immune against political controversy around climate change (as shown in Figures 1 and 3)

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4.3 Discourse on the design of a GIB

Figure 5: Design of a GIB: Target sectors. The doughnut charts show the overall distribution of disaggregated argument categories. Here N represents the total number of arguments made regarding the target sectors that a GIB should or shouldn't invest in. The bar charts show the distribution of arguments either in support of investing in a certain target sector (right side for each country) or in opposition to it (left side for each country). Here N represents the total number of arguments made for each argument category. The breakdown of each argument category by an MP's political party affiliation can also be seen by color and per cent.

MPs also debated various design features in relation to a GIB. In Figure 5 we take a more detailed look at the debate regarding what a GIB should or shouldn't invest in, in terms of target technologies and sectors. Both countries' debates mostly focused on renewable energy technologies (RETs), particularly in Australia. Energy efficiency technologies (EET) were discussed much less in both countries, which may reflect a general lack of knowledge of the sector and its financing, which is considered complex (Yeatts et al., 2017). There was also very little debate around support for ("clean") fossil fuel technologies and carbon capture and storage (FFT & CCS) in either country despite a large coal generation sector in Australia and coal generation and carbon intensive industries (e.g. steel, cement etc.) in the UK (POST, 2012; Vallak et al., 2011). Nuclear is banned in Australia and was not discussed at all and its debate in the UK may have been minimal because support for nuclear energy was conditional on EU state aid approval (approval that was not given) (Ares, 2017; BIS, 2011). Again for the most debated topics we can see generally more consensus in the UK debates whereas we see partisanship along party lines in the Australian debates. There was some opposition by UK MPs to certain arguments, namely FFT & CCS and nuclear, but this opposition was minimal and not partisan.

