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International markets and technological innovation systems: The case of offshore wind



H.Z. Adriaan van der Loos*, Simona O. Negro, Marko P. Hekkert

Copernicus Institute of Sustainable Development, Utrecht University, Netherlands

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ABSTRACT

This research addresses the challenging question of how to support industry formation policies without relying on expensive domestic market formation strategies. Innovation systems literature classically focuses on the need to support home market development to encourage both technological diffusion and generation of a promising technology. However, it is possible to decouple these notions in a national context under certain conditions. Through in-depth interviews with key stakeholders in the Dutch offshore wind industry, we unearth the conditions for young and established firms to access international markets in the absence of a home market. We determine that established firms can access international markets without significant hinderances or domestic support and can help form the backbone of an emerging industry. Young firms are dependent on a well-functioning innovation system, which facilitates international market access through three pathways: 1) via local incumbents; 2) direct access to international markets; 3) via protected niche-spaces.

1. Introduction

In order to prevent extreme climate change, a massive transition of both consumption and production practices needs to take place (Negro et al., 2012a). Under current market conditions, many firms lack incentives to radically alter production processes and business models. As such, governments play a critical role in developing policies to foster this sustainability transition (Jänicke and Jacob, 2004).

While this transition can be a threat to current business models, it also provides ample opportunities for new and established firms since radical technological change often leads to shifts in industrial leadership (Utterback, 1994). Industries that now dominate our energy supply and production of materials and consumer products may not be the industries that dominate the market in 20 years from now. As globalization facilitates knowledge exchange, international marketplaces and multinational actors, technologies are not confined to national boundaries, but rather spill-over into a globalized context of both production and consumption. Exacerbated by the multifaceted layers of global challenges, such as climate change, addressing these connundra implies a transnational analytical perspective of these production and consumption practices. For this reason, governments have a key interest in developing policies that stimulate local industries while realizing environmental targets that are both locally and globally beneficial. Successful examples are Denmark and Germany that realized a steep rise in the share of renewable energy and at the same time created new industrial strongholds.

A key issue in industry formation policy is the role of home markets (Beise, 2004; Fagerberg, 2010; Linder, 1961). Governments

* Corresponding author at: Copernicus Institute of Sustainable Development, Princetonlaan 8a, Vening Meinesz building A, Room 7.86, 3584 CB, Utrecht, Netherlands.

E-mail address: h.z.a.vanderloos@uu.nl (H.Z.A. van der Loos).

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that create a home market stimulate the conditions necessary for a technology to be adopted and diffused into society by guiding market demand or creating an artificial market, such as the Dutch or Norwegian electric vehicle markets or German solar PV market (Boon and Edler, 2018; Dewald and Truffer, 2011; Nemet, 2009; Wesseling, 2016). The logic argues that by creating a commercial market, innovation, competitiveness and subsequently industrial capacity will follow (Boon and Edler, 2018; Davis and Weinstein, 2003; Horbach et al., 2012; Porter, 1990). The downside is that it is often a very expensive approach since the state artificially establishes a market for a product that is by definition costlier in the early stages of development than existing technologies (for example, renewable energy versus fossil fuels) (Kavlak et al., 2018; Utterback, 1994). For example, the German energy transition program, *Energiewende*, is estimated to have cost 500 billion Euros upfront due to a mandatory phase-out of nuclear power combined with massive renewable energy installation while renewable energy technologies were still expensive, leading to increasing resistance amongst civil society (Unnerstall, 2017).

A cheaper alternative policy approach is the ‘science-technology push’ strategy, which emphasizes investing in research and development (R&D) to drive innovation, for example through research subsidy programs, specialized institutes and knowledge development. (Horbach et al., 2012; Kamp et al., 2004; Negro et al., 2012a, 2012b). Countries with this approach assume that market demand follows technology push because R&D lowers the cost of the technology and therefore future demand will pay for the upfront R&D investments (Kavlak et al., 2018; Nemet, 2009). For example, this has been the Dutch approach to the solar sector, leading to internationally competitive firms that produce solar cell machines, but has lagged other countries in new installed solar photovoltaic capacity (Kamp et al., 2004; Negro et al., 2012a, 2012b). Governments that apply this policy approach wait with commercial home market formation until technologies have gone through the learning curve and become more affordable. While cheaper, this approach implies a significantly slower uptake of potentially promising technologies, thus delaying the societal benefits of the technology, such as a reduction of carbon emissions.

