Climate policy with the chequebook—An economic analysis of climate investment support

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ABSTRACT

Across the globe, climate policy is increasingly using investment support instruments, such as grants, concessional loans, and guarantees—whereas carbon prices are losing importance. This development substantially increases the risk of inefficient public spending. In this paper, we examine the ability of finance instruments to effectively and efficiently address market failures related to clean energy investments. We characterise these market imperfections—emission externalities, knowledge spillovers and capital market imperfections—and identify their negative impacts on the investor-relevant risk-return characteristics. We argue that finance instruments are able to address the effects of these market failures. However, a carbon price is superior in internalising the emission externalities. With respect to the latter two inefficiencies, investment support instruments can effectively compensate the market failures if designed appropriately. We further provide policy recommendations on the choice of finance instruments to address the various market failures and guidance on how to use these instruments avoiding inefficient government spending.

Keywords: climate finance, investment support, market failures, policy instruments

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1. INTRODUCTION—IS CLIMATE POLICY STILL ON TRACK?

Over the past few years, climate related policy intervention has witnessed a stark increase in the use of government subsidised financing. The corresponding instruments are neither directly tied to the emissions abated nor do they make carbon emissions more costly, but rather decrease the financing costs of certain projects and thereby increase the attractiveness of the corresponding investment. Essentially, the government moves away from its role as regulator determining the market rules and tackling externalities at their origin by introducing prices through carbon taxes or permit trading schemes. Governments take on the role of an actor on financial markets by providing financing to specific projects or programmes, often through their public finance institutions.

Environmental regulation and in particular climate policy have been through a dynamic history. Traditional command and control instruments dominated early policies characterised by government-defined technological standards such as "best available technologies" or direct

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input or output controls (Harrington and Morgenstern, 2007). The economic literature following the work of Pigou (1920) powerfully demonstrated the superiority of market-based instruments—at least in terms of their ability to implement a given level of emissions at least cost.[1] One key issue is the decentralised nature of those market-based instruments that allows for cost efficient implementation without requiring detailed knowledge at the government level of technologies and individual firms' abatement cost structures. Rather than giving explicit directives on pollution levels, market-based instruments provide incentives through market signals to encourage the behaviour. These instruments—if designed and applied appropriately—realise a desired level of pollution abatement at least cost to society (Baumol and Oates, 1988; Montgomery, 1972; Tietenberg, 1995). The price signal induces an equalisation of marginal abatement costs across firms such that the pollution abatement burden is allocated efficiently among polluters, where firms with the lowest abatement cost will be the first to abate. Furthermore, market-based instruments perform better in terms of incentivising the development of new technologies which has led to a rapid increase in the use of these instruments since the 1970s across OECD countries (Hahn and Stavins, 1992; Jaffe and Stavins, 1995; Stavins, 2003; OECD, 1999). The most prominent economic instruments in climate policy are the CO_2 emissions trading scheme introduced by the European Union (EU) and the state-level emissions trading foreseen in the Kyoto Protocol to the United Nations Framework Convention on Climate Change in 2005 or 2009, respectively. Other policy schemes were introduced in parallel that mainly target the promotion of renewable energy (Menanteau et al., 2003).

In very recent years the trend of increased climate related government investment subsidy appeared, mainly through grants, interest subsidised loans or (less often) guarantees. Even the use of more complex so-called structured investment vehicles can be observed.[2] The EU recently set regulations on the use of financial instruments of various European funds for, among other goals, reducing pollution.[3] The International Development Finance Club (IDFC)—consisting of 20 national development banks operating nationally and internationally, inside and outside the OECD—reports total green financing by 18 reporting institutions of USD 99 billion in 2013 (Khosla et al., 2014). Multilateral Development Banks—not included in the figures above—report USD 28 billion of climate finance in 2014 compared to USD 27 billion in 2011 (World Bank, 2015). In addition to these financial institutions, 22 multilateral and 6 bilateral funds are dedicated to financing climate related investments.[4] According to the IEA/IRENA Global Renewable Energy Policies and Measures database, currently 208 support policies (subsidy and loan programmes) for renewable energy are in force worldwide.[5]

Consistent with this development, the international climate policy debate drifted from "emission targets" towards "financing commitments." A major element of the United Nations (UN) climate process is the promise of the industrialised countries to mobilise climate financing of USD 100 billion per year from 2020 on, to finance mitigation and adaptation in

1. See Sumner, Bird, and Dobos (2011) for a review of carbon tax policies.
2. An example is the *Global Climate Partnership Fund*, structured similarly to a credit default obligation (CDO) where the riskiest tranche is held by the government and serves as a risk buffer to attract private investment for the less risky tranches.
3. See EU Regulations No 1303/2013 and No 480/2014 as well as the Commission Implementing Regulation No 821/2014.
4. See Climate Funds Update, available at http://www.climatefundsupdate.org/ (last accessed 22 March, 2016).
5. The database is available at http://www.iea.org/policiesandmeasures/renewableenergy/ (last accessed 22 March, 2016).

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developing countries (UNFCCC, 2012) and the establishment of the UN Green Climate Fund (GCF) by the Conference of the Parties (COP) in Durban (2011).

