

## ADVANCED REVIEW

# Mobilizing private finance for coastal adaptation: A literature review

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Coastal adaptation can reduce climate change impacts and investing now, though costly, will bring greater benefits over the longer term, particularly in urban areas. Yet public actors currently cover a small fraction of needed coastal adaptation investments, a finance gap set to widen as coastal adaptation costs continue to increase. Mobilizing private finance for coastal adaptation is thus a salient challenge, as emphasized in the Paris Agreement. Key under-researched dimensions of this challenge are what promotes private investment in coastal adaptation and how can public actors' interest in adaptation be aligned with private investor interests. To address this, we review the literatures on coastal adaptation finance and on financial arrangements involving both public actors and private investors. We describe key actors and interests, and identify coastal financial arrangements that align public actor and private investor interests, finding that private provisioning, public-private Partnerships (PPP), and public debt arrangements are promising. We then survey empirical examples, finding that private provisioning attracts investment when returns are high, for example, in urban real estate, and that PPPs attract dredging and construction companies' investment, particularly for adaptation measures with a large share of operational costs, for example, beach nourishment. We find little evidence of institutional investment through public debt instruments. A number of policy instruments, for example, concessional loans, tax incentives, and standards, may address this gap and enhance private coastal adaptation investment. Our results are also relevant for other sectors that involve long-term infrastructure adaptation measures.

This article is categorized under:

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**KEYWORDS**

adaptation finance, coasts, public finance, public-private partnerships

## 1 | INTRODUCTION

Climate change will impact the world's coasts, raising sea levels, and increasing flood risk, threatening lives and assets. Adaptation measures such as coastal protection can reduce these risks, and while such measures require large up-front investments, the benefits over the longer term are expected to exceed the costs by 2–3 orders of magnitude for urban areas (Hinkel et al., 2014). Yet many of the world's coastal cities remain under-protected (Wong et al., 2014). Indeed, global estimates of public coastal protection investments, approximately \$1 billion in 2014 (Buchner, Trabacchi, Mazza, Abramskiehn, & Wang,

2015), are far below estimates of levels needed for adaptation to sea-level rise. Minimum estimates range from roughly \$10 billion in the near term up to \$70 billion annually by the end of the century (Hinkel et al., 2014).

Coastal adaptation, including the required investments, has generally been seen as a responsibility of governments (Biesbroek et al., 2010). Yet given the substantial investment costs for coastal adaptation, public finances alone do not appear to be sufficient. Public budgets are increasingly strained in the wake of the global financial crisis and the European sovereign debt crisis is triggered. Austerity policies have seen several national governments reducing investment levels more generally (OECD, 2015a). These developments have followed a broader trend of governments around the world seeking private sector involvement in infrastructure provisioning to reduce pressure on their own balance sheets (Moszoro, Araya, Nunez, & Schwartz, 2015). In light of such limits, adaptation policy discourse has focused on increasing private finance for adaptation (UNEP, 2016) and this has been emphasized in the 2015 Paris Agreement.

Against this background, an important question is what hinders investment in coastal adaptation and which financial arrangements hold most promise for overcoming these barriers and attracting private finance to coastal adaptation investment. We address this question by analyzing the alignment of investor and public actor interests in financial arrangements for coastal adaptation investment. Because investment involves voluntary market transactions, promising arrangements must be attractive to both investors (supply of finance) and the public actors responsible for adaptation (demand for finance).

The remainder of the paper is organized as follows. The next section reviews barriers faced by public and private actors to invest in coastal adaptation. The section “Coastal finance arrangements and public interest” describes possible financial arrangements between public and private actors in coastal adaptation projects. The section “Aligning public and private interests” then develops a theoretical analysis, based on the literature, of promising financial arrangements that align investors’ and public actors interests’ in coastal adaptation. The following section “Evidence from cases” surveys empirical examples of coastal adaptation investment and examines whether and under what conditions theoretical alignments lead to investment in practice. When theoretical alignments are not observed in practice, we discuss policy instruments that may increase private investment through the identified financial arrangements. The final section reflects on the implications for policy and future research to enhance private investment in coastal adaptation.

## 2 | BARRIERS TO ADAPTATION FINANCE

### 2.1 | Barriers for public actors to invest in coastal adaptation

Coastal adaptation is generally a social welfare improving undertaking, particularly in urban areas, as mentioned. Coastal adaptation has public good characteristics, providing benefits that are nonrival and nonexcludable, and therefore is not efficiently provided by private actors (Olson, 1968). Further, coastal adaptation involves flood protection and land-use planning, often both explicit constitutional responsibilities of the government (Schneider, 2014). The public actor is thus responsible for coastal adaptation as they may be legally mandated to provide coastal flood protection (Sterr, 2008) or otherwise responsible for land-use planning, for example, setting zoning laws, building codes, and developing master plans (Harman, Taylor, & Lane, 2015).

Public actors are the main investors in coastal adaptation to date and nonetheless currently cover only about one tenth of needed investments (Buchner et al., 2015). A number of barriers help to explain this coastal adaptation public investment gap. One such barrier arises from the political economy of coastal adaptation. Coastal areas often involve high-value real estate and infrastructure, and adaptation measures can affect these values. For example, sea walls may reduce flood risk, but may also reduce amenities, such as unobstructed waterfront views or beach access. When such coastal investment decisions are taken by public actors, incentives arise for private actors to engage in rent-seeking behavior to influence these decisions (Storbjörk & Hedrén, 2011). For example, vested interests, waterfront property owners, may oppose adaptation measures that negatively affect their local amenities. These interests can shape coastal decision-making and even block coastal adaptation measures, such as, hard protection measures, or collective retreat, which would reduce the value of their properties (Beatley, 2012).

Another political economy barrier to public investment arises from the fact that coastal flooding events are relatively infrequent, and thus public perception of risk is low. Rewards to public actors for making coastal protection investments, for example, in terms of increased popularity with voters, are scarce. Moreover, coastal protection investments are made to avoid damages, and decision-makers are rarely rewarded for avoiding crises. In contrast, investments to address more frequent and immediate issues, such as municipal traffic or daycare provisioning, are often more salient local concerns, and thus offer immediate rewards to public actors addressing them (Storbjörk & Hedrén, 2011).

Another barrier to public investment in coastal adaptation is the regional nature of the public goods provided. In contrast to classical public goods such as air quality or security, the localized nature of coastal adaptation public goods gives rise to conflicts of interests between public actors in federal systems. For example, a regional government on the coast may consider funding an adaptation measure socially optimal, while a national government funding the same measure may be undertaking

redistribution, if funding comes from the national tax base (Osberghaus, Dannenberg, Mennel, & Sturm, 2010). Distributional conflicts between regions or jurisdictions are thus entailed in central government support for coastal adaptation and differing perceptions of fairness and opposition to public interventions may ensue (Adger, Quinn, Lorenzoni, & Murphy, 2016). Moreover, influential actors may enable their jurisdictions to attract more central government funds, leading to sub-optimal levels adaptation investment overall (Wolff, Bisaro, Sterr, & Hinkel, 2016).