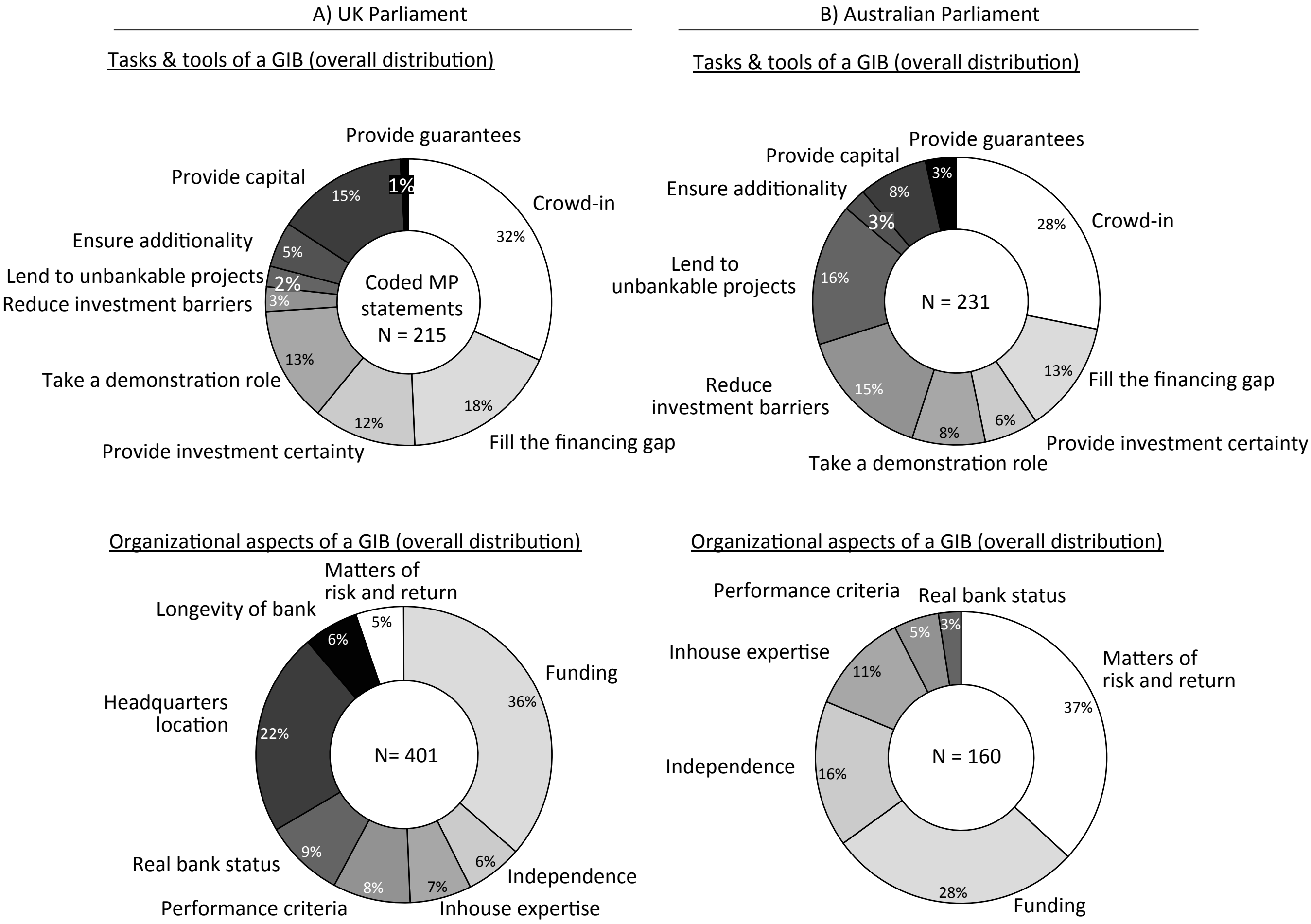

Figure 6: Design of a GIB: Tasks and tools, and organizational aspects. The doughnut charts show the overall distribution of disaggregated argument categories debated around the tasks & tools (top charts) and organizational aspects (bottom charts) of a GIB. Here N represents the total number of arguments made regarding the tasks and tools of a GIB (top charts) and the organizational aspects (bottom charts).

In addition to a GIB's target sectors, MPs also debated two other design features, namely the tasks and tools to be fulfilled and implemented by a GIB, and organizational aspects. Figure 6[5] presents more detail on the debate around these features. As seen in the upper charts, arguments that the GIB should attract private investment as co-investors and thereby "crowd-in" private finance to the low-carbon sector dominated both countries' discussion about the tasks and tools of a GIB, with one UK MP asserting that "the GIB is about crowding in private sector investment into a viable green economy". This was closely followed by arguments in both countries that it should 'fill the finance gap' faced by low-carbon projects.

[5] Much of the debate on tasks and tools and organizational aspects was too nuanced and complex to display the consensus and partisanship in the figure. Therefore we have not included a graphical representation of partisanship for this part of the debate.

Debate in the UK was then more concerned with ensuring the GIB provided investment certainty, played a demonstration role and that it should provide capital (market rate debt and equity finance), whereas Australia was more focused on concerns about a GIB's role in reducing investment barriers and lending to un-bankable projects. As an Australian MP argued, "In our view, the remit of the CEFC should be to look for genuine, commercially acceptable projects. It should not be markets that are unproven or too speculative or too risky for any investor to touch with a 40-foot barge pole."

As seen in the lower charts of Figure 6, discussions around funding received much attention in both countries. The bulk of the debate in the UK focused on when the GIB would have access to capital markets with MPs arguing that "The green investment bank will be critical to the transition that we need, but it absolutely has to be a real bank, not just a fund in the Treasury with "bank" attached to it. It has to be a genuine bank that can lend money, raise money, raise bonds and so forth." In comparison, funding arguments in Australia were mostly about how the CEFC would be accounted for in the government budget (whether it's entire foundation funding should be accounted for or just it's predicted 7% loss). Matters of risk and return, i.e., that the CEFC should take more or less risk than that proposed, should perform risk reallocation, should take higher risks because it's supporting more innovative technology, accept more or less of a return etc., were greatly debated in Australia. The location of the headquarters of the UKGIB was important to the UK. Although not shown in Figure 6, once more we saw greater consensus in the UK and partisanship in Australia around these design issues.

5 Discussion and Conclusions

Analyzing the political discourse behind the establishment and design of these GIBs has shed light on the politics behind their establishment, why they look the way they look and whether there is similar political controversy surrounding them as surrounds other climate change mitigation policies.

Firstly our findings indicate that a GIB as a policy instrument is not 'immune' to the existing level political controversy or partisanship. When the establishment of a GIB was being debated, Australian politics was considerably more partisan around climate change than that in the UK (Carter, 2014; Carter and Clements, 2015; Rootes, 2014; Warren et al., 2016). Our results show that the existing partisanship or consensus level was also manifested in each country's debate, with Australia's debates displaying distinct partisanship on all debate topics, whereas the UK's debates displayed clear consensus on the majority of debated topics. These findings imply that overall, because the level of political conflict or consensus may be mirrored in the debates behind the establishment and design of a GIB, either a political consensus or a government majority may be needed to pass through legislation to establish such a GIB.

Secondly, our findings indicate that the political controversy level can have an impact on what is debated. Debate on higher-level concepts, especially the role of the state in relation to a GIB's establishment, received more attention in Australia where political conflict existed: MPs were therefore potentially more inclined to debate whether a GIB should be established at all and why it should or should not be established. In the UK however, there was greater discussion of organizational aspects, where the existing political consensus potentially meant MPs were more inclined to debate GIB design details, such as bank headquarters location. UK MPs were already in agreement that a GIB should be established and that it would create co-benefits by helping to meet the high level policy goals of energy industry, cost, security and climate change and environmental goals. These findings imply that if the establishment of a GIB is introduced during times of political consensus, debate may be more centered on the detailed qualities of a GIB's design, and hence there is an opportunity for legislators to have greater influence over these aspects. This finding relates to the literature on policy design (Howlett, 2014; Howlett et al., 2015; Schneider and Ingram, 2008) and stresses the need to better understand the role of partisanship in design processes (something that is hardly done in this literature).

