Global Environmental Change 80 (2023) 102657

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Finance for fossils – The role of public financing in expanding petrochemicals

Jakob Skovgaard [a,*], Guy Finkill [b], Fredric Bauer [a], Max Åhman [a], Tobias Dan Nielsen [c]

[a] Lund University, Sweden
[b] Manchester University, United Kingdom
[c] IVL Swedish Environmental Research Institute, Sweden

ARTICLE INFO

Keywords:
Petrochemicals
Finance
Plastics
Fertilizer
Climate change
Lock-in

ABSTRACT

The petrochemicals industry (mainly plastics and fertilizer production) is expanding, despite increasing attention to the environmental impact of petrochemicals. In our paper, we explore the role public finance plays in the petrochemicals industry. We do so by mapping the public and private financial flows into large-scale petrochemical projects for the decade 2010–20 and discuss the role of public financial institutions for the development of the industry globally. Secondly, we provide a detailed analysis of the roles international and national public finance has played in enabling two prominent petrochemical projects: namely the Sadara plant in Saudi Arabia and the Surgil plant in Uzbekistan. The cases are illustrative of the dynamics of state interest and involvement in fossil fuel producing countries as well as of lending and guarantees from foreign export credit agencies (ECAs) and development finance institutions, and how such public finance plays an important role in leveraging private finance. Our findings show how public finance for petrochemicals is highly globalized and to a large degree originates in developed countries. As petrochemical industrial infrastructures are designed to last decades, the public finance thus strongly contributes to the carbon lock-in of the sector and limits the possibilities for low-carbon investments needed to comply with the UN Paris Agreement.

1. Introduction

The global production of petrochemicals (plastics, nitrogen fertilizers, solvents etc.) continues to increase, made possible inter alia by a continuous flow of financial capital for petrochemical plants and related infrastructure. This persists despite increasing concerns about plastic pollution and the climate impact of petrochemicals, as well as international governance efforts to mitigate these negative impacts (Bond et al., 2020). The workings of financial markets are increasingly highlighted as a central issue for understanding the potential for transformations aligned with global sustainability targets (Galaz et al., 2015) as is the financial risk of investments in industries affected by such transformations (Semieniuk et al., 2020). Most notably, the Paris Agreement explicitly aims to make "finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (UNFCCC, 2015, art 2.1c). There is however still limited knowledge of how and to which extent public finance is contributing to investments in the fossil-fuel dependent and emissions-intensive petrochemicals sector.

The petrochemicals sector constitutes a hard-to-abate sector, which often has been politically and academically overlooked in comparison to the energy and transportation sectors (Åhman et al., 2017; Bataille et al., 2018). Direct CO_2 emissions from the petrochemical industry amounted to 1,500 Mt (IEA 2018), making it the third most emitting industrial sector. Apart from direct emissions associated with the production processes there are also substantial emissions related to energy use (Scope 2), extraction and processing of feedstocks (Scope 3 – Upstream), as well as waste incineration after end-of-life for plastic products (Scope 3 – Downstream) (Cabernard et al. 2022; Bauer et al. 2023). Similar to other hard-to-abate sectors such as steel or cement, it is characterized by high capital costs, long investment cycles, thin profit margins and zero or low-carbon technologies being in nascent states of development (Wesseling et al., 2017). Consequently, investment in new carbon intensive petrochemical production infrastructure will need to be scaled down immediately and cease completely by 2030 if the sector is to reach the target of a low-carbon economy by 2050 (IEA, 2021b).

The literature on financing of fossil fuel infrastructure has shown that finance constitutes a key component of the lock-in of carbon-intense production and consumption (Kim & Urpelainen, 2013; Newell, 2021;

* Corresponding author at: Department of Political Science, Lund University, P.O. Box 52, SE-221 00 Lund, Sweden.
E-mail address: Jakob.skovgaard@svet.lu.se (J. Skovgaard).

https://doi.org/10.1016/j.gloenvcha.2023.102657
Received 10 June 2022; Received in revised form 9 February 2023; Accepted 6 March 2023
Available online 17 March 2023

Rainforest Action Network et al., 2020). This literature has inter-alia focused on the role of different kinds of public finance, including national level fossil fuel subsidies (Skovgaard & van Asselt, 2018; 2019), as well as overseas development finance from multilateral (Hansen et al., 2016; Steffen & Schmidt, 2019) and bilateral sources (Chen et al., 2021; Hopewell, 2019). Such fossil fuel financing maintains fossil fuel incumbency through keeping fossil fuel companies solvent and the wider public tied into a fossil fuel based system of production (Newell, 2021, p 118-119). Finance can uphold this incumbency or accelerate its demise, but while financing to fossil fuels outnumbers financing for renewable energy, political attention has focused on increasing financing for renewable energy and other low-carbon activities rather than diverting finance away from carbon intense activities (Newell, 2021; Skovgaard & van Asselt, 2019).

While the literature on public finance for fossil fuels has given us an idea of its scope, importance and current trends, we do not have similar knowledge for the petrochemical sector. Likewise, the small but growing literature on the connection between petrochemicals and climate change has focused on the growing share of global emissions coming from this sector and providing techno-centric low-carbon scenarios. Few have critically analysed the enabling role financial flows play in enabling the expansion of fossil-based petrochemicals (but see CIEL, 2018; Tobin, 2012). This raises the question of what role public finance plays for petrochemicals. In this article, we address this question and lay the foundation for future research to explore this in further detail. We do so first by mapping the public and private financial flows into large-scale petrochemical projects for the period 2010–20 and discussing the role of public finance on a macro level. Secondly, we provide a more detailed analysis of the roles international and national public finance has in enabling such projects, including from which kinds of institutions and countries the finance originates. Our analysis includes two case studies of prominent petrochemical projects that have received substantial international and national public finance, namely the Sadara plant in Saudi Arabia and the Surgil plant in Uzbekistan. The cases are illustrative of the dynamics of state interest and involvement in fossil fuel producing countries as well as public finance, and how such finance plays an important role in leveraging private finance to make the petrochemical infrastructure expansion possible. Furthermore, they represent large petrochemical plants in Asia and the Middle East & North Africa (MENA), the two largest recipients of petrochemical finance.

The paper is organised as follows. Section 2 provides background to the connections between the climate impact of petrochemicals production and the particularly strong role the sector has in countries with large fossil fuel resources. In section 3 we present the roles that different types of financial institutions have for increasing the dependency on fossil fuels and emissions intensive industrial activities. Section 4 presents the research design used for the analysis. The macro level analysis of global financial flows is presented in section 5. Section 6 explores the role of public finance in the two case studies. We conclude the paper with a discussion of our findings that public support and finance contribute to the lock-in of fossil fuels by supporting the expansion of the petrochemicals sector, and place them in the wider context of making (public) finance sustainable.

2. Petrochemicals – Expanding and carbon-intense

Petrochemicals denotes a diverse group of products mainly produced from oil or gas, with a small share of global production being based on coal (primarily in China). Plastics remains the single largest product category from the petrochemical industry (Levi & Cullen, 2018) followed by nitrogen fertilizers and a diverse group of solvents, explosives, and other chemical products. Petrochemicals are ubiquitous and intrinsic to current practices in agriculture, transportation, electronics, and many other sectors. This is evident in the massive growth in demand for petrochemicals, which has outpaced that of GDP growth, since the 1970s (IEA, 2018) with an average annual growth rate of global sales of 7.5% from 2010 to 2019 (Cefic, 2021). A substantial continued growth is expected, with forecasts indicating that global petrochemical capacity could grow another 40% this decade, from 2,200 million tonnes per annum (Mtpa) in 2020 to 3,100 Mtpa in 2030, primarily in Asia (India and China) due to demand growth and in gas and oil producing regions such as the former Soviet Union and MENA regions (Global Data, 2021).

The production of petrochemicals requires vast volumes of fossil fuels. Roughly half of it is used as feedstocks, providing the molecules which through chemical processes are turned into petrochemicals. The other half is used as energy in the conversion processes. The petrochemical sector consumes an estimated 14% of global petroleum (oil) and 8% of natural gas, and it has the highest primary energy demand of all industries (IEA, 2020). Due to extensive economies of scale, chemical plants have grown in size for decades, reaching the scale of "ultra-mega plants" in the 2000s (Fertilizer International, 2011). Thus, new investments are very large, on the scale of billions of USD for a significant expansion or a greenfield project. Firms in the industry have made record investments (Bauer & Fontenit, 2021), and as oil majors see the sector becoming an increasingly important downstream market there has been a strategic push for closer integration between oil and chemicals, exemplified by 2019 Saudi Aramco's acquisition of a shareholder majority in SABIC, at the time the fourth largest chemicals firm in the world (Tullo, 2020).