Some argue that the optimal policy strategy is a combination of the science-technology push and market pull for a technology to develop and grow, such as the strategy adopted by Denmark for on- and offshore wind (Kamp et al., 2004; Nemet, 2009; Wieczorek et al., 2013). In this case, Denmark heavily promoted wind energy as a means to reduce fossil fuel consumption while also strongly supporting the wind industry, leading to the growth of one of the world’s largest wind turbine manufacturers, Vestas, and the world’s largest offshore wind owner and developer, Ørsted (formerly DONG Energy) (4C Offshore Ltd., 2018c; Wieczorek et al., 2015).

The key issue that we focus on is whether costly commercial home market formation can be avoided while still creating favorable conditions where future industry leaders may emerge, a concept contradictory to classic notions of trade and competitiveness (Beise, 2004; Fagerberg, 2010; Linder, 1961). We understand that a commercial market implies a well-articulated critical demand, in contrast to the formation of temporary niche-spaces (Hekkert et al., 2007, 2011; Schot et al., 1994). Literature shows that foreign markets can compensate for a weak home market under certain circumstances (Bergek et al., 2008a; Corsetti et al., 2007; Davis and Weinstein, 2003; Schumacher and Siliverstovs, 2006; Wieczorek et al., 2013). Importantly, we do not deny the potential value of a commercial home market, which has been substantiated in previous literature (Fagerberg, 2010); rather, we claim that developing a home market is not always necessary as a means to develop industrial capacity and export advantage and explore the conditions in which this is possible.

By understanding the conditions and mechanisms necessary to facilitate international market access processes, it becomes possible to highlight scenarios and existing context conditions in which governments do not need to rely on expensive home market formation policies, and can therefore rather focus on the more cost-friendly science-technology push approach supported by a strong innovation system. Innovation system approaches, and particularly the technological innovation systems (TIS) framework, go a step further than the science-technology push to not only focus on promoting technologies through basic R&D, but also to analyze the entire system that supports it, including entrepreneurial activities, knowledge exchange, political guidance, resource deployment and technological legitimacy (Hekkert et al., 2007; van Lente et al., 2011; Negro and Hekkert, 2008). Therefore, we try to understand how companies are able to succeed in accessing international markets through a science-technology push context that is couched in a technological innovation systems framework.

Within this notion, we understand that the needs and capabilities of firms vary depending on a number of conditions, including access to resources and attaining global legitimacy (Wieczorek et al., 2015). “The notion of a global opportunity set is therefore replaced by a concept of differential access to unevenly distributed resources in the spaces of a ‘global TIS’” (Binz et al., 2014, 139). For established firms with long histories in different, but related, industries, gaining access to international markets requires a different approach than for younger firms that are directly engaged in developing new technologies, but who do not yet have the resources or legitimacy necessary to access these markets (Dawar and Frost, 1999; Geels et al., 2008; Hekkert et al., 2007). This leaves us with a differentiated notion of how established and young firms can access international markets and how innovation systems can be supportive or confuting. Through in-depth interviews, we grasp the mechanisms, strategies and contexts that facilitate or hinder both established and young companies from gaining access to international markets.

Our research question is hence: How and under what circumstances can firms access international markets in the absence of a commercial home market and what are the implications for industry formation and innovation system policy?