Thirdly, for mitigation action on a national level there are different political issues than those seen at the international level: instead of the fair burden-sharing controversy there has been a shift to seizing economic and technological opportunities (Schmidt and Sewerin, 2017). Our findings confirm this opportunity-oriented perspective, with a large proportion of arguments on GIBs emphasizing the opportunity, and not the cost, of this climate change mitigation instrument. Nevertheless this policy was not immune to controversy. Even opportunities for certain industries within a country can be seen as disadvantages for other incumbent industries, which was the case in Australia but not in the UK (Hughes and Urpelainen, 2015). Hence introducing policies to help maximize (green) industrial developmental opportunities and attain industrial goals, for example via the establishment of a GIB, can also face political conflict. We also see that where there is partisanship around climate change, parties that have traditionally played down climate change or denied its existence, i.e. the more conservative or center-right parties (Dunlap and McCright, 2015; Hamilton, 2007; McCright and Dunlap, 2011; McCright et al., 2016; McKewon, 2012), are at the same time often against state intervention in (financial) markets. This presents a problem for policy instruments such as GIBs that address climate change while simultaneously aiming to create and shape national low-carbon economies (Mazzucato and Penna, 2016).

Finally we saw surprisingly little debate on certain topics that are relevant for establishing and designing GIBs. First, the low number of arguments on whether a GIB would help or hinder the attainment of climate change and environmental goals (cf. Fig. 3) is similar to findings in Schmidt et al. (2019) where the authors found only minimal discussion of environmental goals compared to industry policy goals in German parliamentary debate on policy supporting renewable energy. Second, other than a GIB's demonstration role, few of the roles of green state investment banks identified in other literature, such as in Geddes et al. (2018) or Mazzucato and Penna (2016), were debated (cf. Fig. 6). Third, there was also little discussion around the tools (financial instruments) that a GIB should implement. This may be because these banks were among the first of their kind and hence the roles and tools discussed in more recent literature were not well known at the time of debate.

This is the first work to investigate the political discourse behind a GIB. Such banks are gaining popularity as a policy instrument for national level climate policy (Green Bank Network, 2019). Given their potential versatility, effectiveness and wide reach (Geddes et al., 2018; Mazzucato and Penna, 2016), more governments are beginning to debate their establishment and deliberate over decisions concerning their design and operation (Green Bank Network, 2019). Our findings are particularly relevant given that political debate to establish a national GIB is about to commence in the United States where climate policy is highly controversial and partisan (McCright and Dunlap, 2011; McCright et al., 2016).

Nevertheless this work would benefit from expanding it to include more than these two empirical cases. We limited our data to political parliamentary debates but this work could be expanded to investigate the political discourse behind GIBs within public opinion, the media and even the role of cross-country GIB advocacy groups such as the Green Bank Network. A longitudinal analysis could provide further insights as to how politics and partisanship play a role over time. After its establishment the CEFC survived several attempts to abolish it and it underwent regular mandate changes. Similarly, the UKGIB was eventually privatized: it is no longer mandated to focus exclusively on UK projects and may no longer be legally bound to achieve its original environmental performance requirements (Cumbo, 2019; Pratley, 2018; Vaughan, 2018). Extending the time frame of this work could show how the political controversy level and partisanship of the debate changed over time and what impact it may have had, i.e. what role it played in the attempted abolition of the CEFC, what impact it had upon any mandate changes and what role it may have played in the eventual privatization of the UKGIB. There could also be value in studying cases that feature different varieties of capitalism to contrast the liberal-market economy variety of capitalism of the UK and Australia, to countries with a more coordinated market economy, such as France, where a climate bank is also being considered. Insights may also be gained by examining whether other climate or energy policy tools are more immune to existing political controversy levels, such as government run power auctions, which may also be considered a less direct form of government intervention. Finally by investigating the history and origins of GIBs, and how they came to be introduced to parliament, we may be able to determine what it takes for a country to start considering a GIB at the political level and why those who are well placed to implement such a tool, such as Switzerland for example, have not yet done so.

With this work we have made a first contribution towards investigating the political discourse behind GIBs and have shown that politics matters for this potentially important policy instrument. These findings are relevant for other countries as they look to implement climate finance policies to operationalize the Paris Agreement and mobilize the finance essential for addressing climate change.

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Appendix 1

Parliament and Political Party Description

Both countries follow a Westminster-style democracy featuring two legislative chambers; an upper and a lower house. Legislation, in the form of a bill, introduced in one house must pass through both houses in order to receive assent and pass into legislation.