Investment decisions in the petrochemical industry have impacts far into the future: from the decision there is several years of design and construction before a new plant is operational, and thereafter the lifetime of key equipment and infrastructure is several decades (Erickson et al., 2015). In this way investments in new fossil-based production locks in future production and emissions for decades. Accessing capital willing to invest in fossil-dependent and emissions intensive technologies and infrastructures is thus a necessity for the industry to materialize its expected growth. Investments until 2030 are estimated to total more than 300 billion USD (Global Data, 2021). Low-carbon process alternatives addressing both direct emissions from the energy use and feedstock (e.g. electrifying steam crackers and using recycled feedstocks or captured carbon) do exist for key petrochemicals, but are dependent on scale-up of new technologies (IEA, 2020; 2021a). Green hydrogen is identified as a cornerstone of a low-carbon transformation of the industry (e.g. for green ammonia) together with the use of captured carbon (CCU) – but both are processes which require enormous volumes of renewable electricity to be viable as transformative solutions (Kätelhön et al. 2019). Bio-based chemical production is another emerging pathway, although the competition from other uses of bio-based material such as biofuels limits the extent to which the chemical industry can make use of available bioresources. A priority for a low-carbon development of the industry is also the transition to renewable electricity as main energy carrier, but commitments to this remain few in the industry (Bauer et al. 2022a). Alternative pathways for reducing the climate impact of the industry and its products are reducing demand for plastics and improving their circularity to reduce virgin production. The development of these pathways do however meet many barriers as they contradict market logics institutionalized in the industry, require new habits among end consumers now accustomed to cheap synthetic materials in all kinds of products, and are still not strongly supported by policy and governance regimes that remain weak and fragmented (Bauer et al., 2022b).

3. Finance as an enabler of lock-in

While finance plays a role in the lock-in of the petrochemical sector, this finance remains understudied compared to the role of finance for fossil fuels. Yet, there are several overlaps and similarities between finance for fossil fuels and petrochemicals, making it worthwhile to draw on the experiences from finance for fossil fuels. Concerning overlaps, if finance lowers the price of fossil fuels, e.g. through subsidies for

fossil fuel extraction, it indirectly lowers the cost of producing petrochemicals from these fossil fuels. In terms of similarities, in both cases sustainability requires moving beyond the current carbon-intensive modes of production and consumption. Financing for these modes is one of the factors that keeps them locked-in, both because of the infrastructure financed remains in place for decades and because it empowers actors interested in maintaining these carbon-intensive modes of production and consumption (Bernstein & Hoffmann, 2019). Scholars have demonstrated how lock-in at different levels and sectors reinforce each other, with financing of carbon-intense infrastructures supporting carbon-intense and unsustainable consumption (Erickson et al., 2015; Seto et al., 2016). A substantial share of recent investments in petrochemicals has been driven by the desire to avoid the transition risks facing fossil fuel investments due to the expected decrease in demand for fossil fuels for electricity and transportation (Fattouh & Sen, 2021; Goldthau & Westphal, 2019; van de Graaf & Bradshaw, 2018). Yet, the investments in petrochemical infrastructure explored in this paper could become stranded assets in case that regulation reduces demand for petrochemical products such as fertilizers, or if market and technological developments favour low-carbon plastics, thus making fossil based petrochemical production obsolete. Thus, while the investments studied here may intend to limit transition risks, they are also subject to such risks themselves (see e.g. Campiglio et al, 2018 on transition risks).

Due to differences in political contexts, we distinguish between the different types of financiers on the basis of whether they are public or private and whether they are national or international (see Table 1 below). Starting with public and private financiers, following the approach of the Multilateral Development Banks (MDBs), we define public and private financiers in terms of whether they are respectively established "to benefit or promote a specific national interest" or "(a) carrying out or established for business purposes and (b) financially and managerially autonomous from nationals or local government" (World Bank, 2018: 3). In some cases it is difficult to draw a sharp line between the two, and unlike the MDBs we group Sovereign Wealth Funds with the public financiers due to their close ties to "their" states.

We draw on literature on development finance and renewable energy finance to identify how public finance can influence the overall finance for a project. Generally, public finance intends to increase the amount of private finance, an effect referred to as mobilizing, leveraging and catalyzing, and which is well-established in the cases of national, bi- and multilateral development banks as well as ECAs (Zhang 2022; Deleidi et al 2021; Steffen & Schmidt, 2019; Hopewell, 2019; Geddes et al, 2018; de Nevers, 2017; Griffiths, 2012; Hainz and Kleimeister 2012). Such leveraging can take place directly through bringing the "risk-adjusted rate of return on investment in line with the market, increasing the allure of the investment from a private commercial investor perspective" (Attridge & Engen, 2019, p 26). In this way, they can attract more private finance to projects that otherwise would leave private financiers hesitant due to long time-horizons for return on the investment or insecure political and economic climates in the country of investment (Hopewell, 2019). This can be done through loan guarantees, raising finance on the financial market relying on the credit rating of a bilateral or multilateral institution, or through grants or concessional loans from international development institutions (International Financial Consulting, 2019). Leveraging from public financiers can also be indirect through sending a signal to private financiers that the project meets their standards or is less exposed to political risk stemming from government policy, since governments are either involved or, in the case of MDBs, fear antagonising the public financiers (Hainz & Kleimeister, 2012).

Table 1
Typology of financiers and the main financial instruments they provide.

	National	International
Public	National development banks (credit, fixed income, guarantees) State-owned companies – *operating nationally* (equity) Sovereign Wealth Funds – *operating nationally* (equity)	Export credit agencies; (guarantees, credit, fixed income) Multilateral development banks (grants, (often concessional) credit, guarantees, in rare cases equity) Bilateral development agencies (grants, (often concessional) credit, guarantees, in rare cases equity) State-owned companies – *operating internationally* (equity) Sovereign Wealth Funds – *operating internationally* (equity)
Private	Privately owned banks (credit) Petrochemical companies (equity) Fossil fuel companies (equity)	Privately owned banks (credit) Petrochemical companies (equity) Fossil fuel companies (equity)

Here, we distinguish between national and international financiers based on whether they reside in the same country as a given project. National public financiers include National Development Banks established to support domestic industrial development, state-owned companies e.g., within the fossil fuel or petrochemical sectors, and Sovereign Wealth Funds, particularly prominent in fossil fuel producing countries. International public financiers include ECAs created to facilitate exports of domestic goods and technologies, alongside multilateral and bilateral development banks with general mandates to support growth and development. Some public financiers (particularly Sovereign Wealth Funds and state-owned companies) may in the case of one project constitute a national financier and in others an international one. Private financiers are rather similar irrespectively of whether they are national or international as they commonly operate across borders.

The types of financiers given in Table 1 provide different kinds of capital and supporting financial instruments, some of them providing several kinds. We have identified the most important (for the purpose of this paper) kinds of capital and instruments on the basis of existing literature (see e.g. UNFCCC Standing Committee on Finance, 2022; Hopewell, 2019; Geddes et al, 2018; Hainz and Kleimeister 2012). Given that our focus is on public finance directed at petrochemical projects, we do not include finance that may indirectly affect such projects, such as production subsidies for oil and gas or agricultural subsidies for fertilizers. Whereas (state-owned and private) companies (excluding banks) mainly provide equity, (national, multi- and bilateral) development institutions provide loans and guarantees (including insurance) that reduce the risk of private loans and equity, and ECAs and export–import banks provide guarantees and loans. Concessional loans are loans with terms that are more favorable than the market terms, e.g. lower interest rates, longer maturities, grace periods, etc.

As feedstock costs constitute the most important part of petrochemical production costs, the development of new petrochemical projects is often located in regions with access to low cost fossil fuels and feedstock. Commonly, projects are developed in the form of joint ventures between local actors with access to the local market and the fossil resources and one or several of the globally leading petrochemical firms, supplying technologies and licenses (Clews, 2016). Some of the capital for project development is supplied through equity shares in the new firm but as these projects are commonly very expensive, additional capital is acquired on international capital markets. Such capital can be direct loans from commercial banks as well as development banks but is often also raised through the issuance of fixed income instruments such as corporate bonds which are paid back over a decade or longer.

There are considerable motivations for oil and gas producing states and their national development banks to support investments in petrochemicals to ensure economic growth and development. The above-mentioned expected decline in demand for oil and gas, driven by climate policy and shifting consumer preferences (IEA 2018) motivates the downstream investment by such states into petrochemicals as a means to capture a larger part of the value chain, to create much desired domestic jobs, and to "lock in" future demand for both oil and gas

(Goldthau & Westphal, 2019; van de Graaf & Bradshaw, 2018).

Lately, an emerging awareness of sustainability issues within the financial sector has seen a flow of initiatives to discourage, or outright ban, support to coal, oil and gas (ICC, 2021). While several ECAs and MDBs in the past five years have withdrawn from financing exploration of coal mines, new oil exploration, and unconventional gas; yet petrochemicals remain supported by these institutions.

4. Research design

To study public and private finance for petrochemicals, we created a dataset of global finance flows for petrochemical infrastructure investments over the last decade. We also provide two case studies that explore the various roles that transnational public involvement can play in major infrastructure projects in the industry.

The dataset maps investments in petrochemical projects that have had a project capital expenditure (CAPEX) above a threshold of $1 billion USD between the dates of January 1, 2010 and December 31, 2020. For further insight on finance flows within the petrochemical industry in the Covid era up until mid-2021, see Barrowclough & Finkill (2021).