Thus, policy seems to move away from the explicit internalisation of externalities, it requires technology-specific information to formulate the investment subsidy programmes, and, by subsidising individual projects, it moves away from a decentralised approach. Considerations from a political economy perspective might explain parts of this trend. For a policy maker it is more attractive to offer support for climate friendly investments than to introduce additional costs for established conventional technologies (Bowen, 2011; Green and Yatchew, 2012). Green and Yatchew (2012) provide an economic analysis of support schemes focusing on the difference between programmes focusing on prices, e.g. feed-in tariffs, and quantities, e.g. renewable portfolio standards. We complement this work by examining to what extent these instruments can efficiently correct market failures caused by the emission externality, innovation spillovers, and capital market failures as well as providing guidance on how to use them appropriately. We argue that finance instruments are in general inferior to economic instruments in compensating for environmental externalities. However, these instruments seem suitable to effectively address knowledge spillovers and, in particular, capital market failures. Both aspects can be expected to be increasingly relevant as the world is trying to speed-up the structural change towards a low carbon economy as decided in the Paris Agreement under the United Nations Framework Convention on Climate Change.[6]

The remainder of this paper is structured as follows. The following Section 2 presents three major instruments for investment support (grants, interest subsidised loans, and guarantees). In Section 3, we characterise three main market failures relevant to clean energy investments and illustrate their effects from an investor's perspective. In Section 4, we examine whether finance instruments are suitable to address the respective market failure and provide policy recommendations. The final Section 5 concludes.

2. INSTRUMENTS FOR CLIMATE RELATED INVESTMENT SUPPORT

Subsidies to financing renewable energy or energy efficiency investments occur in a variety of instruments.[7] In this analysis, (i) simple grants, (ii) interest-subsidised loans, and (iii) loan guarantees are considered. While this set of instruments is not exhaustive, it still covers the majority of the subsidised financing volume and represents the main elements more complex instruments, such as structured funds, are composed of. Table 1 provides an overview of the major design parameters of a grant programme compared with concessional loans and loan guarantees. These design parameters largely determine the value of an instrument to the recipient (subsidy element) and the cost to the government.

6. According to the *Paris Agreement*, parties to the convention agree to "undertake rapid reductions [. . .], so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century."

7. See Mclean et al. (2008) for an overview. A comprehensive comparison between the different instruments for government-intervention would be complex, since the different instruments imply different rights and obligations on the side of the investor (in our case sometimes the government). While the right of a debt-provider is merely restricted to receiving information and interest, the right of an equity provider may be different and involve decisions of the respective company. Similarly, the risks taken on by the institution providing the instrument are different according to the instrument. In our analysis, we concentrate on debt.

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TABLE 1
Variables characterising the three major instruments for investment support which need to be determined when designing a corresponding support programme.

Grant	Concessional Loan	Guarantee
volume	volume	(implicit: loan characteristics.)
timing	timing	loan fraction covered
	interest (& risk free years)	risks covered
	seniority	trigger event
		pricing

2.1. Grants

A grant is typically a simple payment that is tied to a specific investment. As a support instrument used by a government or a public finance institution, the grant provision as such and its volume can be flexibly coupled to any politically justified parameters. In the field of clean energy, these parameters may be a list of technologies or activities that are eligible for support. It may also be a more abstract description of activities (e.g. by their goal or purpose) in order to keep the instrument flexible. In general, one may also link the grant provision to parameters such as emissions saved. This is, however, rarely the case, since it is often difficult to determine the emissions saved through an investment. If at all, expected savings for standardised technologies, which may be estimated up-front, are used.

The parameters may not be limited to climate related political goals. Typical examples of additional requirements are a certain maximum income of the supported household in order to focus the support on low-income households, or so-called local content rules that require part of the investment to be spent on technologies produced in the country that is funding the support scheme to support the regional economy. Grants are mainly used for two different purposes: (i) to fund early-stage clean technologies in their pre-maturity phase (research, development, and demonstration) and (ii) to subsidise the deployment of small-scale renewable energy.

In any case, the support scheme needs rules to determine whether support is granted, the volume of the support, as well as the timeframe. The latter has strong implications on dynamic incentives. A credible long-term commitment of a government to subsidise, e.g., certain energy efficiency improvements in residential buildings or renewable energy heating systems, might incentivise innovations in these technologies that could lead to cost reductions. A very limited subsidy scheme might not be able to trigger innovation activities.

2.2. Concessional Loans

Concessional loans use public money to extend loans for politically desired projects at more favourable conditions (maturity, interest, seniority) compared to commercial loans available on the market. If a concessional loan programme is used as a support policy, the conditions for the loan provision can—similar to the case of grants—be coupled to any parameters.

A number of reasons make the efficiency analysis for concessional loans fundamentally more complicated than the case for grants. One reason is that a concessional loan is characterised by more variables than a grant. While a grant is largely determined by volume and time of payment, a concessional loan needs to be further specified with respect to maturity,

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interest rate, including potential interest-free years at the beginning plus the seniority relative to other loans. A so-called senior loan will have to be paid back with priority while a "junior"-ranked loan might leave the priority to other loans, perhaps commercial lenders, who would find themselves in a more secure situation.