To unravel these strategies and implications, we focus on the offshore wind innovation system in the Netherlands. Previously, the Dutch government demonstrated little appetite for promoting a domestic commercial market for offshore wind, and yet a number of companies were successful in accessing and servicing rapidly growing international markets (Gullberg, 2013; Wieczorek et al. 2013). Indeed, the Netherlands captured 14% of all European offshore wind activity by 2018 despite having only 6% of all installed capacity (80% of which came in 2015 or later) (4C Offshore Ltd., 2018a, 2018c). While the Netherlands did construct two one-off offshore wind farms in 2006 and 2008 of 108 MW (Egmond aan Zee) and 120 MW (Prinses Amaliawindpark), respectively, these two projects were part of a

protected niche space; indeed, Egmond aan Zee received additional subsidies for construction over the existing renewable energy subsidies available at the time and was strongly pushed by the Dutch government (NoordzeeWind n.d.; Vattenfall, 2019). Further, while two more small offshore wind farms (129 MW and 144 MW) were commissioned in 2015, there was no consistent annual growth, policy support or well-articulated demand until Gemini was commissioned in 2017 and a new tendering system was developed for annual windfarm commissioning starting in 2020 (4C Offshore Ltd., 2018c, 2018a; NoordzeeWind n.d.; RVO, 2015; Vattenfall, 2019). This leaves a six and eight-year gap between the first two offshore wind farms and the next farms. Hence, there was no reliable domestic market for companies to enter and engage in before going international and that this niche market was too unreliable to trigger production and innovation investments. While a domestic market is taking shape with ambitious and consistent plans for the future, we delve into the strategies, conditions and mechanisms of the science-technology push supported offshore wind innovation system that aided or hindered companies from entering and establishing themselves in the international market prior to domestic commercial market formation (Ministry of Economic Affairs and Climate, 2018; Rijksoverheid, 2017; RVO, 2015).

2. Theory

2.1. Firm characteristics: young vs. established firms

We distinguish between established enterprises and young companies because we understand that needs, conditions and capabilities to access markets vary depending on the type of firm in question (OECD, 2019). We define established firms as those that originated from related industries, such as oil and gas, maritime, shipping and dredging, and hence diversified into offshore wind (Bergek et al., 2013; Porter, 1990; Steen and Hansen, 2014). Within established firms, we distinguish established large enterprises from established small and medium enterprises (SME) at a 250-employee threshold (European Commission, 2003; OECD, 2019).

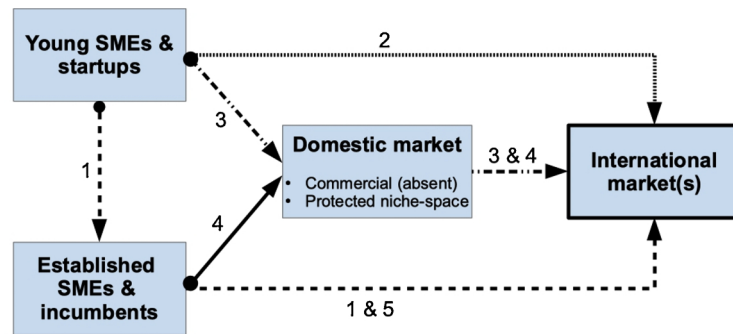
We consider young companies to be those that directly entered (or are trying to enter) the offshore wind industry and typically have a narrow portfolio that specializes on one or two niche products or services (Steen and Hansen, 2014). Young companies have varying degrees of financial independence, with startups being a particularly young and financially dependent subset of young firms. Startups do not yet have a commercially viable product, are therefore still in the research, design and development (RD&D) phase and are still dependent on external financing, such as from the government or private investors. Commercially viable young small and medium enterprises have a proven product, have achieved limited commercial sales and yet are still working to establish their name, reputation and steady orderbook in the industry. Young companies, and especially startups, hence have more limited human and financial resources, legitimacy, knowledge, experience and skills; they thus need to go through additional hoops and employ different strategies to test products and gain access to markets (Binz and Truffer, 2017; Cannone et al., 2014; Dawar and Frost, 1999; Fagerberg, 2018; Geels et al., 2008; Laufs and Schwens, 2014).

Established firms are intrinsically much closer to international markets: they have a well-known global market presence, a wide range of skills and expertise, significant human and financial resources and established informal networks (Dawar and Frost, 1999; Mäkitie et al., 2018). As such, established firms are typically only part of innovation systems that center around radical innovations when they diversify into the new technology; that is to say that we expect that a high degree of relatedness from their core industries positively positions them to embrace a new market and provides for a high chance of success (Dewald and Truffer, 2011; Fagerberg, 2018; van Mossel et al., 2017; Porter, 1990). Further, while the Netherlands is by no means a lead market for offshore wind power, its dominant role in highly related industries positions it well to maintain a competitive advantage and high degree of technological capability necessary for the international offshore wind market.