Further barriers arise from the recent shifting of responsibilities from national governments, toward transnational actors and local actors; a “hollowing-out” of the state (Penning-Rowsell & Johnson, 2015) reflected in Europe in the subsidiary principle embodied in, for example, the EU Water Framework and Floods Directives (Thaler & Priest, 2014). One effect of this shift has been the reduction national public budgets for coastal adaptation investments. In this context, opportunity costs present a significant barrier to coastal adaptation investments for central governments. For example in the United Kingdom, at least a 5:1 benefit to cost ratio is required in order for the national government to invest in flood risk reduction (Defra, 2011). In developing countries, opportunity costs are an even more prominent barrier due to very attractive benefit–cost ratios of the health or education sectors investments (World Bank, 2014).

Another effect of this shift has been to push financing responsibility onto local authorities (Thaler & Priest, 2014). While at subnational scales, distributional conflicts between jurisdictions are reduced, other barriers emerge. Coastal protection taxes or levies raised from adaptation beneficiaries, for example, exposed households or property owners, are likely to encounter opposition due to free-riding dynamics, and, in electoral democracies, politicians who undertake such initiatives risk being voted out of office (Olson, 1968). For example, coastal protection levies have been discussed by various political parties at the federal state level in Germany, but have not been advanced in the legislature because of perceived risks of losing votes (Wolff et al., 2016). One example where such barriers have been overcome is the Netherlands, where regional water authorities (“water boards”) successfully collect taxes on residents and property owners for coastal protection infrastructure. There, however, the very early historical development of these institutions has been partly driven by the exceptionally long history of exposure coastal flooding in the Netherlands (Mostert, 2017).

Further, barriers to public investment arise from the cost of project preparation in the relatively large-scale projects required of coastal adaptation. Project preparation costs can range up to tens of millions of dollars, even before soliciting external investment. For public actors, it is difficult to make such project preparation investments, as they are likely to be subjected to public criticism if large sums of public money are spent for a project that is not eventually implemented (Penning-Rowsell & Johnson, 2015).

Finally, barriers also arise from the limited capacity of many public actors to generate revenues from coastal adaptation investments, and thus recoup a portion of the public money invested. Revenue generation, particularly urban development and land value capture, requires significant government capacity, which is often lacking in developing countries (Suzuki, Murakami, Hong, & Tamayose, 2015). Moreover, when awareness of risks posed by sea-level rise is low, flood risk reduction benefits may not be reflected in land or real estate markets, making direct revenue generation difficult (Druce, Moslener, Gruening, Pauw, & Connell, 2016). We explore these revenue generation channels in greater depth in the section “Coastal finance arrangements and public interest” below.

## 2.2 | Barriers for private actors to invest in coastal adaptation

A number of reasons suggest that it is promising to involve private actors in funding coastal adaptation. Coastal adaptation is often attractive from a purely economic perspective both for hard protection measures, as mentioned, as well as for soft measures, for example, beach nourishment that maintains benefits from tourism (Hinkel et al., 2013). That is, coastal protection measures lead to net economic benefits, and these benefits can produce revenue streams; the latter are essential for attracting private investors. Further, institutional investors with long-term liabilities, that is, pension funds and insurers, have investment horizons that match the long time horizons of coastal adaptation projects. Due to their need to match investments and liabilities (Andonov, Bauer, & Cremers, 2017), pension funds and insurers, who control a large share of global assets, approximately \$92 trillion in 2013 (OECD, 2015b), could be a significant source of private finance for coastal adaptation (Ameli, Bisaro, Drummond, & Grubb, 2017).

Generally, while less is known about current private investment practice in coastal adaptation compared to public investment (Buchner et al., 2015), for example, detailed project-level information of such investments is lacking (UNFCCC PSI, 2016), the literature presents several barriers to private investment in coastal adaptation.

“Country risk” is one key barrier to private investment, particularly in developing countries. Country risk generally refers to risks that arise from uncertainty in a country’s institutional environment, including regulatory and legislative risks as well as currency risks. Country risk is important because revenue generation in coastal adaptation projects depends in part on the government’s capacity to secure property rights, policy, and institutional frameworks. For instance, in coastal adaptation projects involving new real estate development, the government’s ability to secure property rights to the land being developed is

necessary for ensure direct revenue generation that can attract private investors. Similarly, in projects that upgrade existing coastal protection infrastructure, returns to private investors can be provided through long-term contracts with the government, and these returns depend on the government's ability and commitment to honor such contracts (Glaister, 1999).

Country risk is generally higher for less developed countries, and may also be perceived as higher for countries with a history of reneging on policies or securing property rights (Nathanson, 2013). Particularly in emerging economies, country risk is often the main driver of financing costs, and thus a significant barrier to private investment (Feyen, Ghosh, Kibuuka, & Farazi, 2015; Ondraczek, Komendantova, & Patt, 2015). Moreover, as debt, as opposed to equity, instruments have been more extensively used to finance adaptation, and high country risk regions, for example, Africa, do not easily attract debt finance, such regions are likely to have particular difficulty financing adaptation (Atteridge, 2015).

Finally, the distribution of liabilities between public actors and private investors gives rise to further barriers to private investment. On one hand, liability risks to private investors associated with large-scale coastal adaptation investments can pose significant barriers in light of the uncertainties associated with climate change and sea-level rise (IPCC, 2014). For example, investors may be discouraged from investing if high-end sea-level rise could lead to large-scale damage to property or critical infrastructure for which they would be liable (Schneider, 2014). Large-scale liability risks have been addressed to encourage private investment in other key sectors, though not yet for coastal adaptation. For example, governments have introduced liability caps in the nuclear energy sector (Heyes & Liston-Heyes, 2000). On the other hand, however, limiting the liability of private investors, either through such formal policies or informally by acting in practice as the insurer-of-last-resort, can create a moral hazard (Heyes & Liston-Heyes, 2000), disincentivizing private investors from making sufficient coastal protection investments, for example, in land creation or redevelopment projects. Thus, policy instruments that affect the distribution of liabilities should be considered in context of the overall costs to public actors, and the different modes through which coastal adaptation can be provided (see the next section).