A second complexity relative to grants stems from the fact that the subsidy element of a concessional loan is not completely determined by the characteristics of the offered loan, but also by the risk profile of the recipient: At market prices, a high-risk borrower will normally be charged a higher interest rate than a low-risk borrower. Therefore, a concessional loan programme with a standardised interest rate will effectively mean a higher support for the high-risk- borrower than for the low-risk borrower.[8] This support-bias may give rise to standard adverse selection problems. Further, it is obvious that the absolute value of support increases with the volume to be financed.

An alternative to direct public lending are interest subsidies. In this case, the government does not directly provide loans, but rather offers a subsidy on the interest paid by the borrower. In such an interest softening mechanism, the borrower receives a loan at market conditions from a bank, but the interest repayment is partly taken over by the government such that the effective interest rate for the borrower is reduced.

2.3. Guarantees

Public guarantees to loans are typically used in order to lower the financing costs for a specific project. If a lender (e.g. a bank) receives a guarantee for some risks or part of a loan by a credible public institution, he is confronted with less risk and consequently may ask for a lower risk-premium on the interest rate, provide a higher loan amount or provide a loan at all.

A potential investment support programme structured as guarantees needs to specify the loan types (often loan purpose) that are eligible for a guarantee. Hence, implicitly most characteristics of the loan are part of the support scheme (maturity, seniority, volume, etc.). The added complexity of guarantees versus concessional loans comes from defining the trigger of the guarantee, the covered risks, and its pricing. While the pricing is often very similar to loan pricing (as a percentage of the covered loan volume), guarantees usually do not cover the full loan, but rather a certain fraction of the full amount—typically between 70–80% in practice (Honohan, 2010). One main reason is that coverage of (close to) 100% would induce moral hazard, as it would weaken the monitoring incentives of the lender (Anginer et al., 2014).[9] A major complexity—also when it comes to implementation—is the specification of risks to be taken by the public guarantor. In the event of default, it might be difficult to determine the drivers for this default ex-post. Depending on the risks covered by the guarantee, the value (or the subsidy embedded in the guarantee) may be higher for high-risk borrowers/projects.

8. This may be different if the interest rate is formulated relative to some interest rate that the borrower would have been offered on the market.

9. Green (2003) provides an analysis and examples on this moral hazard effect. One case is the Lithuanian *Rural Credit Guarantee Fund* that offered 100% coverage for loans for purchasing agricultural equipment and resulted in a huge amount of defaulted loans. When the Canadian Small Business Loans Act increased its guarantee coverage from 85% to 90%, lenders awarded loans to riskier clients resulting in a drastic increase in defaults.

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3. MARKET FAILURES AND THE INVESTOR PERSPECTIVE

Two main market failures that are related to climate investments and frequently used to justify the promotion of climate investments are the negative externality caused by greenhouse gas emissions and the positive innovation externality (spillover).[10] One class of market imperfections, which is typically disregarded in analyses of instruments for environmental policy, are potential imperfections on capital markets. We argue, however, that it is essential to consider these market imperfections for at least two reasons. Firstly, climate related investments highly depend on services provided by capital markets, as renewable energy investments, e.g., are typically characterised by high up-front investment and low operating costs, which means that the cost structure is dominated by capital costs (Evans et al., 2009; Painuly, 2001; Wiser et al., 1997). For photovoltaics, the capital costs can account for more than 95% of total life cycle costs compared to a share of only 11% in the case of an oil power plant (Kannan et al., 2007). Secondly, climate policy increasingly acts through capital markets, as demonstrated above.

We therefore examine three major economic market failures related to low-carbon investments—(i) environmental emission externality, (ii) innovation spillovers and (iii) capital market failures (Stern and Rydge, 2012)—and, following Dinica (2006), translate these externalities into the investor perspective to illustrate their effects on the risk-return profile of climate investments.

3.1. Environmental Externalities & Innovation Spillovers

Emission externalities are characterised by a (negative) impact of one agent's emissions on the well-being of others. If this market failure is not corrected, e.g., through a price on emissions via taxes or a tradable permit scheme, then renewable energy or energy efficiency projects are commercially less attractive compared to otherwise similar projects based on conventional thermal power generation. There is a cost differential in favour of conventional technologies as long as the external costs of, e.g., fossil-based energy generation are not internalised.[11]

Innovation spillovers refer to the positive effect of inventions or innovations on other market actors. Technological change can be roughly divided into three stages: (i) invention: the creation of ideas, (ii) innovation: creation of new products or processes based on ideas, and (iii) deployment and diffusion: the actual penetration of the relevant market by the new technology (Popp, 2010). A firm invests in innovation activities if the expected returns of these activities exceed the costs. A successful technology innovation or deployment activity, however, usually leads to increased general knowledge due to its public goods nature. It is difficult to exclude others from these benefits. Even if intellectual property rights are in place, patents cannot entirely exclude other firms from profiting, as they can modify the patented innovation and utilise it (Levin et al., 1987). Hence, the social returns of innovation and

10. Other reasons frequently used to justify policy intervention include clean energy investments' contribution to energy security or strategic considerations of industrial policy aimed at establishing competitive advantages for local clean technology firms.