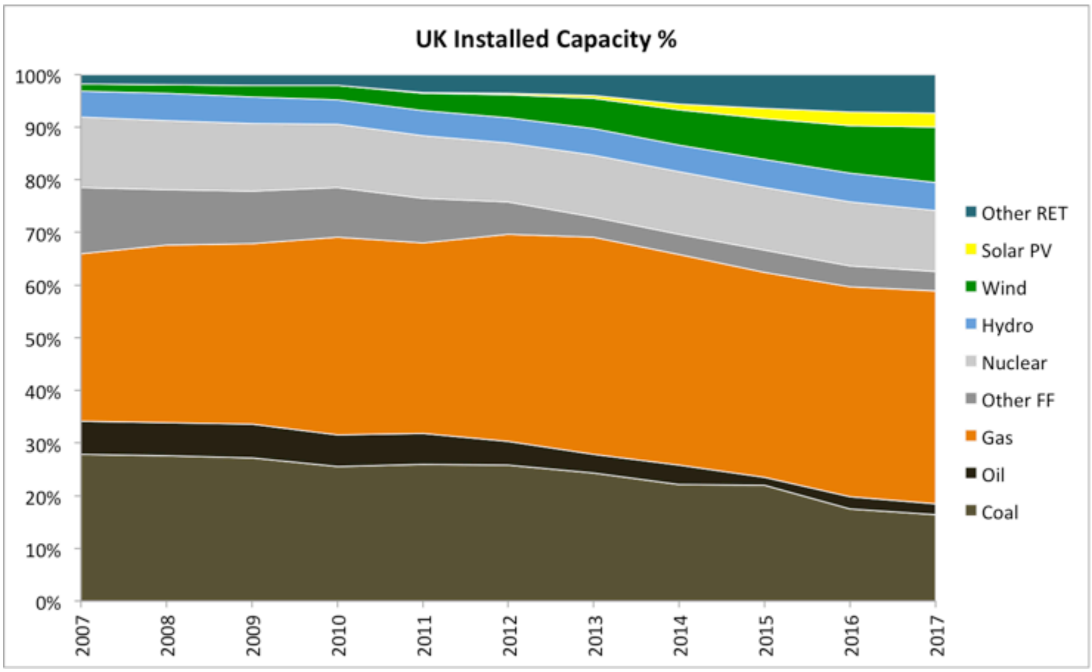
The UK

The UK's lower chamber is known as the House of Commons and upper as the House of Lords and whereas the Commons is elected, the Lords is appointed (UK Parliament, 2018b). The House of Lords has limitations on its powers and apart from very particular circumstances cannot reject government legislation: it uses its time to provide detailed checks on legislation, can delay bills and provide a check on the power of the Commons. The main political parties in the UK include the Conservative party (center-right, officially known as the Conservative and Unionist Party), the Labour party (center-left), the Liberal Democrats (centrist), and there are several minority parties including the Greens (left, officially known as the Green Party of England and Wales) (UK Parliament, 2018a).

Australia

In Australia the chambers are the House of Representatives (lower house) and the Senate (upper house), which is modeled on the American senate, and unlike the UK's Lords it is elected (House of Representatives, 2018). Also unlike the UK's House of Lords the Australian Senate can reject government legislation but does have some restrictions on its power in relation to certain financial legislation. The political parties in Australia include the Australia Labor Party (center-left, ALP), the Liberal Party of Australia (center-right, the Liberals) and the Nationals (right), who together often form the Liberal-Nationals coalition, and several other minor parties, such as the Australian Greens (left), and independent members (House of Representatives, 2019).