### 2.3 | Overcoming barriers through aligning public and private interests

In order to overcome such barriers, and particularly to account for the greater financial responsibility placed on local authorities, new forms of co-operation between public and private actors for coastal adaptation are needed. Most broadly, this requires changing “social contracts” (Adger, Barnett, Brown, Marshall, & O'Brien, 2013), and encompasses novel financial arrangements and instruments (Little, Hobday, Parslow, Davies, & Grafton, 2015) that can align interests of public and private actors in coastal adaptation.

Promising financial instruments in this regard are “green bonds.” Indeed, green bonds can overcome finance barriers attracting private investors to coastal adaptation investment through highly liquid debt instruments. Multilateral development banks and municipalities have initially been the lead issuers of green bonds (CBI, 2016), while private issuers are increasingly entering the market. To date, only a small share of the overall climate bond market, approximately \$65 billion labeled in 2016, is related to adaptation. For example, of the \$25 billion in water bonds issued by utilities and municipalities on the market in 2013, only two issuances, accounting for \$266 million, explicitly consider adaptation (CBI, 2016). Activities to increase information sharing and accounting transparency, for example, climate bond standards including coastal adaptation, are underway and may increase the importance of green bonds for coastal adaptation investment (CBI, 2016).

Further, recent scholarly work addresses other novel financial arrangements, for example, public–private partnerships (PPP), entailed in mobilizing private finance for adaptation. This work has largely analyzed interactions between the broader institutional environment and private finance initiatives. For example, analysis of PPPs in adaptation has focused the role of trust (Bäckstrand, 2008) or inclusiveness, for example, assessing the extent to which PPPs affect participation in climate governance (Pattberg, 2010), as well as the influence of the discursive setting on project's ability to address long-term adaptation (Taylor & Harman, 2015). Relatively little attention has been paid to the material project-level incentives facing public actors and private investors in coastal adaptation, with some recent exceptions being work PPPs for coastal protection in Australia (Ware, Colleter, Carley, & Cox, 2015).

Generally, while there are calls for greater alignment between public and private interests in coastal adaptation, which would enable greater private involvement, little systematic analysis of the mechanisms by which such alignments can be achieved exists. Much of the current literature focuses on the broader institutional environment, while analysis of project level of financial arrangements is lacking. The remainder of the paper addresses this gap.

## 3 | COASTAL FINANCIAL ARRANGEMENTS AND PUBLIC INTEREST

For the purpose of this paper, we define *financial arrangements* for coastal adaptation projects as financial instruments within a particular coastal adaptation provisioning mode. Each concept is elaborated in a subsection below, and for the provisioning modes we also describe the public interest therein.

### 3.1 | Coastal adaptation projects

Here, we consider coastal adaptation projects involving collective flood risk reduction measures, that is, hard coastal protection infrastructure, for example, dikes or sea-walls, as well as soft protection measures, for example, beach nourishment. Individual household level measures, for example, flood-proofing homes, are not considered here because they do not provide public goods.

Such coastal adaptation projects are characterized by: (a) long time horizons; (b) high upfront investment costs; and (c) benefits that are non-excludable, that is, distributed over a range of stakeholders. For example, in some settings it may be easier to exclude potential beneficiaries, for example, if the flood plain is hardly populated beyond the immediate coast, it is easier to build collective protection for properties only on the sea-front.

Further, the coastal adaptation projects we consider are typically characterized by *construction risks*, including risks from building coastal protection, water supply and roads infrastructure, dredging activities, and real estate development. For instance, coastal adaptation projects in urban areas often involve urban land renewal or reclamation, which is developed for real estate, for example, in Helsinki, Hamburg (Mees, Driessen, & Runhaar, 2014) or the Maldives (Morrison, 2014). Construction risks include a range of risks that can lead to project failure, for example, equipment failure, unseasonal temperatures during key building periods leading to property damage and delays, building supply chain risks, and so on.

A necessary characteristic for attracting private investors is a coastal adaptation project's ability to generate revenues. Generally, there are two channels by which revenues can be generated from infrastructure investments, which have been examined by a substantial literature in urban and transportation studies (Petersen, 2007; van der Krabben & Needham, 2008).

First, revenue can be generated directly through the sale or lease of land or other assets that have increased in price due to the value created by infrastructure investments. For example, adaptation projects that create flood protected land in high-value urban areas can generate revenues because the costs of land reclamation and site preparation are generally much lower than the value of land around the world (Li, Shi, Zhu, Cao, & Yu, 2014). Typically, urban redevelopment involves a public actor buying up affected land, building infrastructure, and recouping costs by selling increased value land at higher price. Alternative revenue generation models include urban land adjustment, which involves private land owners co-financing part of the infrastructure cost (van der Krabben & Needham, 2008).

Direct revenue generating potential differs between coastal adaptation projects, for example, building a sea-wall to protect existing areas generates less direct revenue than building a sea-wall to reclaim and protect new land (Petersen, 2007). Generally, coastal adaptation infrastructure projects with little direct revenue generating potential depend on public actors because the increased value from coastal adaptation infrastructure accrues to diverse actors.

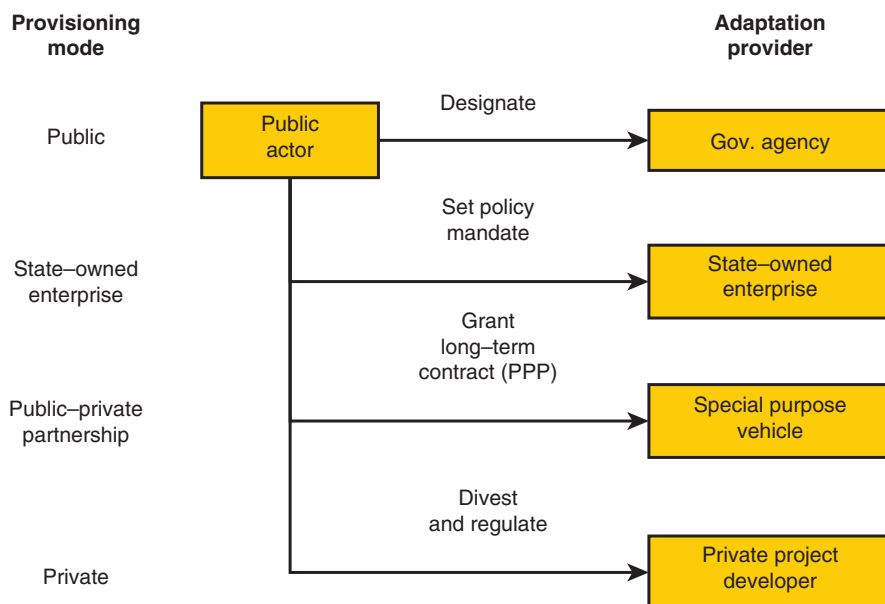
Second, revenue can be thus generated indirectly through taxes or levies on land or other activities, whose value has increased due to infrastructure investments. This is generally referred to as land value capture, and a wide array of tools are available here to public actors (Suzuki et al., 2015). Prominent tools are tax increment finance, used largely in the United States and the Netherlands (Root, van der Krabben, & Spit, 2015); land value tax; and special levies, such as special assessment districts and impact fees. Coastal adaptation projects can generate indirect revenues through maintaining or increasing existing economic activities with coastal protection infrastructure. For example, beach nourishment to provide flood risk reduction, while also maintaining tourism activities, can generate indirect revenues because the associated tourism activities can be taxed (Kok, de Bel, Bisaro, Hinkel, & Bouwer, 2017). While land value capture tools have been applied successfully particularly in the United States and Europe, in developing countries significant barriers due to low government capacity, including lack of land title or bureaucratic corruption (Smith & Gihring, 2006) have been observed.