11. Renewable energy, however, might also be associated with negative externalities as negative impacts of visual and noise pollution from wind turbines on neighbouring properties' prices (Jensen et al., 2014) or changes in the landscape and impoverishment of natural diversity caused by hydropower (Kataria, 2009). Ladenburg and Lutzeyer (2012) provide a review on visual impacts of offshore wind.

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deployment activities exceed the private returns of the innovator and result in an under-provision of such activities (Arrow, 1962; Griliches, 1992; Jaffe, 1987; Jones and Williams, 1998). Private actors invest too little, or possibly not at all, in certain socially beneficial innovation activities, as they cannot fully exploit the resulting benefits. Dechezlepretre et al. (2014) and Braun et al. (2010) provide evidence for knowledge spillovers in the clean-technology sector.

Environmental externalities and innovation spillovers may also interact. Successful innovation and diffusion of clean technologies reduce the marginal costs of achieving a desired pollution level. Policies targeting one of these externalities might also indirectly affect the other. Acemoglu et al. (2012) and Fischer (2008) show that it is inefficient if only one of both externalities is addressed by policy.[12] Hence, a portfolio of public policy instruments might be better suited to address both externalities (Bennear and Stavins, 2007; Jaffe et al., 2005).

3.2. Capital Market Failures

Less specific to renewable energy or energy efficiency, but relevant for the discussion of the government acting through the capital market, are imperfections on the capital market itself. This refers to cases where—despite a hypothetical absence of other market failures—the market does not allocate capital such that it is used most productively from a social point of view (see, e.g., Akerlof, 1970; Stiglitz and Weiss, 1981; and Stiglitz, 1993). In this context, we consider two types of capital market failures that systematically affect investment decisions on clean energy projects. These are (i) the lack of a liquid market for long-term debt (credit rationing) and (ii) imperfect credit markets.

These market failures are caused by information asymmetries between the lender (principal) and the potential borrower (agent) that knows the expected return and risk of his project. Expenditures to reduce this asymmetry might be sufficiently high such that transactions are limited or deterred. This credit rationing particularly affects long-term contracts, where information asymmetries and hence the risks for the lender are particularly large, and result in a lack of a market for *long-term debt* (Stiglitz, 1993).

However, even in successful transactions, *imperfections on credit markets* might result in interest rate rationing, i.e. a borrower receives a loan, but at unfavourable conditions (Jaffee and Stiglitz, 1990). We focus on two major externalities on capital markets that are particularly relevant for climate related projects. The first imperfection, *relationship banking*, refers to the relationship of the lender (bank) and the potential borrower. As the costs of screening a borrower, i.e. reducing information asymmetry, are sunk, a lender has an incentive for multiple transactions with the same borrower. A continuing relationship with a borrower results in cost savings, as the private information the bank obtained in previous transactions can be used for future deals. Hence, borrowers with a certain relationship with a bank are offered loans at more favourable conditions compared to unknown potential borrowers.[13]

Another imperfection is caused by *externalities of monitoring, selection, and lending* (Stiglitz, 1993). One main task of banks is the selection of projects and subsequent monitoring.

12. There are also interactions between externalities and capital market imperfections (see, e.g., Hoffmann et al., 2016). They may lead to optimal emission taxes deviating from a linear pigouvian tax.

13. A number of studies have shown empirical support for the positive effect of lending relationships on loan conditions (Bharath et al., 2011; Bräuning and Fecht, 2012; Jiménez and Saurina, 2004; Petersen and Rajan, 1995). Boot (2000) provides a survey on relationship banking.

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Other lenders interpret a positive lending decision by a bank as a signal that the project was deemed as attractive after thorough screening, which informs part of their financing decision. Consequently, it will be easier for the project to raise additional financing. Furthermore, similar projects (e.g. using the same technology) will receive loans more easily or at better terms. Banks do not account for this positive externality on subsequent (other) lenders for the project or similar projects. Hence, there might be an under-provision of loans (or a provision of loans with bad conditions) for projects using novel technologies or project developers or technology firms with a limited track record.

These capital market failures are not exclusive for innovative clean technology, but are particularly present in this sector due to the following reason. Carpenter and Petersen (2002) show that particularly young high-tech firms have issues obtaining debt financing as high-tech investments are associated with higher uncertainty compared to conventional projects using established technologies. The fact that young firms do not have an established relationship with a lender further fosters credit rationing (Berger and Udell, 2002). The clean-technology sector plays an important role among small high-tech firms and attracts a large amount of venture capital investments.[14] Substantial information asymmetry between these firms and potential lenders aggravates the aforementioned capital market failures.

Capital market failures in this sector may be reinforced by the corresponding project finance characteristics. Due to the high up-front costs of renewable energy generation investments only utilities and large project developers are sufficiently capitalised to use on-balance sheet (corporate) finance (Kann, 2009). More typically, project finance structures are used.[15] These project finance structures are often long-term and characterised by a large share of debt, typically 70 to 80 % (Pollio, 1998), but do not involve any collateral as the lending is based on the project cash-flow. Collateral, however, is an important signalling device that can otherwise reduce the information asymmetry between lender and borrower.[16] Consequently, a limited capability to provide collateral can result in credit rationing (Bester, 1987).