Based on our conceptualization of market access flows in the absence of a strong domestic market (see Section 2.2, below), we evaluate the challenges and strategies that companies face and use to access international markets. Table 1 summarizes some of the defining features of established versus young firms.

Table 1
Key firm characteristics.

Characteristic	Established firms	Young firms	Sources
Age/history/ reputation	Established commercial presence prior to offshore wind; reputation in industry for competencies	Young, established for offshore wind; some or no commercial activity; little to no reputation	(Carmeli and Tishler, 2004; Coenen et al., 2012; Hall, 1992, 1993; Musiolik, 2012; Nielsen, 1984; Normann and Hanson, 2015)
Resources	Large financial and human resources; commercial activity; often multiple offices	Few financial and human resources, often dependent on public and/or private financing	(Dawar and Frost, 1999; Fuensching and Truffer, 2014; Geels, 2004; Lindholm-dahlstrand et al., 2018; Mäkitie et al., 2018; Musiolik, 2012)
Skill sets	Wide set of skills and diversified activities, often in related sectors	Highly specialized and focused on one or two niche activities	(Dawar and Frost, 1999; Lindholm-dahlstrand et al., 2018; Normann, 2015; Normann and Hanson, 2015; Steen and Hansen, 2014; Steen and Weaver, 2017)
Project experience	Extensive and numerous large and small-scale projects in the industry or related industries	Limited to no experience up to a few commercial projects	(Dewald and Truffer, 2011; Mäkitie et al., 2018; Steen and Hansen, 2014)
Networks	Large, multinational informal networks	Small and often local informal networks; dependent on formal networking organizations	(Musiolik, 2012; Musiolik et al., 2012)



- 1) Young firms access international markets via established firms
- 2) Young firms directly access international markets
- 3) Young firms access international markets via local market formation (when available)
- 4) Established firms also access international markets via local markets (when available)
- 5) Established firms directly access international markets

Chart 1. Potential international market access pathways.

2.2. Theorizing international market access flows for established and new entrants

The key missing link in our case is the unique situation emblematic of a growing international commercial market, a weak domestic market and yet strong industrial participation (4C Offshore Ltd., 2018c; Normann and Hanson, 2015; Wieczorek et al., 2013). By definition, for an industry to develop, there must be a commercial market somewhere, hence in the absence of a home market, this must occur abroad. Essentially, accessing international markets becomes our *de facto* indicator of success for the growth of an industry, hence companies ultimately need to find ways to access these markets when a commercial home market is not available, and a well-performing innovation system helps create the conditions to do so.

In the flow chart below (Chart 1), we theorize the potential market access flows for this aforementioned conundrum. The mechanisms for which these pathways occur are theorized in Section 2.3, below. As the flow chart demonstrates, established firms can directly link up with international markets if they choose to do so (Lindholm-dahlstrand et al., 2018; Steen and Weaver, 2017; Suurs et al., 2010). On the other hand, younger firms have a more difficult time in accessing these markets (Lindholm-dahlstrand et al., 2018). These younger firms essentially have three potential pathways: 1) through established firms; 2) direct access to international markets; 3) capitalize on protected niche-space market formation. In the first instance, companies link up with larger, local firms either through ‘piggy-backing’ or more traditional partnerships (Steen and Weaver, 2017). Piggy-backing implies securing a first contract with a larger company from a local context that has access to the international market, which then allows the young company to prove its technology in real-world circumstances and subsequently compete for projects on its own (Dawar and Frost, 1999; Normann and Hanson, 2018). Partnering is a more classic business approach wherein startups are bought by or merged with another firm.

The second pathway – directly accessing international markets – occurs when a startup or young enterprise successfully secures a contract directly in a foreign market (Cannone et al., 2014).

The third pathway, local market formation, occurs either through commercial market growth (which is absent in our case) or the creation of protected niche spaces, such as demonstration sites or pilot projects to develop the skills and reputation necessary to feedback into the international market space (Cannone et al., 2014). Regardless of the pathway, young firms need to find some mechanism(s) to develop and test their technologies in real-world circumstances and then secure a first commercial contract, as explained below.