As this paper focuses on mobilizing private finance, particularly through the alignment of interests between private investors and public actors responsible for coastal adaptation, we do not analyze value capture tools in-depth. Referring to Figure 1 below, our paper addresses the relationships between investors, responsible public actors and adaptation providers, whereas land value capture instruments encompass relationships between adaptation providers, responsible public actors and adaptation beneficiaries. Moreover, land value capture is well represented in the literature (see subsection "Barriers for private actors"), whereas the incentives for private investment in coastal adaptation projects have hardly been explored beyond the general perspectives reviewed above in the section "Barriers to adaptation finance."

### 3.2 | Provisioning modes and public actor interests

A public actor (e.g., government ministry, agency or local authority) is generally responsible for coastal adaptation through its mandate for flood protection and/or land-use planning. This public actor selects the coastal adaptation provisioning mode and adaptation provider (Figure 1). A *provisioning mode* consists of the legal relationship, that is, the distribution of rights and responsibilities, between the public actor and the adaptation provider.





**FIGURE 1** Coastal adaptation provisioning modes. The public actor chooses a provisioning mode and adaptation provider

Four top-level provisioning modes are relevant for coastal adaptation (Delmon, 2010). In the *public* provisioning mode, the public actor designates a government entity to provide coastal adaptation. To date, most coastal adaptation has been provided in this mode. Private investors are not involved in the ownership structure of the adaptation provider.

In the *state-owned enterprise* (SOE) provisioning mode, the public actor sets a policy mandate for a SOE to carry out coastal adaptation. The adaptation provider is a majority publicly owned corporate entity. Private investors may be involved as minority shareholders. The SOE mode entails a separation between political decision-making processes and the managerial process of the SOE as an adaptation provider. In theory, decisions made by an SOE aim to maximize value subject to the designated policy objective, for example, coastal adaptation (Detter & Fölster, 2015).

In the *PPP* provisioning mode, the public actor grants a long-term contract, for example, 20–30 years, to a special purpose vehicle (SPV), a legal entity established solely for the purpose and duration of the coastal adaptation project. The SPV is the adaptation provider and may be exclusively privately owned or may also include the public actor as a shareholder (Vining & Boardman, 2008).

In the *private* provisioning mode, the public actor sells or leases assets to private actors and regulates the private provisioning of coastal adaptation. The adaptation provider is privately owned, for example, private project developers.

The public actor's choice of provisioning modes is driven by two competing objectives: first, to limit their own financing costs and size of their balance sheet; second, to achieve their policy objectives. Provisioning modes with greater private sector involvement entail giving up some degree of control in regard to the latter. The public actor's two objectives thus give rise to trade-offs, because less direct control of policy outcomes can increase the public actor's costs from designing, monitoring, and enforcing contracts or regulations, though the latter costs are difficult to estimate *ex ante* (Vatn, 2005).

Public provisioning makes the greatest demands on public financing costs and balance sheet. SOE provisioning can have advantages here over pure public provisioning. First, SOE debt is generally not included on the government balance sheet, though this varies according to national accounting practices (Detter & Fölster, 2015). Second, SOEs generally conduct more comprehensive and transparent accounting of their assets compared to government agencies. SOEs can thus reduce finance costs for public actors (Detter & Fölster, 2015).

Provisioning modes with greater private sector involvement, that is, the PPP and private modes, allow the public actor to move liabilities off its balance sheet. In the PPP mode, the public actor often makes annual payments (annuities) over the lifetime of the contract (typically 20–30 years), thus reducing the overall size of their balance sheet, while the SPV finances upfront investments through a mix of debt and equity instruments. In the private provisioning mode, investment costs are moved off the public actor's balance sheet, as the relevant land or infrastructure is sold or leased to the private sector.

It should be noted that private sector cost of capital is generally higher than for a public entity undertaking a similar project (Helm, 2009), which is significant for the overall cost efficiency of the project, for example, in PPPs. Relative cost of capital is, however, not a primary consideration for the public actor in selecting a provisioning mode because in the PPP or private mode these costs are borne by the private sector.

In terms of policy outcomes, while public modes clearly offer public actors greatest control, the PPP mode offers more control than the private mode because performance measures in PPPs can be selected and iteratively adjusted to minimize monitoring costs (Yescombe, 2002). Finding contractible metrics needed for PPPs in the well-developed domain of coastal engineering (Nicholls, Hanson, Brown, & Hinkel, 2010) is generally straightforward. However, PPP arrangements need to be carefully designed as costs arising from contract disputes in PPPs can be significant (Vining & Boardman, 2008).

For private provisioning, regulation is likely required to ensure that coastal adaptation is provided because the adaptation providers' business model generally depends on reselling assets, for example, real estate development (Taylor, Harman, Heyenga, & McAllister, 2012). Thus, they have little incentive to invest in adaptation beyond what the market into which they are selling demands. Costs of regulation of coastal adaptation can arise, for example, from approving building designs, building code inspections, and conflict resolutions (Alexander, 2001).