The role of capital market failures for energy efficiency investments is similar, as they have a similar structure compared to renewable energy projects: high initial capital costs and lower energy costs in the future (Gillingham et al., 2009). Credit rationing for energy efficiency can be caused by limited information of the lender on the (certainty) of potential payoff of the energy efficiency investment and future energy prices (Golove and Eto, 1996; Gillingham and Palmer, 2014). Furthermore, energy efficiency loans are typically not secured as energy efficiency investments can typically not be used as collateral. However, capital market constraints seem to be less severe for energy efficiency compared to other clean technology investments. In developed countries, lenders can rely on credit ratings/histories of firms and households such that the lender does not have to rely on returns from energy savings for the repayment of a loan. An overview of recent empirical studies on industrial energy efficiency investments

14. In 2011, the US clean-tech sector attracted more than one quarter of the total venture investments (Pernick et al., 2014). This indicates the importance of small high-tech firms in the sector and might give an indication for credit rationing in the clean-tech sector as equity financing, e.g. through venture capital, seems to be an option chosen in the case of credit rationing (Carpenter and Petersen, 2002).

15. In a project finance structure, the project is developed and financed off-balance sheet. This means that financing is based upon the future cash flows of the project and only secured by the project assets (rather than the general assets of the sponsor). In 2014, project finance accounted for almost 32% of worldwide investments in utility-scale renewable energy (McCrone et al., 2015).

16. Collateral can be used by the lender to induce a self-selection among borrowers. A high-risk borrower, knowing that his project has a high probability to default, is less likely to accept collateral requirements set by the lender. In contrast, low-risk investors will reveal themselves by accepting the collateral requirement (Bester, 1987).

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by Trianni et al. (2016) shows that, in developing countries, alternative options for investing scarce capital play a more important role in deterring energy efficiency investments than a limited access to capital. Hence, credit constraints are more relevant in developing countries and for borrowers with a poor credit rating (Palmer et al., 2012).[17] Although varying in magnitude, capital market failures therefore affect all types of clean energy related investments.

3.3. The Investor Perspective

When discussing market failures and policy measures in clean energy, it is helpful to complement the policy-maker perspective by an investor perspective through translating the market failures relating to clean energy investments into consequences for the risk-return profile of these projects.[18] A potential investor decides on a certain investment opportunity based on the risk-return characteristics of the underlying project. Hence, an investor's decision on whether or not to move forward with a certain project is indirectly affected by market failures through their effect on the (perceived) risk-return of the underlying project. Furthermore, instruments of public investment support directly influence this risk-return profile. Those instruments may provide financing below market interest rates (concessional loans) or take risk (guarantees), which can directly increase an investment's attractiveness by counteracting the symptoms of market failures.

Environmental externalities affect the risk-profitability of a climate investment, but rather indirectly: If the negative environmental externalities are not internalised, alternatives to clean energy projects—e.g. fossil fuel based electricity or less energy efficient production technology in case of industrial energy efficiency—have higher returns than they should have from a social perspective. Hence, the relative risk-return profile of an emission mitigation project is negatively affected. Knowledge spillovers affect the risk-return characteristics of the clean energy project itself. As not all benefits are exclusive to the investor, the private return is below the social return of an innovative investment. Furthermore, innovative activities, e.g. the deployment of a new technology, have higher risks compared to using established dirty technologies. Finally, capital market imperfections have a direct impact on the financial characteristics of a project. As argued above, capital market imperfections result in worse loan conditions—e.g. higher interest rates—and hence negatively affect the profitability of a project. Hence, all these market imperfections—if uncorrected—decrease the attractiveness of a clean energy investment relative to other investments.

4. ECONOMIC ANALYSIS OF FINANCE INSTRUMENTS

After characterising main market failures associated with clean energy investments and their effects from the investors' perspective above, we now turn to examining the ability of finance instruments to compensate those market failures. For this evaluation, it is important to consider how much value is transferred through such investment support, i.e., the subsidy element

17. Apeaning and Thollander (2013) and Kostka et al. (2013) provide empirical evidence for the relevance of credit constraints for energy efficiency investments. However, overall, other market failures as imperfect information, principal-agent issues, differences between private and social discount rates, or bounded rationality seem to be at least as important in deterring energy efficiency investments (for a review, see Gillingham and Palmer, 2014; and Linares and Labandeira, 2009).

18. Wiser et al. (1997) provided an early contribution focussing on barriers for renewable energy financing from an investor perspective. Dinica (2006) analyses the risk characteristics of support instruments might affect investor behaviour and hence the deployment of renewable energy technologies.

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of such an instrument, as characterised in Section 2. In this section, we first examine to what extent finance instruments are capable of correcting each of these market failures (in comparison to alternative policies) and the information requirements to design those instruments cost-efficiently. Finally, we provide some brief policy recommendations on designing and applying public finance instruments, particularly in cases where alternative first-best policies are unavailable. Table 2 summarises the results of the analysis and the policy recommendations.