Appendix 2



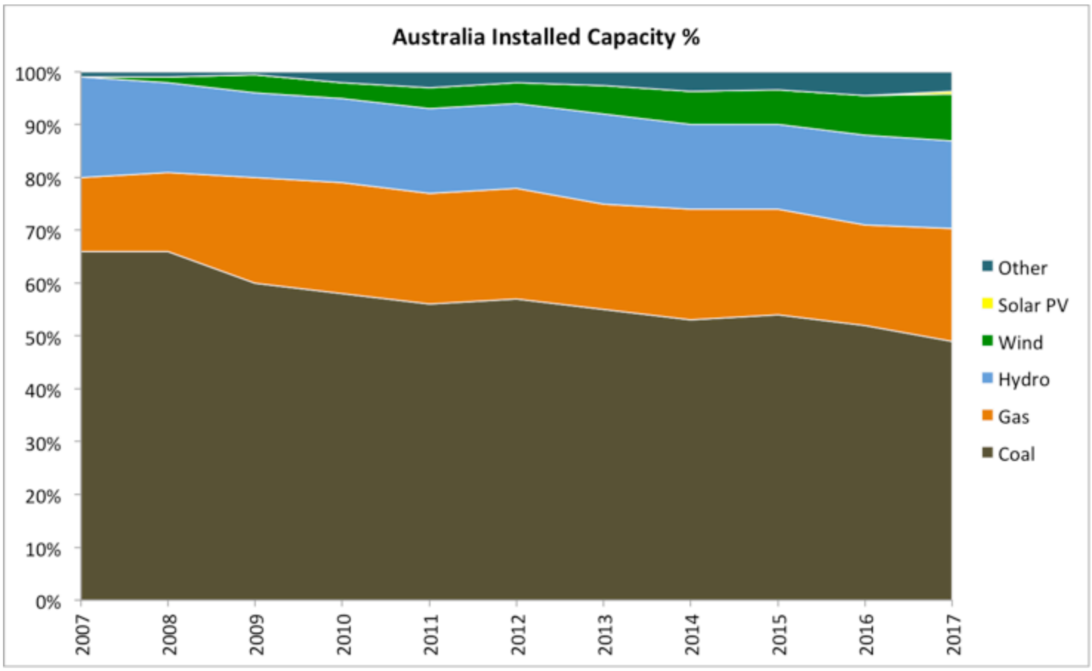


Figure A2: Country energy mix. Installed capacity % by fuel type for UK and Australia (AER, 2018; BEIS, 2018)

Appendix 3

Table A3: Codebook

Meta-category	**Argument category** (N) negative argument	**Description**
A GIB should(n't) be established because…		
Role of the state	State market intervention reasons	Governments should intervene in markets, they can address market failures, they can 'pick winners' and help shape and create markets
	State market intervention reasons (N)	Governments shouldn't intervene in markets, they can't address market failures, they can't 'pick winners' and they distort markets
	State performance reasons	Government programs are successful, similar programs have succeeded elsewhere
	State performance reasons (N)	Government programs fail, are inefficient, wasteful (of tax payers' money) and expensive
A GIB should(n't) be established because it will (not) help to attain…		
High level policy goals	Energy security goals	Establishing a GIB will help attain energy security goals, will improve energy security/diversity and system security
	Energy security goals (N)	Establishing a GIB will not help attain energy security goals, will not improve energy security/diversity and system security
	Energy cost goals	Establishing a GIB will help attain energy cost goals, reduce energy/electricity costs
	Energy cost goals (N)	Establishing a GIB will not help attain energy cost goals, it will increase energy/electricity costs
	Climate change and environmental goals	Establishing a GIB will help attain climate change and environmental goals, reduce GHG/CO2 emissions, reach RE & emissions targets, reduce pollution etc.
	Climate change and environmental goals (N)	Establishing a GIB will not help attain climate change and environmental goals, reduce GHG/CO2 emissions, reach RE & emissions targets, reduce pollution etc.
	Energy industry goals	Establishing a GIB will help attain energy industry goals
	Energy industry goals (N)	Establishing a GIB will not help attain energy industry goals
	Energy industry goals sub-categories:	
	General economic growth	Establishing a GIB will support/ stimulate economic growth
	General economic growth (N)	Establishing a GIB will not support/ stimulate economic growth
	Green economic growth	Establishing a GIB will support/ stimulate green economic growth, support green technological growth, create a green economy
	Green economic growth (N)	Establishing a GIB will not support/ stimulate green economic growth, support green technological growth, create a green economy
	Innovative economy	Establishing a GIB will support/ stimulate a more innovative economy, support innovative growth and novel/innovative markets, create an innovative economy, stimulate innovative technology
	Innovative economy (N)	Establishing a GIB will not support/ stimulate a more innovative economy, support innovative growth and novel/innovative markets, create an innovative economy, stimulate innovative technology
	Manufacturing growth	Establishing a GIB will support (local) manufacturing growth, manufacturing innovation, low-carbon manufacturing & industry etc.
	Manufacturing growth (N)	Establishing a GIB will not support (local) manufacturing growth, manufacturing innovation, low-carbon manufacturing & industry etc.
	Job creation	Establishing a GIB will lead to job creation, employment, low-carbon jobs
	Job creation (N)	Establishing a GIB will not lead to job creation, employment, low-carbon jobs, it will reduce jobs in the fossil fuel industry