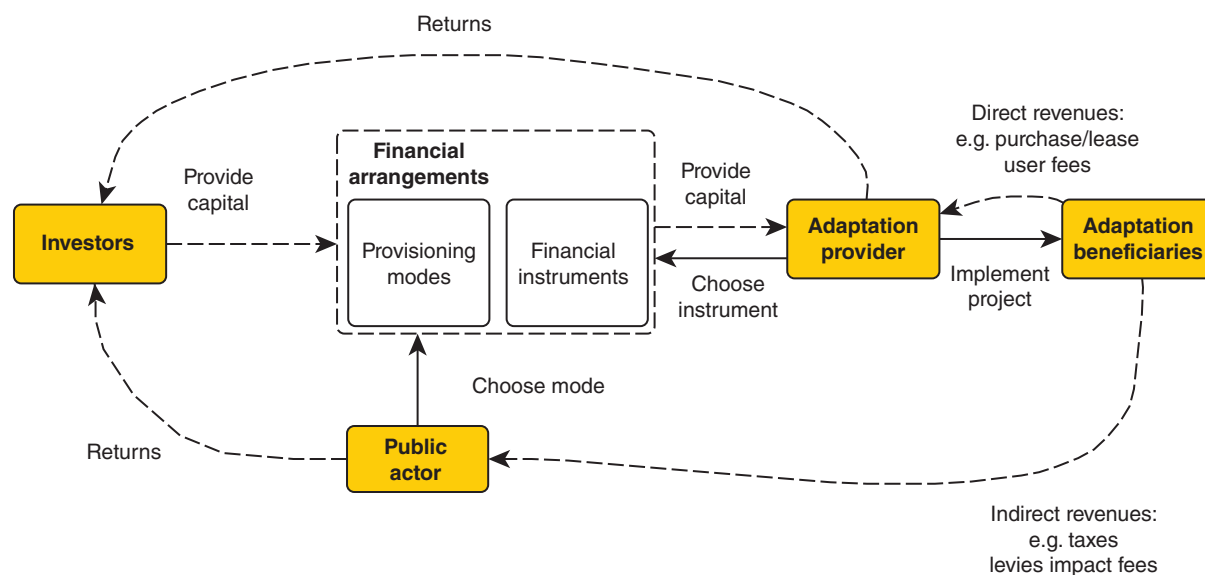
Finally, it should be noted that it can be difficult to make clear cuts between these categories. Real-world examples will often blend different provisioning modes, as projects can involve different adaptation providers at different or concurrent stages of project development and operation. Further, these are only top-level categories, and many more variables can be used to differentiate lower-level categories of governance arrangements. For example, in the literature on PPPs, arrangements differ in terms of, for example, ownership of assets, operation and maintenance, and fee collection responsibilities (Delmon, 2010).

### 3.3 | Financial instruments

Each provisioning mode can be combined with various financial instruments which determine financial flows between the key actors, namely, investors, public actors, adaptation providers, and adaptation beneficiaries (Figure 2).

*Financial instruments* can be defined as “any contract that gives rise to a financial asset of one entity [the investor] and a financial liability of another entity [the investee]” (International Accounting Standards, 2016). At a general level, financial instruments can be classified along two dimensions: first, as equity or debt (alternative instruments, for example, cash, derivatives, etc. are not addressed here); second, as direct or indirect. Equity instruments have lowest seniority recourse, which means that equity investors have the last claims on assets or revenue streams of an investee, being paid out only after debt instrument holders. Equity instruments, however, generally produce higher returns. Conversely, debt instruments have highest seniority recourse and produce lower returns.

Direct instruments involve the investor in a direct contractual relationship with the investee, and the contract is not traded in regulated exchanges, e.g., stock markets. Indirect instruments are traded on regulated exchanges, i.e., stocks and bonds, and are generally standardized, as a requirement for being included on exchanges. As a result, they are characterized by greater accounting transparency. Further, indirect instruments are generally have higher liquidity than direct instruments. Liquidity is a measure of the degree to which an instrument can be either bought or sold without affecting its price (Drehmann & Nikolaou, 2013).



**FIGURE 2** Financing arrangements in terms of responsibilities (drawn-through arrows) and possible financial flows (dashed arrows) between key actors involved in coastal adaptation (yellow boxes)

Combining these two dimensions gives the following four general classes of financial instruments:

1. *Direct equity shares*: the investor provides money to the investee, and gains claims on the future income streams from the investee, as well as decision-making power regarding its actions. The main variables describing equity shares are: price and decision-making rights.
2. *Indirect equity shares* or *stocks*: the investor provides money to the investee and gains claims on the future income streams of the investee, as well as voting rights regarding the actions of the investee. In contrast to shares, stocks are traded on exchanges and subject to the regulations of that exchange. The main variables describing stocks are: price, dividend, voting rights.
3. *Direct debt* or *loans*: the investor provides money to the investee to be repaid in full by the end of the contract lifetime (maturity) plus periodic payments of interest. The main variables describing loans are: principal, interest rate, maturity, and backing. Loans may be backed by an asset, for example, residential building units; an income stream, for example, utility bill payments; or the investee's general balance sheet.
4. *Indirect debt* or *bonds*: the investor provides money to the investee to be repaid by the end of the contract lifetime (at maturity) and subject to periodic payments of interest on the initial sum (yield). The main variables describing bonds are: principal, yield, maturity, backing, and rating. Similar to loans, a bond may be linked to an asset, an income stream or the general balance sheet of the issuer.

Financial instruments can be further classified according to whether they are *project finance* and *balance sheet finance* instruments. *Project finance* can be defined as “limited or non-recourse financing of a newly to be developed project through the establishment of a [special purpose] vehicle company” (Kleimeier & Megginson, 2000). Project finance instruments are backed by the assets or revenues of the project invested in. *Balance sheet finance* refers to instruments in which the investor has full recourse to the assets and revenues of the investee.

## 4 | ALIGNING PRIVATE INVESTORS INTERESTS WITH PUBLIC INTERESTS

### 4.1 | Private actor's interests

Private investors' interest is driven by the risk characteristics of a financial arrangement and these can be described along four dimensions (Table 1): *seniority of recourse* and *liquidity* has been described above. *State guarantee* may be explicit, established through contracts or laws, or may be implicit, for example, SOE debt instruments are often implicitly guaranteed because states will not let certain enterprises fail (Detter & Fölster, 2015). *Accounting transparency* refers to the costs of collecting information on the assets and liabilities of an investee.

**TABLE 1** Risk characteristics of coastal adaptation financial arrangements. Rankings are relative. Each dimension is ranked on a scale from (\*) to (\*\*\*\*\*). A higher score on one dimension indicates a lower level of risk associated with the financial arrangement. A range is indicated for “Guarantee of state” in the PPP mode

Financial arrangements <sup>a</sup>		Financial instruments <sup>a</sup>			
		Equity		Debt	
		Share	Stock	Loan	Bond
Provision mode <sup>a</sup>	Public			S:***** L:* G:***** A:**	S:***** L:***** G:***** A:**
	SOE	S:* L:* G:***** A:***	S:* L:*** G:***** A:***	S:***** L:* G:***** A:***	S:***** L:***** G:***** A:***
	PPP (project finance)	S: * L:* G: ** - ***** A:*****		S:***** L:* G: ** - ***** A:*****	S:***** L:***** G: ** - ***** A:*****
	Private	S: * L:* G:* A:**	S: * L:***** G:* A:*****	S:***** L:* G:* A:**	S:***** L:***** G:* A:*****

S = Seniority of recourse for investor; L = Liquidity; G = Guarantee of state; A = Accounting transparency.