4.1. Environmental Externalities & Innovation Spillovers

Both for environmental externalities and innovation spillovers, instruments of investment support do not directly correct the respective market failure, as, e.g., an emission trading scheme or emission tax do in case of the environmental externality, but rather address their symptoms, namely their negative impact on the risk-return profile of a clean energy investment. Thereby, the incentive to realise the project would be increased, compensating its disadvantage relative to other projects emitting CO_2 or profiting from knowledge spillovers (see Table 2). In order to achieve the internalisation of both externalities through investment support efficiently, the value / cost of the respective finance instrument must not exceed the social value of the avoided emission externality and the knowledge spillover.

Determining the value of the environmental externality requires the amount of avoided emissions and a (hypothetical) price per unit of emissions. In the absence of a CO_2 price, assumptions on a price are required, potentially based on other areas/sectors where CO_2 prices exist.[19] Overall, market-based instruments are more suitable to correct the emission externality at least cost due to two main advantages. Firstly, these instruments provide incentives through markets signals that encourage emission abatement where it can be achieved at least cost (Stavins, 2003). Hence, these instruments do not require detailed information of firms' or technologies' marginal abatement costs. In order to apply financial instruments efficiently, the policy maker would require this information in order to target financial support at the most cost-efficient investments. Secondly, revenues from market-based instruments—revenues from emission taxes or from auctioned permits in emission trading schemes—might be used to reduce other distortionary taxes resulting in the beneficial "revenue-recycling effect" (Goulder and Parry, 2008; Goulder et al., 1997) or to support climate investments in developing economies, where a carbon price might not be feasible (Bowen et al., 2014).

Overall, finance instruments seem to be suitable for targeting this market failure. Evidence suggests that, even in the presence of economic instruments that provide incentives for innovation and deployment of clean technologies, the market failures associated with knowledge spillover cannot be compensated entirely (Jaffe et al., 2005; Popp et al., 2010). Johnstone et al. (2010) find that direct investment incentives, e.g. grants, concessional loans, and guarantees, effectively support innovation in clean technology, particularly in the case of less mature technologies. Olmos et al. (2012) provide a comprehensive analysis on the suitability of different finance instruments for supporting innovation and deployment of clean technologies based on features of innovation that vary across clean technologies, e.g. the maturity of the respective technology. Public (concessional) loans and loan guarantees seem particularly suitable for close-to-maturity technologies that are expected to be profitable large-scale deploy-

19. Note that in general one might argue that the socially optimal CO_2 price should be based on some global cost benefit considerations. We abstract from the issue of a globally optimal emission level but rather look at the question of cost-efficient abatement.

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TABLE 2

Summary of market imperfections, their effect on the investor perspective, and the analysis of investment support instruments.

Market Imperfection	Economic Mechanism	Mapping to Investor's Perspective	Ability of Investment Support Instruments to Compensate	Policy Considerations
Emission Externality	A missing emission price leads to socially inefficient high return for conventional / non-clean investments.	Relative return below social optimum (as compared to conventional alternative).	Finance instruments for clean energy projects reduce financing costs and hence increase their relative return. If the subsidy element is appropriately sized, negative effects of externality on risk-return profile can be compensated.	Market-based instruments are superior policy. If not available, investment support can be considered. To avoid inefficiency, subsidy element of finance instrument should not exceed the (estimated) value of avoided externality.
Innovation Spillover	Innovative projects bear higher risk and provide social benefits through knowledge spillovers that are not reflected in the return.	Increased risk not adequately rewarded and return below social optimum.	Investment support instruments can reduce financing costs and hence (i) mitigate the risk-premium that has to be paid to private lenders and (ii) increase the return to decrease / mitigate the gap between private and social return.	Investment support instruments are suitable to compensate for spillovers. Grants should be applied to early-stage innovation, while subsidised loans and guarantees are best suited to support the deployment of (close to maturity) clean innovations.
Capital Market Failure	Due to information asymmetries between investor and lender, financing is inefficiently expensive (or not available at all).	Return below social optimum (or equal to zero in case of the project not being implemented).	Instruments of investment support directly target the capital market failure. By improving financing costs (through grants, interest subsidies, or guarantees) or direct concessional lending, investment returns can be increased.	Policy interventions through finance instruments are optimal. Interest rate subsidies and guarantees are preferred to investment grants due to lower costs. Direct subsidised lending should be used if (i) government (or public bank) has a better ability to screen and monitor or (ii) a market for (long-term) debt is absent.

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ments in the future. By providing a concessional loan or a loan guarantee that improves the loan conditions, the government subsidises the investor conducting the innovative project by compensating for the knowledge spillovers other actors benefit from. This subsidy lowers the financing costs and hence increases the private return (and lowers the risk) and reduces / closes the gap between the private and the social return of innovative activities with knowledge spillovers. Grants can, in principle, be used for any clean innovation activity. Considering the higher costs of this instrument—in contrast to loans, grants are not paid back—it seems particularly suitable to support early-stage clean technology innovation which is commercially the least attractive. For concessional loans or guarantees, the value of the support is determined relative to the same instrument at market prices. Note, however, that this does not solve the issue of determining the appropriate level of support (which exists for clean energy technologies as well as for all other innovations) that should not supersede the benefits, i.e. the social value of knowledge spillovers that is challenging to quantify (Hall, 1996).[20]

4.2. Capital Market Failures

Providing public finance instruments means that the government acts as player on the capital market. In contrast to compensating emission externalities or knowledge spillovers, here the public intervention is aimed at the market where the failure actually occurs. According to previous studies, public intervention on financial markets can effectively correct market imperfections (see, e.g., Arping et al., 2010; Gale, 1990; Honohan, 2010; Janda, 2011; Philippon and Skreta, 2012).