The minimum threshold of $1 billion was adopted to focus on major petrochemical projects that often require external forms of financing to proceed. The decade long timeframe from 2010 to 2020 was chosen to provide a substantial overview of petrochemical project financing across an era which has borne witness to ramped up climate ambition across the finance industry, especially in the wake of the landmark Paris Agreement in 2015, and because these large projects are often financed by several investment decisions that can be announced years apart. Our data has been derived from the IJ Global database, the largest global database of financial transactions for infrastructure. IJ Global may miss some transactions due to lack of transparency, reporting inadequacies, but focusing on large projects minimizes this risk. Loan guarantees, not constituting a flow of finance but rather used as an instrument leveraging such (private) finance, are not included in this part of the analysis.

We identified 58 projects that matched our criteria. In order to be eligible for assessment, the projects had to have reached a stage of financial closing[1] and not be cancelled after financing had been confirmed. One case was removed from the data analysis for this reason, leaving 57 projects to disaggregate financing for. These cases had a capital expenditure (used to buy, maintain, or improve fixed assets, such as infrastructure or buildings) value ranging from $1 billion to $20 billion, averaging $4.1 billion and with a median of $2.5 billion. At the time of writing, these projects range from being in pre-development stage, under construction, or already operating at commercial scale.

Following our analysis of global finance flows in this era, we selected two cases that exemplify the important role that public finance can play in realizing major petrochemical infrastructural projects. The cases were selected as they illustrate how both national and international public finance is integrated with private interests and capital to create new fossil infrastructure. The cases are thus not representative of the full sample. The cases are based in the two regions where the industry is currently expanding most and that receive the highest amount of global financing for petrochemical infrastructure, as the global analysis shows. Importantly, unlike our global mapping, the case studies include loan guarantees, e.g. from ECAs.

The first case study is the Sadara Petrochemical Complex, situated in Al-Jubail, Saudi Arabia. Sadara is one of 18 projects from the MENA region in the dataset, where Saudi Arabia stands out with 10 projects. With its $20 billion investment Sadara is the largest project in the sample, one of six projects with a CAPEX of $10 billion or higher, and thus constitutes an extreme case. Sadara directly links public and private interests from different continents through its structure as a joint venture and was record-breaking as it was the largest petrochemical complex to be built in a single phase (Singh, 2020). The second case study is the Surgil Petrochemical and Natural Gas Complex located in the Usyurt region of Uzbekistan, one of 20 projects in Asia Pacific and very close to the average size in the dataset. The Surgil project connects the construction of a petrochemical complex to the development of the Surgil gas field through its combination of gas processing and petrochemicals production. The case thus shows how petrochemicals are becoming a fully integrated part of strategic planning for maximising the economic value of fossil fuel resources. The case provides insights into developments in Central Asia, an often overlooked part of a continent that is likely to continue investing in oil, gas and chemicals, as well as how public financial institutions from non-Western countries are also deeply investing in petrochemicals. Taken together the cases thus illustrate investment dynamics in a mature as well as an emerging petrochemical hub, which both rely on international public finance to support their growth.

5. An overview of petrochemical finance flows

A total of $238 billion has been provided for the 57 projects studied between 2010 and 2020, of which public finance accounts for about 14% of the total, as illustrated in the Sankey diagram (Fig. 1) below. However, this does not account for the way in which public finance may influence the amounts of private finance invested, as discussed in section 3 and explored in the two case studies. Specifically, public financing may be utilized in the initiation of large-scale petrochemical plants and complexes. We tracked public financing arising from national development banks, MDBs, ECAs and sovereign wealth funds. There were also a few examples of commercial banks making up sections of project financing as part of private consortiums with publicly owned finance initiatives as majority shareholders, but still fall under the label of private as recognized by IJ Global, something which is highlighted in the case studies featured below. Public financing was detected in 26 of 57 the assessed projects (45%), covering an average 26% of the investment in the projects with public finance involvement. In geographical terms, there was public finance in all regions, ranging from 7% of all finance in North America to 17% in MENA and sub-Saharan Africa. While it was not possible to study to which degree public finance leveraged private finance in all (or even a majority) of the studied projects, we found examples of such leverage in all regions except Latin America. For instance the South Korean government guaranteed 80% of the $1.56 billion debt for a greenfield plant in Singapore (Kan, 2011), and guarantees and loans from the ECAs and MDBs leveraged loans from ten commercial banks in the case of a similar plant in Mexico[2] (Braskem, 2012).

Clearly visible in Fig. 1 is the concentration of production situated in the Asia Pacific (covering Asia and the Pacific) and MENA regions with 20 and 18 projects respectively. These regions account for all brownfield projects and 75% of all greenfield projects. The Asia Pacific region received 40% of all finance, making it the largest recipient region, and constituting an underlying factor (together with e.g., increased demand) behind the region's substantial marine littering and plastic pollution (Kapinga & Chung, 2020; Marks et al., 2020). The MENA region received almost $22.5 billion of financing from public coffers, from a mixture of state-owned enterprises in the surrounding region and notably from public finance institutions (PFIs) from further afield; exemplified by the role of the US Export-Import Bank and others in the Sadara case study (Table 2). Europe and North America have received less finance, corresponding to their lower growth in production (Geng

[1] The event in which the debt financing procurement has been completed and contracts have been signed.

[2] We follow IJ Global's classification as Mexico as belonging to North America rather than Latin America.

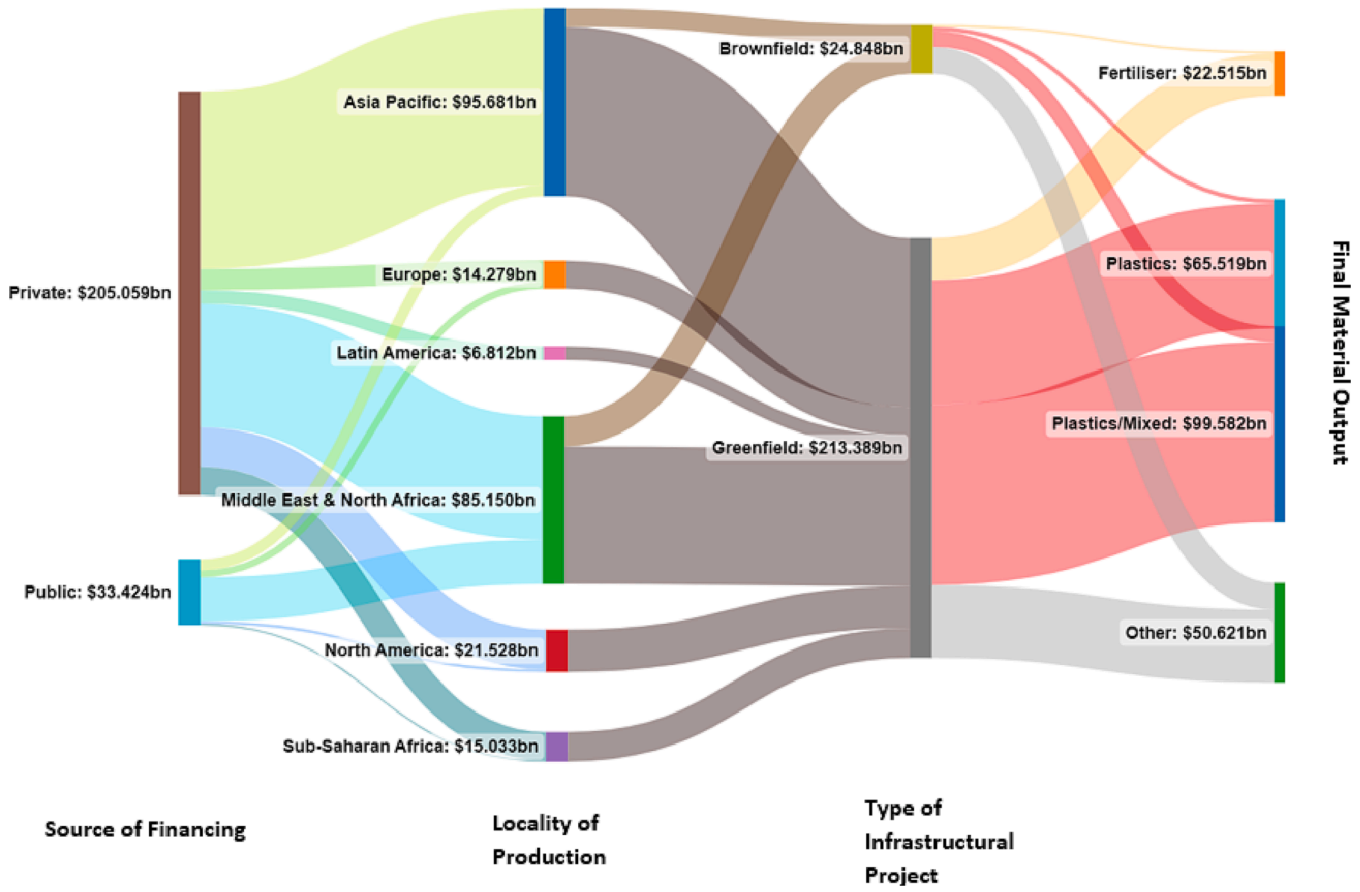

Fig. 1. Finance flows to petrochemicals projects with a CAPEX above $1 billion between 2010 and 2020. Source: Data derived from IJ Global database. All geographical, types of project, and final material outputs are defined by the classifications used in the IJ Global database. Authors' own calculations.

et al., 2019). Yet, a substantial share of global petrochemicals finance emanates from these regions, and much of this finance flows into new petrochemical projects outside of their borders (Barrowclough & Finkill, 2021), specifically in the MENA and Asia Pacific regions. This illustrates the global character of petrochemical finance. (Table 2, 3, 4 and 5).