<sup>a</sup> Dimension reducing risk.



In the public mode, equity is not relevant. Debt instruments issued by governments are generally one of the lowest risk instruments available, as seniority of recourse is high and state guarantees are explicit. In terms of liquidity, there are differences between bonds and loans. While government bonds are generally highly liquid due to well-developed secondary bond markets, particularly in OECD countries (OECD, 2015c) loans are not tradable and thus illiquid. For accounting transparency, government debt instruments are less transparent than SOE debt instruments because public asset ownership data are often not available, particularly at subnational levels (Detter & Fölster, 2015).

In the SOE mode, debt instruments are particularly important as SOE bonds make up approximately one tenth of the global bond market (Detter & Fölster, 2015). Risks are higher compared to government debt instruments in that state guarantees of SOE instruments are not always explicit, though investors, however, often assume an implicit guarantee (Detter & Fölster, 2015). Furthermore, accounting transparency, as mentioned, is often higher compared to government debt.

SOE equity instruments are influenced by the fact that the state is the majority owner. Liquidity of SOE equity instruments is therefore lower compared to other equity financial arrangements because at least 50% of shares remain with the state, constraining the market in the remaining shares. SOE equity is generally subject to an implicit state guarantee, thus reducing risks of SOE equity compared to equity in a private company.

In the PPP mode, state guarantees are determined by contract specifics, as this determine whether the public actor has a direct financial stake in PPP performance. Generally, state guarantees are high, when the public actor is a shareholder in the SPV (James, 2008). Accounting transparency is generally high because as a project finance arrangements, SPV assets and liabilities relate to just one project. In contrast, a company generally has many projects and activities, and associated assets and liabilities (Yescombe, 2002).

In the private mode, we note that state guarantees are nonexistent for companies engaged as coastal adaptation providers, for example, real-estate developers, construction, or dredging firms. Accounting transparency is greater for private indirect instruments than for private direct instruments because of stock exchange regulations.

Finally, we note that these generic characteristics lead to different levels of risk in different institutional environments. For example, a financial instrument with state guarantee from a developing country may nonetheless be high risk due to, for example, country risk. Similarly, an instrument guaranteed by a highly indebted country may be riskier than one guaranteed by a country with little public debt. The generic characterization of financial arrangements provided in Table 1 provides high-level entry points for identifying private investor interests in coastal adaptation. Specific risk characteristics of financial arrangements, for example, arising from the institutional environment, need to be considered on a case-by-case basis in the context of the specific project at hand.

## 4.2 | Four financial arrangements aligning public and private interests

Different kinds of investors prefer different risk characteristics and hence different financial arrangements. Most generally, one can distinguish between institutional investors, who pool the capital of others, and noninstitutional investors, who invest their own shareholders' capital. Institutional investors include equity and hedge funds, commercial banks, pension funds, and insurers, while noninstitutional investors include corporations and natural persons. Among these investors, we identified two groups of investors interested in coastal adaptation and four types financial arrangements that align public and private interests (Table 2).

**TABLE 2** Coastal financial arrangements aligning public actor interests and investor interests

Financial arrangement aligning public and private interests and relevant investor	Public actor interest	Investor's interest			
		General interest in coastal adaptation	Source of capital	Liquidity needs	Preferred size of investment
Private equity instruments and real estate developers	Reducing public expenditures	Coastal adaptation projects involve activities that are part of core business.	Own equity	Low to Moderate	\$10,000–\$100 million
Public–private partnership equity instruments and construction and real estate developers	Reducing balance sheet, while maintaining moderate control of project outcomes				
Public–private partnership bonds and institutional investors			Investment horizon of coastal adaptation projects matches long-term liabilities.	Short- and long-term policy holders	High
Public bonds and institutional investors	Maintaining control of project outcomes while accessing debt markets				

A first kind of financial arrangement aligning private investor and public actor interests is private equity instruments that involve real estate development companies. This arrangement is attractive to real estate development companies because it allows them to retain construction and revenue risks in coastal adaptation projects that are part of their core business, that is, risks associated to building and selling or leasing real estate. By retaining the revenue risk of selling or leasing real estate, real estate companies can earn higher returns than compared with being involved in the public provisioning mode as a contractor to a public adaptation provider. Moreover, liquidity constraints for corporations are generally lower than for institutional investors because corporations have their own (shareholder) capital. Thus direct equity instruments, which are less liquid and can typically provide higher returns than debt instruments, are attractive to them. For the public actor, the private provisioning mode is attractive because it reduces the size of the public balance sheet and overall public expenditures. However, it also requires the public actor to take on the costs of regulation and enforcement in order to ensure that adaptation objectives are achieved.

A second kind of financial arrangement aligning private investor and public actor interests is PPP equity instruments involving construction and dredging companies. This arrangement is attractive to construction and dredging companies because it allows them to retain construction risks which are their core business. Moreover the long-term nature of the PPP contract provides sufficient time for these companies to learn and improve their service delivery performance, and the SPV equity instrument allows them to capture the gains from this improved performance. For public actors, the PPP mode is attractive because it reduces the public balance sheet and allows some control over outcomes, for example, in the design and tendering of the contract.

A third kind of financial arrangement aligning private investor and public actor interests is PPP bonds involving insurers and pension funds. This arrangement is attractive to insurers and pensions funds because both have substantial long-term liabilities (Kaminker, Kawanishi, Stewart, Caldecott, & Howarth, 2013) matching the long time horizons of coastal adaptation projects. Other institutional investors, for example, hedge funds, private equity funds or commercial banks, do not have such long-term liabilities, and thus no such interest in coastal adaptation. Insurers and pension funds have typically invested in bonds, government bonds in particular (OECD, 2015b), partly due to regulations, for example, Solvency II, that make illiquid direct investments more costly for them (Buchner et al., 2015). However, due to recent low returns on public debt, they have an increasing interest in PPP bond instruments that can provide higher yields. Pension funds in Canada and Australia, for example, have increased infrastructure investment significantly (OECD, 2015b). The size of investment available through a particular financial arrangement, however, remains an important constraint, as the investments must be large enough to cover due diligence costs (Ameli et al., 2017). Only the largest pension funds and insurers consider direct project investments, and then with a lower investment size limit of around \$30 million. Only larger coastal adaptation projects pass this threshold. For public actors, the PPP mode is attractive because it reduces the size of the public balance sheet, despite higher costs of capital for the private sector, and allows the public actor to maintain some control over policy outcomes.