Policy interventions on capital markets have the ability to remedy the negative effects of market failures on climate related investments. The provision of (concessional) public loans is the most direct instrument: the regulator provides debt for climate related investments that is underprovided, or offered at unfavourable conditions, by private lenders due to asymmetric information. This instrument seems particularly suitable for the case of the lack of a market for long-term debt for climate related investments (credit rationing). As a loan guarantee partly takes over the risk of default, the lender can improve the loan conditions, e.g. reduce the interest rate, of loans for clean energy investments. In the absence of a guarantee, the private lender charges a higher interest to account for the risk, while the interest payments of the borrower can be reduced through interest subsidies.

In spite of the differences of both instruments, interest rate subsidies and loan guarantees generally have the same effect: they diminish the unfavourable loan conditions induced by information asymmetries. Minelli and Modica (2009) show that both subsidised loans and loan guarantees are optimal to correct market failures on credit markets and imply similar costs to the regulator.[21] As guarantees are only paid in the case of failure, the costs of this instrument increase with the guaranteed loan's risk of default and maturity (Honohan, 2010). The costs of interest subsidies (also the subsidy component) occur even in the case of a successful project and rise with difference to the market interest, volume, and maturity. Hence, for both instruments the costs increase with the magnitude of market failure. Grants also have the ability to remedy capital market failures, but, as they are normally not paid back, grants are in general the more expensive instrument and hence inferior to loans and guarantees in

20. See Kaiser (2002) and Nelson (2009) for an overview of alternative approaches of approximating knowledge spillovers.

21. Janda (2011) argues that the costs of guarantees and interest subsidies depend on the diversity of projects, i.e. the difference in the success probability of high-risk and low-risk projects. The author shows that guarantees are less costly in case of high project diversity, while interest subsidies are less costly in case of low project diversity.

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addressing capital market failures (Minelli and Modica, 2009). With respect to costs, direct concessional lending by the state combines the attributes of interest subsidies and guarantees. If government budget is used to subsidise interest, the costs are similar to paying an interest subsidy on a loan provided by a private lender. The amount of the subsidy, however, is likely to be smaller in case of public loans, as government institutions—at least in developed countries –usually have lower refinancing costs than private institutions. In case of a default, the government has costs amounting to the defaulted loan, which is similar to the cost attributes of guarantees. The latter, however, are potentially lower as they typically do not cover the whole loan amount.

In addition to the static effects, capital market interventions also have a dynamic effect by reducing information asymmetries over time. When projects supported by public finance instruments materialise, private lenders acquire information on those projects. Hence, lenders have better information on the profitability of investments in, e.g. certain clean technologies. The same applies to clean technology firms or project developers that might build up a track record that can reduce the information asymmetry between them and lenders. Overall, finance instruments seem to be the instruments of choice to correct capital market failures related to clean energy investments.

4.3. Policy Considerations

Climate related investments, as renewable energy and energy efficiency projects in the real world, are subject to more than one market imperfection and frequently a number of policy instruments and incentives coexist. Designing appropriate support policy schemes in such a context is challenging (Fischer and Preonas, 2010; Sijm, 2005; Sorrell and Sijm, 2003). Nevertheless, their design will benefit from a clear understanding of the individual market imperfections. Note that in order to implement the first-best optimum, theoretically each externality needs to be internalised and this could be achieved with one instrument per externality. If we assume, however, that this design of multiple internalisation policies is not possible, then one approach could be the following: In general, and if all the externalities could be quantified, one would be able to aggregate them with respect to their effect on risk and return. These aggregate effects could then be compensated through support policies.

As market-based instruments are the first-best choice to internalise the emission externality, other policies, such as finance instruments, should only be considered if an emission price is (politically) not feasible. When using finance instruments to correct the emission externality, government support should aim to achieve a certain benefit at least cost, which requires some estimate of the benefit of saved emissions. In the case of a renewable energy project, e.g., expected emission savings can be estimated based on assumptions about: the technology, the capacity, the expected lifetime, and some reference generation technology. In the case of an energy efficiency investment, emission savings estimations have to be based on the lifetime and usage of the technology. Quantifying the value of the externality requires an emission (shadow) price assumption to value the avoided emissions. A potential approach for such a quantification of emissions avoided by renewable energy projects could be the use of standardised baselines as suggested by Spalding-Fecher and Michaelowa (2013) for the Clean Development Mechanism. A corresponding estimation for an energy efficiency project (e.g. a new technology) might be less straightforward.[22] The costs of the applied finance instrument,

22. With some assumptions, it might be possible to estimate the expected emissions saved, but the business-as-usual reference is less obvious if the investment in a new cleaner technology was due to other reasons than just increased energy efficiency.