Across all regions, the major projects were most closely linked to plastics production or their immediate chemical feedstocks, with 69% of the total financing being split amongst 30 complexes that had plastics including key derivatives and feedstocks as their primary output, with an average project value of $5.5 billion. Importantly, greenfield investments account for 90 percent of the investment, indicating that the finance will lock in petrochemical production for decades.

New fertilizer production is small in comparison, but 11 projects were directly related to increasing fertilizer production to meet increased demand across the regions (FAO, 2017). The output labelled as 'other' refers to all other petrochemical outputs that could not be connected to plastics or fertilizer, the production of solvents, industrial acids and methanol for example.

Beyond the public finance identified in Fig. 1, the petrochemical industry has for long been closely linked to strategic state interests, constituting an entanglement between public and private interests that can enhance public finance for petrochemicals. Although Western governments in the 1990s started to publicly list their state-owned petrochemical companies, in many cases they still hold significant ownership positions. 18 of the operating companies involved in the 57 transactions detailed in Fig. 1, are featured in the C&EN List of Top-50 Petrochemical Companies (by chemical sales) in 2021 (Tullo, 2021). Four of these companies Braskem (Brazil), Sinopec (China), Saudi Aramco/SABIC (Saudia Arabia), Sasol (South Africa) have a state ownership of greater than 15%, the state being the major equity owner in each case. While state equity holdings are a small proportion of total equity for the petrochemical companies, the numbers are substantial: for the mentioned top 50 petrochemical companies, state holdings are worth around $179 billion (close to the GDP of New Zealand). Private equity owners are represented more evenly across all the companies (MarketScreener, 2022). Even when governments are not directly involved, states are often indirectly involved through their sovereign wealth funds and public pension funds with equity holdings. This is the case for the funds of states such as South Korea, Sweden, and Thailand which hold equity investments in several petrochemical companies. Most notably the Norwegian state has equity holdings in just over half of the top 50 petrochemical companies, through its state pension funds. Even if a state only holds a few percent of the total equity, this adds legitimacy to the company and means that the state has an interest in the financial performance of the company (Fernandes, 2014). These connections can also constitute informal channels for company influence.

Beyond state-ownership, the ECAs and development banks – as discussed in section 3 – provide essential financial support and a degree of risk reduction (and arguably also legitimacy) for large-scale infrastructural projects, especially in developing or emerging economies, despite making up a relatively small proportion of the overall funding (Humphrey, 2018). In this way, they can leverage the amounts of private finance invested, e.g. as part of a wider industrialization strategy such as China's Belt and Road initiative (Chan, 2018).

6. The role of public funding for petrochemical expansion

In this section we turn to the cases of Sadara in Saudi Arabia and Surgil in Uzbekistan to illustrate how public funding in the petrochemical industry can materialize into new petrochemical complexes.

These case studies include the public finance included in the analysis above (loans and equity), as well as export credits. As discussed in Section 3, these credits reduce the risks associated with export of technical expertise and technology.

The investments in the two case studies are driven by both fossil fuel companies and producer economies as a diversification strategy to move up the value chain and get more revenue from their fossil resources (Åhman, 2021; Halff & Mills, 2021; Yamada, 2011). Furthermore, as highlighted in Section3, investing in petrochemical production is a strategy to secure future demand for oil and gas in the light of expected lower global demand (Halff & Mills, 2021; Yamada, 2011).

6.1. Case Study: Sadara (Saudi Arabia)

Saudia Arabia is highly dependent on oil rents and has the worlds largest reserves of easily accessible oil. In 2019, oil rents represented 24% of Saudi Arabia's GDP (World Bank, 2022). However, the oil rents contribution has fluctuated strongly from 50% down to 20% of GDP the past 10 years depending on the oil prices. Saudi Arabiás dependency on oil revenues is a major problem with oil revenues potentially deteriorating due to "peak demand" and associated lower prices on the global market (Fattouh & Sen, 2021). The need to diversify and find a replacement industry that "exceeds the loss of revenue from oil export" (Kingdom of Saudi Arabia, 2015) is well recognised in Saudi Arabian long-term plans. The long-term plan "Vision 2030" emphasizes economic diversification including the development of the petrochemical sector. The ongoing Saudi transformation necessitates both economic and political change (Krane 2021, Fattouh and Sen 2021). Saudi Arabia's efforts to move into petrochemicals with the Sadara joint venture with Dow chemicals are part of this diversification strategy. Together with downstream investments in both foreign refineries and end users, Sadara is part of the strategy to lock in demand for Saudi Arabian oil and limit transition risks (Krane 2021).

The Sadara project is a joint 65/35% effort by the state-owned oil company Saudi Aramco and US-based Dow Chemical Company, providing respectively $4.39 and $2.37 billion. Saudi Aramco is completely controlled by the Saudi state. The project was approved in 2011 and is operational across some facilities and received refinancing for the project debt in February 2021 to enable further facilities to become operational (Global, 2022). The complex, which when completed will include 26 manufacturing units, a mixed-feed steam cracker and an aromatics plant, will constitute the largest petrochemical facility ever built in a single phase, as most petrochemical complexes are constructed across an extended timeframe with multiple expansions. The project is located in the Jubail Industrial City II in eastern Saudi Arabia. Output will be dominated by value-added chemicals, as well as plastics for use in the energy, transportation, construction, electrical, and electronics sectors (Global, 2022). The facility is capable of producing 1.5 million metric tons of ethylene and 400,000 metric tons of propylene per year. The ethylene and propylene will serve as feedstock for multiple downstream production lines, producing materials that can later end up in market segments such as plastic packaging, textiles or toys.

Beyond the funds invested by Saudi Aramco and Dow, finance (outlined in Table 2 below) also includes a $1.3 billion injection from Saudi Arabia's own Public Investment Fund. The Saudi Public Investment Fund (PIF) has the aim to be the "leading catalyst for Vision 2030, Saudi Arabia's economic transformation program" (PIF, 2022). There was a $220 million direct loan with the multilateral Islamic Development Bank (IDB), $169 million of combined public money stemming from the development banks of Canada and Germany. A striking $5 billion of direct financing stemmed from the US Export-Import Bank (Global, 2022). ECAs were also providing guarantees for debt financing to the tune of $2bn (ibid). Table 2 and 3 below disaggregates the financing by each individual form of financier. Specifically connected to the project, but not included in the table below there was a $2 billion Sukuk bond issuance by Saudi Aramco. It was simultaneously listed alongside a private consortium of commercial banks that mustered $1.8 billion between them. Petrochemical companies issue bonds without specifying in the prospectus whether they will fund a particular project, although this is often the case. Therefore, it is very likely that there is a larger share of the Sadara financing that stems indirectly from such bonds than what we have identified.

Despite the immense wealth of the Saudi Public Investment Fund, Saudi Aramco[3], and Dow, this project still obtained a sizeable international public finance injection from overseas, through which international public finance reduced risks for private actors, in the case of bilateral institutions from their own countries that put forward their patented technology as well as technical knowhow during the facilities' construction and operations (Oramah, 2020). The $5 billion loan from the US Export-Import Bank is described as the largest in the bank's history (U.S. EXIM Bank, 2013), as well as the largest in the Saudi petrochemical industry (DOW, 2017). The US EXIM Bank (2012) justified the loan with reference to that the entire Sadara project would support approximately 18,400 American jobs, across 70 private US-based exporters that are providing technical expertise, equipment, and services during the complex's construction and operation. The financial backing of Germany's KfW paved the way for major German exporters such as ThyssenKrupp and Siemens to be involved in the project (KfW IPEX-Bank, 2013) as well as numerous medium-large size enterprises. The role of public finance vis-à-vis private finance is also evident in some of the loan underwriters stemming from non-MENA PFIs, such as Canada (EDC, 2013) and the UK (UK Export Finance, 2013). These loan guarantees allowed a consortium of private banks to provide financing with significantly less risk than would have otherwise been the case, as exemplified in the journal Global Trade Review; "Given the stability and reputations of the sponsors, it was unlikely that Sadara would ever have had great difficulty attracting commercial debt." (Bermingham, 2015). Altogether, while we cannot say how much private finance the public finance leveraged, it was intended and perceived as facilitating increased private finance.