A fourth kind of financial arrangement aligning private investor and public actor interests is public bonds. As mentioned, insurers and pension funds' typically have an interest in low-risk, long-term, and liquid instruments, that is, government bonds. For public actors, the public mode is attractive specifically for projects that do not generate direct revenues because (a) it allows meeting policy objectives through implementing projects that create value for a diverse range of actors through flood risk reduction and (b) it is difficult to attract equity investors without direct revenues.

Attracting institutional investors to public coastal adaptation bonds represents an opportunity to reduce the cost of public debt in such projects. As with PPP debt, the size of investment available is an important constraint, due to investment volume required to be attractive to large institutional investors. Moreover, the attractiveness of such public debt instruments will also depend on the value capture model in place, and the capacity of the government to implement it.

As noted, a suite of further variables related to, for example, geographical setting and institutional environment, further determine the risk associated to financial arrangements and thus whether these generic alignments lead to actual private coastal adaptation investment. We explore cases for each of these alignments below, discussing variables that influence their success in practice. For alignments in which we do not find cases, we discuss reasons for this, and potential policy instruments to address this gap.

## 5 | EVIDENCE FROM CASES

This section surveys empirical evidence for the four financial arrangement aligning public and private interests identified in the last section. Each alignment is discussed in terms of (a) observed private investment in coastal adaptation and (b) further variables, for example, policies and other incentives, that have influenced observed investment. In the case of no investment being observed in practice, possible barriers to investment, and policy instruments that could trigger investment are discussed.

## 5.1 | Private equity instruments and real estate developers

Private equity arrangements involving real estate developers as investors can already be observed in practice. For example, in 1997, the City of Hamburg embarked on HafenCity, a major inner-city development project that envisioned redevelopment of 155 ha of industrial and port land in the Elbe river estuary outside the main Hamburg city dikes. The project foresees providing up to 7,000 new residential and commercial units by 2025, expanding the city center area by around 40%, while providing the same level of flood protection as the main Hamburg city dike. The city dike height is 7.5 m above mean sea-level, and thus provides a high level of protection even considering sea-level rise (Polkowski, 2008).

To achieve the required flood protection level, roads and public transport infrastructure connecting the project to the rest of the city have been raised by between 7.5 and 8.3 m above current sea-level, while private real estate developers are responsible for raising new buildings between 7.5 and 9 m above sea-level on land they purchase. Importantly, segments of HafenCity are being developed and sold gradually. As of 2016, approximately 30% of the entire project area had been redeveloped. The step-by-step approach, involving selling real estate assets to private real estate developers with the requirement to raise buildings, has reduced major upfront investments for the public actor, spreading them over time and sharing coastal adaptation costs between public and private actors (Mees et al., 2014). Only the costs for land preparation and raised road access for a project segment must be borne by HafenCity, which can then be covered by sale of land without much delay. Required investment for the entire project is approximately €10.9 billion of investment. Public funds make up around €2.4 billion, nearly all from the City of Hamburg, and the remaining from private sources, for example, through purchase of land within the project by real estate developers.

In terms of further variables influencing private investment, the regulation and tendering process for land sale in HafenCity has played an important role. Regulation is needed in HafenCity because real estate developers do not have incentives to invest in adaptation beyond what the real estate market demands (Agrawala et al., 2011). To maintain some control over achievement of its adaptation objectives, the City of Hamburg set up a careful procedure of tendering process for land sale and building development within HafenCity. Winning bidders received an option period in which they could further specify plans and sell units, before finalizing the purchase and initiating the project.

The tendering process is also attractive for real estate developers, as it positively influences the quality of developments within the project, reducing the risk of poorly design or failed developments. These could negatively impact the value of other real estate investments through reducing the attractiveness of, and thus demand for, individual units.

## 5.2 | PPP equity instruments and construction and real estate companies

PPP arrangements with construction and real estate companies as equity investors can already be observed in practice. For example, at Pevensey Bay, a 9-km stretch on the south-east coast of the United Kingdom, around 17,000 property owners and a Ramsar wetland are protected from coastal flooding by a sand shingle bank operated through a PPP. In the United Kingdom, the Environment Agency, responsible for coastal protection, was faced at the end of the 1990s with large investment needs, as the shingle bank and existing groynes at Pevensey Bay were deteriorating. The Environment Agency chose a PPP provisioning mode, tendering a long-term contract from 2000 to 2025 eventually won by the Pevensey Coastal Defence Limited (PCDL), a consortium of four dredging and construction companies, at a value of £30 million (Sutherland & Thomas, 2011). The contract stipulated an initial 200,000 m<sup>3</sup> of shingle be provided by PCDL to upgrade the shingle bank to a 1/400 year flood protection standard, and that this protection standard be maintained for the contract duration, also incorporating sea-level rise. To ensure achievement of flood protection level and facilitate monitoring, performance measures over the life of the contract were also agreed. These measures included 20,000 m<sup>3</sup> of annual shingle supply, a 2 million m<sup>3</sup> shingle volume for the entire coastline and a minimum width of the bank at its crest (22 m). As a service provision contract, it does not specify how these targets are to be met, which is key for achieving efficiency gains from private involvement. An Environment Agency ex ante assessment of the project estimated 15% savings of the PPP over traditional public provisioning (Tanis & Vergeer, 2008).

For the construction and dredging companies who are shareholders in the PCDL, equity investments were attractive for two reasons. First, the PPP contract is flexible in terms of service delivery. For instance, the required annual volume of shingle supply can be delivered at any time during the course of the year, rather than at regular intervals. This is attractive to PCDL because shingle is supplied using a near-shore dredging ship owned by one of the PCDL shareholders. As the ship is also engaged in other projects, for example, dredging coastal harbors on the south coast of the United Kingdom, the flexibility of the contract allows PCDL to integrate the planning of dredging with its other projects. Dredging costs for the PCDL are thus lowered because dredging can be scheduled at the times when the ship is not otherwise in use.

Second, the long-term nature of the contract offered by the Environmental Agency provides the opportunity to improve efficiency of service delivery over time as the PCDL learns about the project site over a longer period. This also provides incentives to PCDL to make such improvements because they are translated into profits. Indeed, the PCDL has improved efficiency by monitoring sediment flows at the site and improving timing of shingle delivery with respect to tides

(Sutherland & Thomas, 2011). Generally, in order for such learning opportunities in long-term contracts to translate to economic incentives for private investors, operating costs need to make up a significant share of the overall project costs (Tanis & Vergeer, 2008). In the United Kingdom, PPP contracts are required to consist in over 50% of their present value from operation and maintenance costs, as is the case for the Pevensy PPP (Chester, 2000).