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i.e. the subsidy element, should not exceed the benefit of the avoided emission externality. Even under these considerations, investment support for clean energy might induce additional inefficiencies. Consider subsidies to an energy efficiency investment that illustrates the non-equivalence of an emission price on the one hand and subsidising carbon free technology on the other. Inefficiencies particularly result if the (subsidised) investment also raises the emission baseline. An example would be the provision of low-interest loans for cars with relatively low emissions. On top of making relatively efficient cars more attractive, the low-interest loan may have two additional effects: (i) it subsidises the use of cars in general (leading to additional emissions, especially if clean / cleaner means of transportation are substituted) and (ii) the subsidy element increases with the price of the vehicle, which typically means a higher subsidy to bigger (more expensive) cars often emitting more carbon than smaller (cheaper) ones.

In contrast to the emission externality, finance instruments are suitable to address market failures due to knowledge spillovers and, in particular, market failures on capital markets. In case of knowledge spillovers, a main guideline for using financial support is that grants should be used for early-stage, far-from-maturity clean-tech innovation investments, whereas the support of more mature technologies, in particular their deployment, can be more cost efficiently supported by subsidised loans or even guarantees. In order to avoid crowding out, particularly loans and guarantees should be only employed for innovation and deployment projects, where (i) the investors have difficulties receiving private finance due to the gap between social and private returns or (ii) the public sector is more knowledgeable / experienced with the respective technology than the private sector (Olmos et al., 2012).

Within the group of finance instruments, loan guarantees and interest subsidies are the most appropriate policies to address capital market failures as they are generally more cost efficient compared to (investment) grants. However, direct government lending bears the risk of crowding out private lending. Whether direct (concessional) lending is an appropriate instrument also depends on the development of the financial sector and its liquidity.[23] In case of limited liquidity, direct public lending might be the only instrument to provide finance to clean energy projects. This could be the case in emerging and developing countries as well as in developed countries in periods of credit crunches during, e.g., a financial crisis.[24] Furthermore, when the financial sector development is low, the public sector lender might have an advantage in assessing projects of potential borrowers (lower information asymmetry) due to better screening skills based on previous experience and knowledge. Hence, concessional lending by, e.g. bilateral or multilateral development banks, are particularly suitable to finance clean energy investments in emerging and developing countries, where financial sectors are less developed.[25] In this case, direct public lending might be an effective tool to reduce the information asymmetry by providing finance to pilot projects. The learning effect for private lenders might be increased by public and private co-financing of clean energy projects.

23. Lending by governments or mandated public finance institutions in fact may either happen directly or through other commercial banks which are for these projects refinanced by public finance institutions (so-called on-lending). Inter alia this is used to limit crowding out or to use specific strengths of the commercial bank such as an established client base.

24. Due to the current expansionary monetary policy in a majority of OECD countries and the resulting low interest rates, liquidity seems, at least currently, not to be a major issue on credit markets in developed economies.

25. Brunnschweiler (2010) provides empirical evidence for the importance of financial sector development for the deployment of renewable energy in emerging and developing countries.

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5. CONCLUSIONS

In this paper, we raise the issue of whether the intensified use of public finance instruments to support climate related investments is compatible with facilitating the structural change at least cost to society, or whether they run the risk of being overly expensive or extensively using scarce public funds, therefore impeding the transition towards a low carbon economy.

In general, finance instruments are capable of compensating for the main market imperfections associated with clean energy investments. From an investor's perspective, all market failures analysed here negatively affect the risk-return characteristics of the underlying clean energy investment. As public finance instruments for investment support are able to directly influence risk and capital cost (i.e. return), they can be flexibly designed to compensate where climate related investments are less attractive from the investors' perspective than they should be—based on societal / economic considerations. Whether these instruments are the first-best choice, however, largely differs across market failures and investment environments.

With respect to emission externalities, policies of finance support are economically inferior to market-based instruments. Whenever economic instruments are not politically possible, e.g. in emerging and developing countries, finance instruments might be second-best choice. When applying these instruments, however, the design of public investment support programmes—e.g. the magnitude of an interest subsidy or the proportion of a loan that is covered by a guarantee—should be based on cost benefit considerations. The cost of a finance instrument and the subsidy element should not exceed the value of abated emissions.

An additional advantage of market-based instruments, if designed appropriately, is their ability to provide incentives to innovate and deploy clean technologies (Bennear and Stavins, 2007; Jaffe et al., 2005). Although these policies cannot fully compensate for the market failures related to innovation and deployment, they can reduce the social cost of innovation policies, as, with a carbon price in place, clean technology innovation investments require less financial support. As economic instruments cannot fully overcome the innovation market failures, a combination of this policy with financial support innovation and deployment can compensate both market failures at least cost. Finally, finance instruments are optimal policies to address capital market failures.

Given the global consensus of limiting global warming, a substantial structural change in the energy infrastructure is required. Based on our examination, this speaks strongly in favour of (i) introducing carbon-price-based regulation to cope with the corresponding externality and (ii) focusing on understanding the non-emission market imperfections when designing investment support policies in order to avoid inefficient government spending. While it can be technically challenging to quantify all market imperfections, understanding them provides a reliable foundation when designing policy to moderate structural change.

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