This entanglement of different public and private sources of finance underscores the importance of public finance for private finance but also that public finance was not driven by the particular context in oil and gas producing countries or regions. Rather, there are 3 PFIs not situated in the MENA region that are providing direct financing as well as 5 non-MENA countries providing loan guarantees via ECAs, and the public finance comes from countries including from 5 of the G7 countries and 7 out of 19 countries in the G20. These international PFIs ignored international safeguards when it came to the Sadara project: In 2015, the OECD found that the project adhered to none of World Bank's Safeguard Policies and Performance Standards, which are usually used to assess Export Credits and Credit Guarantees (OECD, 2016 pp.41–42). These safeguards cover the following areas; Environmental Assessment, Natural Habitats, Pest Management, Indigenous People, Physical Cultural Resources, Involuntary Resettlement, Forests, Safety of Dams, International Waterways, Disputed Areas (OECD, 2016; World Bank, 2016).

6.2. Case Study: Surgil (Uzbekistan)

Uzbekistan has an economy dependent on export of natural resources such as cotton (the world's largest exporter), oil and gas. The gas reserves are minor compared to neighbouring Turkmenistan and Kazakhstan and the gas production has been stable for the past 10 years. The gas rents contribution to the GDP has fluctuated between 2 and 10% the past 10 years depending on gas prices (World Bank, 2022). During former President Karimov's tenure, the economy was a state-led autarchic economy led by a number of large capital-intensive state-owned companies (Pirani, 2019). After his death in 2016, his successor,

[3] The parent company of chemical subsidiary SABIC.

Table 2
Financial support for the Sadara project.

State Financing	Quantity ($m)	Private Financing	Quantity ($m)	Loan Guarantees	Quantity ($m)
Saudi Public Investment Fund	1,300	Abu Dhabi Commercial Bank*	220	K-Exim (Korea)	80
Islamic Development Bank	220	Arab National Bank*	220	K-Sure (Korea)	500
US EXIM	5,000	Banque Saudi Fransi***	220	Hermes (Germany)	425
Export Development Canada	84.62	SABB	220	UKEF (United Kingdom)	700
KfW (Germany)	84.62	Citigroup	84.62	Instituto de Credito Oficial (Spain)	225
*Abu Dhabi Commercial Bank is 60% owned by state-owned Abu Dhabi Investment Council.		Credit Agricole Group	84.62	Groupe BPCE (French private ECA)	70
**Arab National Bank [based in Saudi Arabia] is 40% owned by the Arab Bank Group, a Jordanian bank which has 17.2% held by the national social security corporation.		Barclays	84.62	**Equity Owners**	**Percentage**
		BNP Paribas	84.62	Saudi Aramco	65%
		Goldman Sachs	84.62	Dow	35%
***Banque Saudi Fransi is 16.2% held by Kingdom Holding Co. Unclear if directly linked to Saudi royalty or not.		HSBC	84.62		
		JP Morgan	84.62		
		Mizuho Financial Group	84.62		
		MUFG Bank	84.62		
		Standard Chartered Bank	84.62		
		Sumitomo Mitsui Banking Corporation	84.62		

Table 3
Summary of direct financial support for the Sadara project, by type ($m).

$m	National	International
Public	1,300	5,389
Private	660	1,151

president Mirzioyev, has tried to open up the economy and thus allowed foreign companies to make investments in the gas sector (ibid). Most of the gas (2/3^{rds}) is consumed at low prices domestically and the rest is exported mainly to Russia and China via pipelines. The investments in petrochemicals will allow Uzbekistan to create more value out of the slowly dwindling gas resources and can also be seen as a part of the donor supported development strategy of Uzbekistan to liberalise the economy and allowing more foreign investments[4]. These investments are emblematic of a wider global transition to high-value chemical production by oil and gas extractors, made possible by using less fuel for transport fuels and energy production.

The Surgil gas and chemical project is worth approximately $4 billion and can annually process 4.5 billion cubic meters of natural gas and produce 3.7 billion cubic meters of marketable gas, 387 thousand tons of polyethylene, 83 thousand tons of polypropylene (key plastics), as well as many other valuable petrochemical-derived products (Manzurova, 2016). The equity of $1.4 billion for the project is split between four companies, Korea-based STX (5%), Germany-based Lotte Chemical Corporation (17.5%), Korea-based Korea Gas Corporation (17.5%), and the domestic, fully state-owned Uzbekneftegaz (50%). The general announcement tendering external financing began in 2009, the Asian Development Bank signed on in January 2012, with financing closing of the project occurring in late 2013 (Global, 2022).

Beyond equity, the financing for the project is 52% provided by PFIs, mostly based in the Asia Pacific region, with 34% of the debt financing underwritten by state managed ECAs. Financial closing for the project was confirmed in May 2012. Table 4 and 5 disaggregates the financing by each individual form of financier.

Surgil has a similar involvement of ECAs as in the Sadara case, but the financing of this Uzbek project also includes a heavy direct involvement from multi-lateral and national development banks. Korean PFIs lead the way in both direct financing and loan guarantees, unsurprising given that 3 of the 4 owners of the Surgil gas and petrochemical complex are Korean companies, Korea Gas Corporation, Honam Petrochemical, and STX Energy (IJ Global, 2012; Reuters, 2012). The development of the Surgil complex began six years after the then South Korean President Roh Moo-hyun signed an agreement with former Uzbek President Islam Karimov allowing for joint exploration and development of oil and gas fields in the region (Watkins, 2006). The $125 million from the ADB and the $250 million from the CDB is indicative of Asian investment in the region, helping the country to diversify the dominant gas industry (Raimondi, 2019). ADB views the Surgil project as adding "incremental economic value to Uzbekistan's natural gas resources, enabling higher value products to be manufactured and exported"(ADB, 2021).

As it was the case with Sadara, the public finance for the Surgil project comes from a range of sources, including countries typically seen as green on the world stage (Sweden, Germany), as well as an MDB, the Asian Development Bank. The ADB has committed to climate mitigation in recent publications, but they have also continued to finance fossil fuel projects despite this commitment (Delina, 2017). The stated intention behind involving the ADB was for it to act "as an anchor lender and catalyze commercial banks to finance the Surgil Gas Chemicals Project" together with the Export-Import Bank of Korea and the Korea Trade Insurance Corporation that "also played key roles in the term sheet negotiations and due diligence" (ADB 2011).

The social impact or environmental safeguards report that many PFIs write prior to getting involved in a project did not prevent their involvement. In none of the assessed PFI environmental safeguards were any provisions found on making the petrochemical production process low-carbon. In ADB's 'Social Safeguards Report' on the project (2012), there is not a single mentioning of the words "emissions" nor "climate" (ADB, 2012). Likewise, the Swedish EKN's Non-Technical Summary (Volume I, 2011 pp.19–30), mentions both Volatile Organic Compounds and GHG emissions several times, but the risk of impact is consistently deemed "insignificant" or "not applicable", and generally considers the project to be in line with international guidelines and protocols in regard to best practices, citing the Kyoto Protocol nine times (ibid). Sweden as well as Germany have consistently committed themselves both domestically and internationally to climate leadership and the low-carbon transition (Hildingsson & Khan, 2015; Otteni & Weisskircher, 2021), but their treatment of the safeguards appear to reflect industry and export interests rather than these commitments.

7. Discussion

Our analysis shows that the entanglement of private and public finance is truly global. In the two case studies, public financial institutions from 5 countries in the G7 and 7 out of 19 countries in the G20, supported the investments. Furthermore, public finance from countries long committed to the low-carbon transition (Germany, Sweden, the Netherlands) was deeply involved. The case studies show that wider political and economic structures were important for providing public

[4] The Strategy of Actions on Five Priority Areas of Development of the Republic of Uzbekistan for 2017–2021 (reforms.uz).

Table 4
Summary of financial support for the Surgil project (IJ Global & AIDDATA).

State Financing	Quantity ($m)	Private Financing	Quantity ($m)	Loan Guarantees	Quantity ($m)
Export-Import Bank of Korea	700	ING Group	160	KSure (Korea)	800
Asian Development Bank	125	Credit Suisse	75	K-Exim (Korea)	300
Korea Finance Corporation	500	Siemens Financial Services	75	EKN (Sweden)	140
Korea Development Bank	300	BayernLB*	70	Hermes (Germany)	124
China Development Bank	250	Nordea	60	**Equity Owners**	**Percentage**
National Bank of Uzbekistan	100			Lotte Chemical Corporation	17.50%
*Bayern LB is 75% owned by the State of Bavaria, Germany				SK Group	5%
				Korea Gas Corporation	17.50%
				Uzbekneftegaz	50%
				LG Corporation	5%
				STX	5%

Table 5
Summary of direct financial support for the Surgil project, by type ($m).