### 5.3 | PPP bonds and institutional investors

Despite this alignment seeming attractive from a theoretical point of view, we do not currently observe PPP debt instruments in coastal adaptation projects with institutional investors. This is an interesting result because it has been recently observed that some institutional investors restructure their portfolio precisely toward these instruments, for example, possibly in a search for higher yield (OECD, 2015a) or in the United States, in response to accounting regulations allowing them to discount future liabilities based on the expected nonrisk-adjusted returns of their assets (Andonov et al., 2017). This trend has not yet extended to coastal adaptation projects.

There are several possible reasons for the lack of pension fund and insurer investment in coastal adaptation PPPs. First, the relatively small size of coastal adaptation projects may be a barrier to institutional investor involvement. \$100 million is a realistic lower bound for a coastal adaptation project of interest to insurers or pension funds, as insurers and pension funds require as mentioned roughly \$30 million in investment volume and would not participate as sole investors. While coastal adaptation projects of this size do exist, for example, in major urban redevelopments such as the HafenCity project discussed above, many projects are too small to be of interest for insurers and pension funds. Second, for projects located in developing countries, even those that do meet the required investment volume, country risk is a major barrier for institutional investors. For instance, major projects addressing coastal adaptation in the Maldives and Jakarta, Indonesia have been funded largely through concessional debt provided by development finance institutions (Bisaro, Kok, Hinkel, & de Bel, 2017).

One type of policy instrument that could potentially address these barriers is “de-risking” investments by development banks. Such instruments have supported climate-related infrastructure investment aimed at emission reduction, but as yet have not targeted coastal adaptation. For example, the Europe 2020 Project Bond Initiative of the European Investment Bank provides subordinated debt to projects in transport, energy and ICT sectors, thus enhancing the credit rating of project implementers (EIB, 2012), but does not consider coastal protection infrastructure projects. Including climate adaptation in such derisking programs could encourage institutional investors to invest in adaptation particularly where country risk is higher. Such measures, that is, credit support by major development banks, could also enable smaller institutional investors to invest in coastal adaptation projects without needing to conduct in-house due diligence.

### 5.4 | Public bonds and institutional investors

We also did not observe institutional investors investing in coastal adaptation projects through public debt, e.g. municipal bonds. This was perhaps most surprising given institutional investor preferences for low-risk, long-term, and liquid financial instruments. Several potential barriers to institutional investment in coastal adaptation through public debt instruments arise from the investor perspective. We note that these differ from the barriers to public finance of adaptation discussed in the sub-section “Barriers for public actors,” which were barriers from the public actor perspective.

From the investor perspective, one potential barrier is that tax legislation regarding public debt does not provide appropriate incentives to institutional investors. In the United States, for example, municipal bond yields are exempt from federal income tax. This makes municipal bonds attractive to investors seeking tax relief, such as, high net worth individuals. Pension funds, in contrast, are themselves exempt from federal income tax. Tax laws in the United States thus make municipal debt less attractive to pension funds because high net-worth individuals, for whom the tax incentives are attractive, may bid up the price of municipal bonds.

Another potential barrier for investors is the slower emergence of standards or labels for bonds in adaptation relevant sectors compared to those in mitigation relevant sectors (CBI, 2016). While municipal bonds have been issued to fund renewable energy infrastructure, or transportation infrastructure, and received a “green” label, coastal adaptation is less widely perceived as producing the public good of reducing climate risks (Kaminker et al., 2013). For institutional investors that have made ethical or social investment pledges, which includes a growing share of the largest funds, such labels are important, and the lack of a “green” label for coastal adaptation debt instruments may make investment in other climate relevant activities more attractive. It should be noted though that investments in renewable energy are generally more attractive to institutional investors compared to flood risk reduction measures because in the former case, a clear source of revenue generation exists.

Policy instruments to address these barriers can enable public debt for coastal adaptation to be issued at lower cost to public actors. First, support for the development of standards and labels for coastal adaptation debt instruments would enable

greater investment from institutional investors that have made social or ethical investment pledges (CBI, 2016). Second, tax incentives could be better aligned to the needs of institutional investors in order to support the match between long-term liabilities of institutional investors, and the long time horizons of coastal adaptation projects. Third, in developing countries where country risk is a primary consideration, development finance institutions can play a role in derisking public debt instruments thus making them attractive to private institutional investors.

## 6 | CONCLUSION

This article has analyzed which financial arrangements are promising, both from a theoretical and empirical perspective, to align public actor and private investor interests in coastal adaptation projects in order to overcome prevailing barriers and help to close the coastal adaption financing gap. Financing arrangements were analyzed in terms of four provision modes (i.e., public provisioning, state-owned companies, PPP, private provisioning), financial instruments applied within each mode, and their risk characteristics for private investors.

Based on our theoretical considerations, we identified four financial arrangements that align public and private investor interests. The following two of these arrangements were also observed in practice: Equity investments in the PPP and private provisioning modes. Both of these provide alignment because they reduce public balance sheets and transfer construction risk exposure from public actors to private project developers who are better able to manage such risks because this is part of their core business. For private equity instruments, high direct revenues are needed to compensate investors, for example, real estate developers, for the high up-front costs. As such, private provisioning is likely to be attractive only for projects that include high-value real estate development, that is, projects in urban areas. PPP equity instruments align public and private interests by providing incentives to private investors for learning through long-term contracts, while allowing public actors greater control over outcomes, that is, through contract design and tendering, than in the private mode. PPPs thus offer potential to mobilize private coastal adaptation investment from construction and dredging companies in small- to medium-scale infrastructure projects, particularly when operational costs are a large share of the overall project costs.

While our theoretical analysis also revealed that public debt and PPP arrangements for coastal adaptation investment align interests of public actors and pension funds and insurers, they were not observed in practice. We hypothesize that this lack of observed investment could be overcome through economic policy instruments such as concessional loans or guarantees provided by development banks, which could “de-risk” coastal adaptation project thus attracting greater institutional investment. These instruments deserve renewed attention for coastal adaptation, particularly as the public good nature of coastal adaptation is generally under-recognized (Tompkins & Eakin, 2012) and supporting the provisioning of such public goods fits with the emerging role of “mission-oriented” state investment banks (Mazzucato & Penna, 2015). Further, there is emerging evidence that tax policy reform in many countries could enhance coastal adaptation investment by better targeting institutional investors, who have an interest in the long time horizons of coastal adaptation investment. For instance, federal tax breaks to municipal bond holders in the United States are ill-designed to attract pension fund investment, since these investors are generally already exempt from such taxes. Finally, policy should also continue to support the development of standards and labels for financial instruments that address coastal adaptation, for example, climate bonds, as this can also greatly increase the interest of institutional investors in coastal adaptation.

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## CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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