Meta-category	**Argument category** (N) negative argument	**Description**
	Industry competitiveness	Establishing a GIB will improve industry/ manufacturing competitiveness, create opportunities, help industry catch up
	Industry competitiveness (N)	Establishing a GIB will not improve industry/ manufacturing competitiveness, create opportunities, help industry catch up
A GIB should(n't) invest in…		
Target sector	Renewable energy technology (RET)	Renewable energy technologies, solar PV/ thermal, off/on-shore wind, waste-to-energy, biogas, biomass, tidal, wave, estuary, geothermal
	Energy efficiency technology (EET)	Energy efficiency technologies, industry EE, buildings EE, insulation etc.…
	Fossil fuel technology and carbon capture and storage (FFT & CCS)	Fossil fuel technologies, coal, gas, carbon capture and storage etc
	Nuclear technology (NT)	Nuclear technology
What tasks and tools should a GIB fulfil and implement?		
Tasks and tools	Crowd-in	The GIB should (won't) crowd-in private finance, attract private finance by co-investing, to projects
	Fill the financing gap	The GIB should(n't) fill, close the financing gap for novel, innovative, low carbon projects
	Provide investment certainty	The GIB will/ won't provide policy and investment certainty to investors
	Take a demonstration role	The GIB should(n't) take a demonstration role, demonstrate to the market that innovative, novel, low-c investments are viable, can deliver commercial returns
	Reduce investment barriers	The GIB should (or will not) reduce investment barriers e.g. tenure mismatches, high risk perception etc.
	Lend to un-bankable projects	The GIB shoud(n't) lend to un-bankable projects, projects that banks don't want to finance
	Ensure additionality	The GIB should (or will not) ensure additionality, only provide capital and activities where the "market can't or does not do the same, or otherwise does not provide financing on an adequate scale or on reasonable terms" (Dutch FMO definition)
	Provide capital	The GIB should(n't) provide capital, concessional/market rate debt, equity, mezzanine finance, bridging loans etc.
	Provide guarantees	The GIB should(n't) provide guarantees
How should a GIB be organized?		
Organizational aspects	Funding	How a GIB should be funded (e.g. government asset sales, access to borrow from capital markets, redirection of fossil fuel levy etc.) and declared on the government budget (e.g. declare and account for full funding amount or just predicted GIB losses)
	Matters of risk and return	How a GIB approaches risk and return e.g. take more/ less risk than the market, more/less return than the market, re-allocate risks, perform against a sector portfolio benchmark etc.)
	Independence	The GIB should be more/ less independent from government interference/ decision making
	In-house expertise	How the GIB fosters internal expertise, encourages staff recruitment etc.
	Performance criteria	What type of performance criteria should the GIB track and be judged against
	Real bank status	How a GIB operates and is defined in the market (e.g. like a fund, commercial bank, investment bank or other etc.)
	Headquarters location	Where the GIB should be headquartered
	Longevity of bank	The institution's longevity, how/ whether to design for a long life etc.

Appendix 4

Table A4: List of Members of Parliament

Country	Party	Member of Parliament	Country	Party	Member of Parliament
UK	Conservatives	Tony Baldry	Australia	Australian Labor Party	Mike Kelly
UK	Conservatives	Matthew Hancock	Australia	Australian Labor Party	Gregory Combet
UK	Conservatives	George Osborne	Australia	Australian Labor Party	Graham Perrett
UK	Conservatives	Justine Greening	Australia	Australian Labor Party	Kelvin Thomson
UK	Conservatives	Gregory Barker	Australia	Australian Labor Party	Laura Smyth
UK	Conservatives	Mark Prisk	Australia	Australian Labor Party	Melissa Parke
UK	Conservatives	Peter Aldous	Australia	Australian Labor Party	Gai Brodtmann
UK	Conservatives	Charles Hendry	Australia	Australian Labor Party	Steve Gibbons
UK	Conservatives	Christopher Pincher	Australia	Australian Labor Party	Julia Gillard
UK	Conservatives	Andrea Leadsom	Australia	Australian Labor Party	Catherine King
UK	Conservatives	John Hayes	Australia	Australian Labor Party	Anna Burke
UK	Conservatives	Mark Hoban	Australia	Australian Labor Party	Martin Ferguson
UK	Conservatives	Zac Goldsmith	Australia	Australian Labor Party	Andrew Leigh
UK	Conservatives	Stewart Jackson	Australia	Australian Labor Party	Sharon Grierson
UK	Conservatives	Claire Perry	Australia	Australian Labor Party	Ed Husic
UK	Conservatives	Tim Yeo	Australia	Australian Labor Party	Wayne Swan
UK	Conservatives	Oliver Colvile	Australia	Australian Labor Party	Stephen Jones
UK	Conservatives	Andrew Bridgen	Australia	Australian Labor Party	Mark Dreyfus
UK	Conservatives	Anne McIntosh	Australia	Australian Labor Party	Julie Owens
UK	Conservatives	Simon Kirby	Australia	Australian Labor Party	Greg Combet
UK	Conservatives	David Cameron	Australia	Australian Labor Party	Kim Carr
UK	Conservatives	George Freeman	Australia	Australian Labor Party	Matt Thistlethwaite
UK	Conservatives	Julian Smith	Australia	Australian Labor Party	Penny Wong
UK	Conservatives	Richard Benyon	Australia	Australian Labor Party	Mark Bishop
UK	Conservatives	Graham Stuart	Australia	Australian Labor Party	Chris Evans
UK	Conservatives	Chloe Smith	Australia	Australian Labor Party	Ian Macdonald
UK	Conservatives	Jason McCartney	Australia	Australian Labor Party	Louise Pratt
UK	Conservatives	Guy Opperman	Australia	Australian Labor Party	Anne Urquhart
UK	Conservatives	Chris White	Australia	Green	Adam Bandt
UK	Conservatives	Stephen Mosley	Australia	Green	Christine Milne
UK	Conservatives	David Nuttall	Australia	Green	Larissa Waters
UK	Conservatives	Brandon Lewis	Australia	Liberal Party	Arthur Sinodinos
UK	Conservatives	Peter Lilley	Australia	Liberal Party	Andrew Robb
UK	Conservatives	George Young	Australia	Liberal Party	Joe Hockey
UK	Conservatives	Robin Walker	Australia	Liberal Party	Kelly O'Dwyer
UK	Conservatives	David Willetts	Australia	Liberal Party	Paul Fletcher
UK	Conservatives	Judith Wilcox	Australia	Liberal Party	Nola Marino
UK	Conservatives	Rupert Ponsonby	Australia	Liberal Party	Jamie Briggs
UK	Conservatives	Jonathan Marland	Australia	Liberal Party	Julie Bishop
UK	Conservatives	John Gummer	Australia	Liberal Party	Wyatt Roy
UK	Conservatives	James Sassoon	Australia	Liberal Party	Ian McFarlane
UK	Conservatives	Thomas Galbraith	Australia	Liberal Party	Bert Van Manen
UK	Conservatives	Michael Bates	Australia	Liberal Party	Scott Buchholz
UK	Conservatives	John Cope	Australia	Liberal Party	Joshua Frydenberg
UK	Conservatives	Neil Carmicheal	Australia	Liberal Party	Alan Tudge
UK	Conservatives	Sheila Masters	Australia	Liberal Party	Craig Kelly
UK	Conservatives	John Palmer	Australia	Liberal Party	Russell Matheson
UK	Conservatives	Roger Freeman	Australia	Liberal Party	George Christensen
UK	Conservatives	Mohamed Sheik	Australia	Liberal Party	Alex Hawke
UK	Conservatives	Paul Deighton	Australia	Liberal Party	Dan Tehan
UK	Conservatives	James Younger	Australia	Liberal Party	Ewen Jones
UK	Conservatives	David Mowat	Australia	Liberal Party	Steven Ciobo
UK	Green	Caroline Lucas	Australia	Liberal Party	Simon Birmingham