$m	National	International
Public	100	1,999
Private	0	440

support both in the countries in which the infrastructure is built (state-ownership, national state banks providing capital) and in the countries that provided technical knowhow and engineering expertise (e.g. ECA financial support that is intended for supporting export-oriented industry). While the two case studies are both located in oil and gas producing countries and hence not representative of all countries with petrochemical infrastructure, they reveal important insights into the global public and private sources of petrochemical finance and how national political contexts have been conducive for investments that exacerbate carbon lock-in. The outlook for the future of the industry indicates that capacity growth is focused within a few key regions (mainly Asia and MENA) with a large proportion of the planned expansion taking place in oil and gas producing countries, where the political context is favorable, such as Iran, Nigeria, and Saudi Arabia (Global Data, 2021). The global nature of finance makes it highly likely that finance will flow to the countries with the most political support for petrochemicals, although this is ultimately a question for future research.

Given that virtually all states have signed the Paris Agreement, they have committed to make "finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (UNFCCC, 2015, art 2.1c). So far, these efforts have focused on investments in fossil fuels, especially divesting from new coal, gas and oil extraction, rather than downstream fossil fuel dependent industries such as petrochemicals.

Our analysis shows that this is reflected in how financing of petrochemical projects is largely disconnected from the ambitions of the Paris Agreement, as evident in how several PFIs that have committed to divest from fossil fuels, or face pressure to do so, have invested in petrochemicals without much scrutiny. Given the global nature of petrochemicals finance, there is a need for global governance of such (particularly public) finance. These global governance arrangements could draw on examples from the governance of public finance for fossil fuels, particularly the commitment of 39 public actors (mainly states) adopted in the context of UNFCCC COP26 to end public finance for unabated fossil fuel energy by the end of 2021 and to work for similar policies within international institutions, including MDBs (UK Government, 2021). Thus, the arrangements for petrochemical finance could set an end-date for public finance for high-carbon petrochemical projects, and should at the very least ensure transparency and encourage more accountability regarding such finance.

The current expansion of fossil-based petrochemical infrastructure is not sustainable, and sustainability can only be achieved by reducing output based on fossil resources and transforming production from high-carbon to low-carbon. Both the high and low-carbon pathways require substantial amounts of finance, which is why redirecting finance from the former to the latter within the next decade will be essential to avoid further lock-in. Considering that some petrochemical products (from windmill blades to cables) serve purposes with no alternatives, it is better to adopt conditionalities and safeguards for public (and ideally also private) finance for petrochemicals than commit to ending petrochemical production completely. These conditionalities could consist of requirements that the petrochemical infrastructure financed will be low-carbon or easily converted to forthcoming low-carbon modes of production. Public finance for petrochemicals could play an important role in this respect, since it is the result of decisions by policymakers that in the end are responsible to voters (more indirectly in the case of MDBs). Moreover, public finance institutions are well-suited financiers of low-carbon projects as they tend to be less profit-driven and operate with longer time horizons. Since national public finance often is tied up with national fossil fuel interests, international finance is better suited to play a transformative role.

Finally, PFIs in developed countries finance new fossil-based petrochemicals production in emerging and developing countries. These products are likely to be traded on international markets and converted into products that are imported to developed countries to be consumed. There is thus a geographic pattern of capital and demand in developed countries that leads to expansion of new emissions-intensive production in emerging and developing countries.

8. Conclusion

The paper investigated the role that public finance play in expanding the petrochemical industry – the industry with the largest use of fossil energy and among the largest sources of industrial GHG emissions. We did so by mapping investments in large projects over the past decade, showing that while direct public finance supplied only about 14 percent of the capital it was involved in nearly half of all the projects, and in our case studies, Surgil and Sadara, provided the majority of direct funding. The two case studies demonstrated how different forms of finance from a wide range of international sources can be instrumental in expanding petrochemical production in states with conducive national political environments, in these cases related to national political interests in ensuring continued demand for fossil fuels.

We conclude that public finance is deeply entangled with private finance. PFIs engage in petrochemical projects in different ways, but the transparency remains highly limited. Support comes not only from national PFIs in the target countries, but is highly globalized and to a large degree originates in developed countries that often claim to spearhead the green transition. As these industrial infrastructures are planned to operate for decades, the public finance thus strongly contributes to the carbon lock-in of the sector. As both the expansion of fossil-based and low-carbon industrial infrastructure are capital intensive, the support for carbon-intensive infrastructures directly limits the possibilities for low-carbon investments. Public finance for the expansion of fossil-based

petrochemical infrastructure is thus far from being aligned with the target stated in the Paris agreement of focusing on investments for a green transformation. International commitments to improve transparency, end finance for fossil fuel-based petrochemical production and in the long run seek to scale down petrochemical production are all important international steps to ensure a sustainable transition of petrochemicals.

Our findings open up different venues for future research: Firstly, on the causal relations between public and private finance in more detail, e.g. through in-depth case studies of financing decisions. Such research could study exactly how much private finance is leveraged by public finance, which petrochemical projects that were made possible due to public finance, and which public finance instruments (loans, guarantees, etc.) have the largest effect on private finance. Secondly, on the role of finance safeguards, including why they often do not seem to have much effect. Thirdly, on if and how the emerging divestment movement is influencing public financiers of petrochemicals. Lastly, research could study cases where public finance has had a positive impact on low-carbon petrochemical production to show which instruments that may have an impact.

In terms of policy recommendations, as mentioned in Section 7, global governance arrangements should focus on setting end dates for public finance for petrochemical projects that do not meet requirements for being low-carbon or easily convertible to low-carbon. These requirements should also prevent an unsustainable level of supply of cheap petrochemicals. The internal processes of supporting industrial infrastructure within PFIs should also be reformed, aiming to improve transparency and implement low-carbon requirements for such projects.

Funding

The research for this article was undertaken as part of the project "Petrochemicals and climate change gonvernance: Powerful fossil fuel lock-ins and policy options for transformative change", which has been funded by the V. Kann Rasmussen Foundation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Please consult Appendix 1 for information about the data used. For further information, please contact the authors

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2023.102657.

References

ADB (2011) - Asian Development Bank - Report and recommendation of the president to the Board of Directors - Proposed Loan and Political Risk Guarantee Uz-Kor Gas Chemical LLC Surgil Natural Gas Chemicals Project (Uzbekistan). Available at: https://www.adb.org/sites/default/files/project-document/60294/44944-01-uzb-rrp.pdf. (Accessed: Jun 7, 2022).

ADB (2012) - Asian Development Bank - UZB: Surgil Natural Gas Chemicals Social Safeguards Audit Report. Available at: https://www.adb.org/sites/default/files/project-document/60114/44944-01-uzb-sa.pdf (Accessed: June 7, 2022).

ADB (2021). *Uzbekistan: UZB: SURGIL NATURAL GAS CHEMICALS. ADB Project Data Sheet.* Asian Development Bank. .

Åhman, M., Nilsson, L.J., Johansson, B., 2017. Global climate policy and deep decarbonization of energy-intensive industries. Clim. Policy 17 (5), 634–649. https://doi.org/10.1080/14693062.2016.1167009.

Åhman, M. (2021). *When gold turns to sand: A review of the challenges for fossil fuel rich states posed by climate policy* (No. 124; IMES/EESS Reports). 10.13140/RG.2.2.33001.21600.

AIDDATA (2016). CDB participates in a $2.54 billion USD syndicated loan to Uz-Kor Gas Chemical LLC for the Ustyurt Natural Gas and Petrochemicals Complex at Surgil Gas Field Project (2016) CHINA.AIDDATA.ORG. Available at: https://china.aiddata.org/projects/53953/ (Accessed: February 3, 2023).

Attridge, S., & Engen, L. (2019). Blended finance in the poorest countries: The need for a better approach. In *ODI Report* (Issue February). Overseas Development Institute. https://odi.org/en/publications/blended-finance-in-the-poorest-countries-the-need-for-a-better-approach/.

Barrowclough, D., & Finkill, G. (2021). Banks, bonds and petrochemicals - Greening the path from the Copenhagen Agreement, through Covid and Beyond. *UNCTAD Research Paper*, *69*, UNCTAD/SER.RP/2021/12.

Bataille, C., Åhman, M., Neuhoff, K., Nilsson, L.J., Fischedick, M., Lechtenböhmer, S., Solano-Rodriquez, B., Denis-Ryan, A., Stiebert, S., Waisman, H., Sartor, O., Rahbar, S., 2018. A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement. J. Clean. Prod. 187, 960–973. https://doi.org/10.1016/j.jclepro.2018.03.107.

Bauer, F., Kulionis, V., Oberschelp, C., Pfister, S., Tilsted, J.P., Finkill, G.D. (2022a) *Petrochemicals and Climate Change: Tracing Globally Growing Emissions and Key Blind Spots in a Fossil-Based Industry*. IMES/EESS Report 126. Lund University, Lund.

Bauer, F., Fontenit, G., 2021. Plastic dinosaurs – Digging deep into the accelerating carbon lock-in of plastics. Energy Policy 156, 112418. https://doi.org/10.1016/j.enpol.2021.112418.

Bauer, F., Nielsen, T.D., Nilsson, L.J., Palm, E., Ericsson, K., Fråne, A., Cullen, J., 2022b. Plastics and climate change—Breaking carbon lock-ins through three mitigation pathways. One Earth 5 (4), 361–376. https://doi.org/10.1016/j.oneear.2022.03.007.

Bauer, F., Tilsted, J.P., Pfister, S., Oberschelp, C., Kulionis, V., 2023. Mapping GHG emissions and prospects for renewable energy in the chemical industry. Curr. Opin. Chem. Eng. 39, 100881 https://doi.org/10.1016/j.coche.2022.100881.

Bermingham, F. (2015, January 15). Sadara case study: Chemical reaction | Global Trade Review (GTR). *Global Trade Review*. https://www.gtreview.com/magazine/jan-feb-2014/sadara-case-study-chemical-reaction/.

Bernstein, S., Hoffmann, M., 2019. Climate politics, metaphors and the fractal carbon trap. Nat. Clim. Chang. 9 (12), 919–925. https://doi.org/10.1038/s41558-019-0618-2.

Bond, K., Benham, H., Vaughan, E., Chau, L., 2020. The Future's Not in Plastics: Why plastics demand won't rescue the oil sector. Carbon Tracker. https://carbontracker.org/reports/the-futures-not-in-plastics/.

Cabernard, L., Pfister, S., Oberschelp, C., Hellweg, S., 2022. Growing environmental footprint of plastics driven by coal combustion. Nat. Sustainability 5, 139–148. https://doi.org/10.1038/s41893-021-00807-2.

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., Tanaka, M., 2018. Climate change challenges for central banks and financial regulators. Nat. Clim. Chang. 8 (6), 462–468. https://doi.org/10.1038/s41558-018-0175-0.

Cefic. (2021). *Facts and Figures of the European Chemical Industry 2021*. Cefic, Brussels.

Chan, M.H.T., 2018. The Belt and Road Initiative – the New Silk Road: A research agenda. J. Contemporary East Asia Stud. 7 (2), 104–123. https://doi.org/10.1080/24761028.2019.1580407.

Chen, X., Li, Z., Gallagher, K.P., Mauzerall, D.L., 2021. Financing carbon lock-in in developing countries: Bilateral financing for power generation technologies from China, Japan, and the United States. Appl. Energy 300, 117318. https://doi.org/10.1016/J.APENERGY.2021.117318.

CIEL. (2018). *Fueling Plastics: Untested Assumptions and Unanswered Questions in the Plastics Boom*. Center for International Environmental Law.

Clews, R.J., 2016. The Petrochemicals Industry. In: Clews, R.J. (Ed.), Project Finance for the International Petroleum Industry. Academic Press, pp. 187–203. https://doi.org/10.1016/b978-0-12-800158-5.00011-6.

de Nevers, M. (2017). Assessing "Leverage" in the Climate Investment Funds. In *CGD Policy Paper*. Center for Global Development. https://www.cgdev.org/publication/assessing- leverage-climate-investment-funds%0A1.

Deleidi, M., Mazzucato, M., Semieniuk, G., 2020. Neither crowding in nor out: Public direct investment mobilising private investment into renewable electricity projects. Energy Policy 140, 111195. https://doi.org/10.1016/j.enpol.2019.111195.

Delina, L., 2017. Multilateral development banking in a fragmented climate system: shifting priorities in energy finance at the Asian Development Bank. Int. Environ. Agreements: Politics Law Econ. 17 (1), 73–88. https://doi.org/10.1007/s10784-016-9344-7.

DOW. (2017). *Sadara the Worlds Largest Chemicals Complex Built in a Single Phase Commemorates Commissioning of All 26 Plants*. https://corporate.dow.com/en-us/news/press-releases/sadara-the-worlds-largest-chemicals-complex-built-in-a-single-phase-commemorates-commissioning-of-all-26-plants.html.

EDC, 2013. EDC Project Review Summary: Sadara Chemicals Project. Export Development Canada.

EKN - Swedish Export Credit System. (2011). Non Technical Summary - Surgil Project ESIA – Volume I & II. [online] Available at: <https://www.ekn.se/globalassets/vad-vi-gor/hallbarhet/arkiv/surgilprojektet-uzbekistan/volume-i-nts-final.pdf/> & <https://www.ekn.se/globalassets/vad-vi-gor/hallbarhet/arkiv/surgilprojektet-uzbekistan/volume-ii-esia-final.pdf/> [Accessed 19 January 2022].

Erickson, P., Kartha, S., Lazarus, M., Tempest, K., 2015. Assessing carbon lock-in. Environ. Res. Lett. 10 (8), 084023 https://doi.org/10.1088/1748-9326/10/8/084023.