Country	Party	Member of Parliament	Country	Party	Member of Parliament
UK	Labour	William Bain	Australia	Liberal Party	Sue Boyce
UK	Labour	John Denham	Australia	Liberal Party	Michael Ronaldson
UK	Labour	Clive Betts	Australia	Liberal Party	Mathias Cormann
UK	Labour	Laura Moffatt	Australia	Liberal Party	Concetta Fierravanti-Wells
UK	Labour	Jack Dromey	Australia	Liberal Party	Scott Ryan
UK	Labour	Alan Whitehead	Australia	Liberal Party	David Fawcett
UK	Labour	Mark Lazarowicz	Australia	Liberal Party	Gary Humphries
UK	Labour	Edward Miliband	Australia	Liberal Party	Dean Smith
UK	Labour	Tom Greatrex	Australia	Liberal Party	Greg Hunt
UK	Labour	Clive Efford	Australia	National Party	Michael McCormack
UK	Labour	Luciana Berger	Australia	National Party	Luke Hartsuyker
UK	Labour	Meg Hillier	Australia	National Party	Darren Chester
UK	Labour	Rachel Reeves	Australia	National Party	Ron Boswell
UK	Labour	Barry Gardiner	Australia	National Party	Barnaby Joyce
UK	Labour	Diana Johnson			
UK	Labour	John McDonnell			
UK	Labour	Andrew Gwynne			
UK	Labour	Barry Sheerman			
UK	Labour	Geoffrey Robinson			
UK	Labour	Fabian Hamilton			
UK	Labour	Caroline Flint			
UK	Labour	Glenda Jackson			
UK	Labour	Tony Lloyd			
UK	Labour	Chuka Umunna			
UK	Labour	Ronnie Campbell			
UK	Labour	Stella Creasy			
UK	Labour	Cathy Jamieson			
UK	Labour	Kumar Bhattacharyya			
UK	Labour	Anthony Giddens			
UK	Labour	Simon Haskel			
UK	Labour	Nicholas Stern			
UK	Labour	Angela Smith			
UK	Labour	Christopher Suenson-Taylor			
UK	Labour	Jim Cunningham			
UK	Labour	Micheal Meacher			
UK	Labour	Bryony Worthington			
UK	Labour	John McFall			
UK	Labour	David Pollock			
UK	Labour	Janet Royall			
UK	Labour	Anthony Young			
UK	Labour	John Whitty			
UK	Labour	Wilf Stevenson			
UK	Labour	John Monks			
UK	Labour	Joan Walley			
UK	Labour	John Healey			
UK	Labour	William Blain			
UK	Labour	Ann McKechin			
UK	Labour	Adrian Bailey			
UK	Labour	Austin Mitchell			
UK	Labour	Geraint Davies			
UK	Labour	Iain Wright			
UK	Labour	Pat McFadden			
UK	Liberal Democrats	Vince Cable			
UK	Liberal Democrats	Chris Huhne			
UK	Liberal Democrats	Jo Swinson			
UK	Liberal Democrats	Simon Hughes			
UK	Liberal Democrats	Ian Swales			
UK	Liberal Democrats	Michael Moore			
UK	Liberal Democrats	Stephen Williams			
UK	Liberal Democrats	Nick Clegg			