FAO, 2017. World fertilizer trends and outlook to 2020. Food and Agricultural Organisation of the United Nations, Rome.
Fattouh, B., Sen, A., 2021. Economic Diversification in Arab Oil-Exporting Countries in the Context of Peak Oil and the Energy Transition. In: Luciani, G., Moerenhout, T. (Eds.), When Can Oil Economies Be Deemed Sustainable? Palgrave Macmillan, pp. 73–97. https://doi.org/10.1007/978-981-15-5728-6_5.
Fernandes, N., 2014. The impact of sovereign wealth funds on corporate value and performance. J. Appl. Corp. Financ. 26 (1), 76–84.
Fertilizer International, 2011. Ultra-mega plants - An assessment. Fertilizer Int. 444, 38–43.
Galaz, V., Gars, J., Moberg, F., Nykvist, B., Repinski, C., 2015. Why Ecologists Should Care about Financial Markets. Trends Ecol. Evol. 30 (10), 571–580. https://doi.org/10.1016/j.tree.2015.06.015.
Geddes, A., Schmidt, T.S., Steffen, B., 2018. The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany. Energy Policy 115, 158–170. https://doi.org/10.1016/j.enpol.2018.01.009.
Geng, Y., Sarkis, J., Bleischwitz, R., 2019. How to globalize the circular economy. Nature 565 (7738), 153–155. https://doi.org/10.1038/d41586-019-00017-z.
Global Data. (2021). Global Petrochemicals Capacity and Capital Expenditure Outlook, 2021-2030 – Asia Leads Global Petrochemical Capacity Additions. Global Data.
Goldthau, A., Westphal, K., 2019. Why the Global Energy Transition Does Not Mean the End of the Petrostate. Global Pol. 10 (2), 279–283. https://doi.org/10.1111/1758-5899.12649.
Griffiths, J., 2012. 'Leveraging' private sector finance: How does it work and what are the risks? Bretton Woods Project, London.
Hainz, C., Kleimeier, S., 2012. Political risk, project finance, and the participation of development banks in syndicated lending. J. Financ. Intermed. 21 (2), 287–314. https://doi.org/10.1016/j.jfi.2011.10.002.
Halff, A., Mills, R., 2021. Having It Both Ways: GCC Oil Faces Peak Demand. Columbia University Center on Global Energy Policy.
Hansen, G., Eckstein, D., Weischer, L., Bals, C., Grimm, J., Simon Layout, J., Baum, D., 2016. Shifting the Trillions: The Role of the G20 in Making Financial Flows Consistent with Global Long-Term Climate Goals Brief Summary. GermanWatch.
Hildingsson, R., Khan, J., 2015. Towards a decarbonized green state? The politics of low-carbon governance in Sweden. In: Bäckstrand, K., Kronsell, A. (Eds.), Rethinking the Green State: Environmental governance towards climate and sustainability transitions. Routledge, pp. 156–173. https://doi.org/10.4324/9781315761978.
Hopewell, K., 2019. How Rising Powers Create Governance Gaps: The Case of Export Credit and the Environment. Global Environ. Polit. 19 (1), 34–52. https://doi.org/10.1162/glep_a_00490.
Humphrey, C. (2018). Channelling private investment to infrastructure: What can multilateral development banks realistically do? *ODI Working Paper*, *534*.
ICC. (2021). Sustainability in Export Finance - Leveraging Export Finance to support the delivery of the SDGs. In *ICC White Paper*. International Chamber of Commerce.
Iea, 2018. The Future of Petrochemicals: Towards more sustainable plastics and fertilisers. OECD. https://doi.org/10.1787/9789264307414-en.
IEA. (2020). *Energy Technology Perspectives 2020*. International Energy Agency, Paris. 10.1787/d07136f0-en.
IEA. (2021a). *Ammonia Technology Roadmap: Towards more sustainable nitrogen fertiliser production*. International Energy Agency, Paris. 10.1787/f6daa4a0-en.
IEA. (2021b). *Net Zero by 2050: A Roadmap for the Global Energy Sector*. International Energy Agency, Paris.
IJ Global. (2012). *DEAL ANALYSIS: Surgil*. https://www.ijglobal.com/articles/123338/deal-analysis-surgil.
International Financial Consulting, 2019. Study on Convergence of Development Finance and Export Finance. International Financial Consulting, Ottawa.
IJ Global (2022). Available at: https://www.ijglobal.com/ (Accessed: June 7, 2022).
Kapinga, C.P. and Chung, S.H. (2020). *Marine plastic pollution in South Asia*. South and South-West Asia Development Papers 20-02. United Nations Economic and Social Commission for Asia and the Pacific, New Delhi.
Kätelhön, A., Meys, R., Deutz, S., Suh, S., Bardow, A. (2019) Climate change mitigation potential of carbon capture and utilization in the chemical industry. *Proceedings of the National Academy of Sciences of the United States of America* 166, 11187–11194. 10.1073/pnas.1821029116.
KfW IPEX-Bank. (2013). *German know-how for petrochemical complex in Saudi Arabia*. https://www.kfw-ipex-bank.de/Presse/News/News-Details_150464-2.html.
Kim, S.E., Urpelainen, J., 2013. International energy lending: who funds fossil fuels, who funds energy access for the poor? Int. Environ. Agreements: Politics Law Econ. 13 (4), 411–423. https://doi.org/10.1007/s10784-012-9197-7.
Kingdom of Saudi Arabia (2015). INDC submitted to the UNFCCC. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Saudi%20Arabia%20First/KSA-INDCs%20English.pdf.
Krane, J (2019). Energy Governance in Saudi Arabia: An Assessment of the Kingdom's Resources, Policies, and Climate Approach. James A. Baker III Institute for Public Policy of Rice University.
Levi, P.G., Cullen, J.M., 2018. Mapping Global Flows of Chemicals: From Fossil Fuel Feedstocks to Chemical Products. Environ. Sci. Tech. 52 (4), 1725–1734. https://doi.org/10.1021/acs.est.7b04573.
Manzurova, N. (2016, May 16). Uzbek and South Korean PMs attend completion ceremony of petrochemical complex project. *Kun.Uz*. https://kun.uz/en/76479567.
MarketScreener (2022) Stock market quotes and news : Equities, indexes, Commodities, forex on Marketscreener.com, MarketScreener.com. Available at: https://www.marketscreener.com/(Accessed: June 7, 2022).
Marks, D., Miller, M.A., Vassanadumrongdee, S., 2020. The geopolitical economy of Thailand's marine plastic pollution crisis. Asia Pac. Viewp. 61 (2), 266–282.
Newell, P. (2021). *Power Shift*. Cambridge University Press, Cambridge. 10.1017/9781108966184.
OECD (2016). *Working Party on Export Credits and Credit Guarantees - INFORMATION ON CATEGORY A AND CATEGORY B PROJECTS (2013 REPORTS)*. TAD/ECG(2015)15/FINAL. Organisation for Economic Co-operation and Development, Paris.
Oramah, B. O. (2020). Export Credit Arrangements in Capital-Scarce Developing Economies. In A. Klasen (Ed.), *The Handbook of Global Trade Policy* (pp. 494–535). Wiley. 10.1002/9781119167402.ch19.
Otteni, C., Weisskircher, M., 2021. Global warming and polarization. Wind turbines and the electoral success of the greens and the populist radical right. Eur J Polit Res. https://doi.org/10.1111/1475-6765.12487.
PIF (2022). Public Investment Fund Saudi Arabia. https://www.pif.gov.sa/en/pages/aboutpif.aspx Access 7th of December 2022.
Pirani, S. (2019). Central Asian Gas: prospects for the 2020. *Oxford Institute for Energy Studies Paper*, *155*. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2019/12/Central-Asian-Gas-NG-155.pdf.
Raimondi, P. P. (2019). Central Asia Oil and Gas Industry - The External Powers' Energy Interests in Kazakhstan, Turkmenistan and Uzbekistan. *FEEM Working Paper*, *006.2019*. 10.2139/ssrn.3386053.
Rainforest Action Network, Banktrack, Indigenous Environmental Network, Oil Change International, Reclaim Finance, & Sierra Club. (2020). *Banking on Climate Change - Fossil Fuel Finance Report 2020*. Rainforest Action Network.
Reuters. (2012, May 21). Uzbekistan gets $2.54 bln in loans for gas project. *Reuters.com*. https://www.reuters.com/article/gas-uzbekistan-loan/uzbekistan-gets-2-54-bln-in-loans-for-gas-project-idUKL5E8GL2JQ20120521.
Semieniuk, G., Campiglio, E., Mercure, J., Volz, U., Edwards, N.R., 2020. Low-carbon transition risks for finance. *WIREs*. Clim. Change e678. https://doi.org/10.1002/wcc.678.
Seto, K.C., Davis, S.J., Mitchell, R.B., Stokes, E.C., Unruh, G., Ürge-Vorsatz, D., 2016. Carbon Lock-In: Types, Causes, and Policy Implications. Annu. Rev. Env. Resour. 41 (1), 425–452. https://doi.org/10.1146/annurev-environ-110615-085934.
Singh, S. (2020). Petrochemical Complex Mega Project Starts Up On Time. *Chemicalprocessing.com*. Available at: https://www.chemicalprocessing.com/articles/2020/petrochemical-complex-mega-project-starts-up-on-time [Accessed January 20, 2022].
Skovgaard, J., van Asselt, H. (Eds.), 2018. The Politics of Fossil Fuel Subsidies and their Reform. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781108241946.
Skovgaard, J., van Asselt, H., 2019. The politics of fossil fuel subsidies and their reform: Implications for climate change mitigation. Wiley Interdiscip. Rev. Clim. Chang. 10 (4), 1–12. https://doi.org/10.1002/wcc.581.
Steffen, B., Schmidt, T.S., 2019. A quantitative analysis of 10 multilateral development banks' investment in conventional and renewable power-generation technologies from 2006 to 2015. Nat. Energy 4 (1), 75–82. https://doi.org/10.1038/s41560-018-0280-3.
Tobin, D., 2012. Pricing Reforms and Capacity Constraints in China's Petrochemical Sector. Oxford Energy Forum 88, 15–17.
Tullo, A.H., 2020. C&EN's Global Top 50. Chem. Eng. News 98 (29), 30–36.
U.S. EXIM Bank. (2012). *Ex-Im Bank Approves Record-breaking Transaction to Support More Than 18,000 Jobs*. Exim.Gov. https://www.exim.gov/news/ex-im-bank-approves-record-breaking-transaction-support-more-18000-jobs.
U.S. EXIM Bank. (2013). *Sadara Chemical Company Transaction is Awarded Ex-Im Bank Deal of the Year*. Exim.Gov. https://www.exim.gov/news/sadara-chemical-company-transaction-awarded-ex-im-bank-deal-year.
UK Export Finance. (2013). *Massive boost to British industry in biggest ever petrochemical project*. Gov.Uk. https://www.gov.uk/government/news/massive-boost-to-british-industry-in-biggest-ever-petrochemical-project.
UK Government. (2021). Statement on International Public Support for the Clean Energy Transition. https://ukcop26.org/statement-on-international-public-support-for-the-clean-energy-transition/.
UNFCCC Standing Committee on Finance. (2022). *Biennial Assessment and Overview of Climate Finance Flows*. https://unfccc.int/process-and-meetings/bodies/constituted-bodies/standing-committee-on-finance-scf/background.
UNFCCC. (2015). *Paris Agreement*. United Nations.
van de Graaf, T., Bradshaw, M., 2018. Stranded wealth: rethinking the politics of oil in an age of abundance. Int. Aff. 94 (6), 1309–1328. https://doi.org/10.1093/ia/iiy197.
Watkins, E., 2006. March 16). Uzbekistan, South Korea sign E&D agreement. Oil Gas J. https://www.ogj.com/exploration-development/article/17279900/uzbekistan-south-korea-sign-ed-agreement.
Wesseling, J.H., Lechtenböhmer, S., Åhman, M., Nilsson, L.J., Worrell, E., Coenen, L., 2017. The transition of energy intensive processing industries towards deep decarbonization: Characteristics and implications for future research. Renew. Sustain. Energy Rev. 79, 1303–1313.
World Bank (2016) Environmental and Social Framework (ESF). Available at: https://www.worldbank.org/en/projects-operations/environmental-and-social-framework (Accessed: June 7, 2022).
World Bank. (2018). *MDB Reporting on Private Investment Mobilization – Reference Guide*.
World Bank. (2022). *World Bank Open Data*. https://data.worldbank.org/.
Yamada, M., 2011. Gulf-Asia Relations as "Post-Rentier" Diversification? The Case of the Petrochemical Industry in Saudi Arabia. J. Arab. Stud. 1 (1), 99–116. https://doi.org/10.1080/21534764.2011.576054.

Zhang, F., 2022. The policy coordinator role of national development banks in scaling climate finance: Evidence from the renewable energy sector. Clim. Pol. 22 (6), 754–769. https://doi.org/10.1080/14693062.2022.2038063.

Kan, F. (2011) Update 1-jurong aromatics signs $1.56 BLN financing - bankers, Reuters. Thomson Reuters. Available at: https://www.reuters.com/article/singapore-jurong-aromatics-idUSL3E7FE0B020110414 (Accessed: March 13, 2023).

Braskem (2012) *Europe. Idesa successfully signs the US$ 3.2 billion financing for its Etileno XXI project in Mexico*. Available at: https://www.braskem.com.br/europe/news-detail/Braskem-Idesa-successfully-signs-the-US-3a2-billion-financing-for-its-Etileno-XXI-Project-in-Mexico (Accessed: March 13, 2023).