Country	Party	Member of Parliament	Country	Party	Member of Parliament
UK	Liberal Democrats	Mike Crockart			
UK	Liberal Democrats	Lorely Burt			
UK	Liberal Democrats	Greg Mulholland			
UK	Liberal Democrats	Edward Davey			
UK	Liberal Democrats	Charles Kennedy			
UK	Liberal Democrats	Richard Newby			
UK	Liberal Democrats	Robin Teverson			
UK	Liberal Democrats	Martin Horwood			
UK	Liberal Democrats	Susan Kramer			
UK	Liberal Democrats	Benjamin Stoneham			
UK	Liberal Democrats	Jennifer Randerson			
UK	Liberal Democrats	Edward Razzall			
UK	Liberal Democrats	Kathryn Parminter			
UK	Liberal Democrats	John Shipley			
UK	Liberal Democrats	Margaret Sharp			
UK	Liberal Democrats	Danny Alexander			
UK	Liberal Democrats	Norman Lamb			

Appendix 5

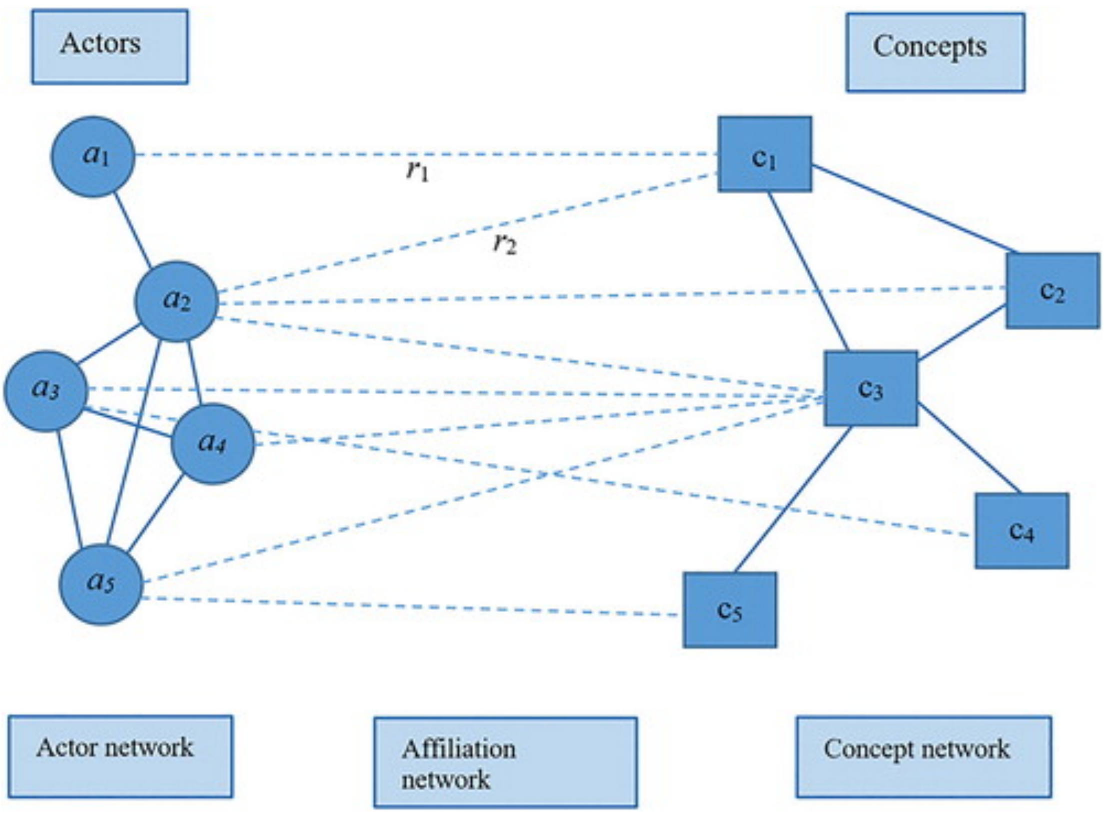


Figure A5. Overview on the model underlying Discourse Network Analysis (adapted from Leifeld 2016)