2.3. Enabling market access flows

We presume that the successful build-up of an innovation system to support a science-technology push strategy facilitates and maximizes the potential of companies to access international markets through one of the aforementioned pathways (Wieczorek et al., 2015; Wieczorek and Hekkert, 2012). For example, advantageous access to local established firms, local networking organizations,

local context conditions and geographical proximity increase the potential of piggy-backing and local partnerships (Coenen et al., 2010; Musiolik et al., 2012; Vestal and Danneels, 2018). For firms to directly enter the international market, they need to find ways to link up with international partners on international projects, which can, for example, be facilitated through networking organizations and participating in international congresses or conventions (Kivimaa et al., 2018). Accessing government sponsored and created demonstration sites, also known as protected niche-space, can be facilitated by local entrepreneurial contexts, such as research, development and demonstration (RD&D) organizations, incubator programs and/or R&D grants, which help companies demonstrate their products in real-world conditions (Coenen et al., 2010; Fevolden et al., 2017; Lindholm-dahlstrand et al., 2018; Stam and Spigel, 2016; Steen and Weaver, 2017; Voormolen et al., 2016). These three potential pathways, and the innovation system build-up that supports them, attempt to demonstrate some of the myriad ways international market access can unfold. Importantly, this is not a one-size-fits-all conceptualization: not every company will engage with every mechanism and companies can engage in different, and multiple, combinations.

2.4. The role of technological innovation systems

Firms do not innovate in isolation. They are dependent on the innovation system in which they operate that creates the necessary conditions to successfully innovate (Musiolik et al., 2012). We depart from the technological innovation system (TIS) framework that adumbrates the prerequisites necessary for a technological artefact to develop, diffuse and grow and follows a theoretical underpinning that proposes a series of system functions (key processes) necessary for it to perform well (Bergek et al., 2008b; Carlsson et al., 2002; Carlsson and Jacobsson, 1994; Hekkert et al., 2007). We define the seven key functions in the table below (Table 2):

While this is not a mathematical formula that outlines a quantified threshold needed to trigger system growth, it is generally understood that there must be some functioning level of each of these conditions (Jacobsson and Bergek, 2011; Markard and Truffer, 2008). Indeed, some functions may be more important than others for an innovation system to develop and facilitate access to international markets based on certain context conditions or the phase of technological development (Bergek et al., 2015; van Lente et al., 2011; Suurs, 2009; Suurs et al., 2010). For example, knowledge development may be more important than legitimacy building for a technology in the nascent pre-development phase (Wieczorek et al., 2013). Additionally, these functions are neither linear nor path dependent, but rather interact in positive (or negative) feedback loops (Bergek et al., 2008b; Planko et al., 2017). Ultimately, the TIS functions are designed to create the conditions necessary to support firms, and in our case, help them access international markets in the absence of a well-defined, commercial home market.

Table 2
definition of the seven TIS functions.

Function	Definition
F1: <i>Entrepreneurial activities</i>	Entrepreneurial activities involve company engagement in projects, high technology readiness level product testing, diversification into new industries, new entrants and commercial activity
F2: <i>Knowledge development</i>	Knowledge development occurs in private, in-house R&D departments or in publicly funded research institutes or universities. It focuses on basic research and low technology readiness levels
F3: <i>Knowledge diffusion</i>	Knowledge diffusion occurs through the exchange of information via networks, partnerships and shared project experience/collaboration
F4: <i>Guidance of the search</i>	Guidance of the search comes from both the government, in the form of discourse and policy visions/targets, and company/private sectors visions
F5: <i>Market formation</i>	Market formation is set by government market policy, tax exemptions, market regulations and consumer and private sector demand
F6: <i>Resource mobilization</i>	Government funds supplied for R&D and market subsidies as well as private investments in human and financial resources
F7: <i>Legitimacy / counteract resistance to change</i>	Legitimacy is driven and supported by the government, consumer acceptance and private lobbying activities

(Bergek et al., 2008a; Hekkert et al., 2007; Hekkert and Negro, 2009; Wieczorek and Hekkert, 2012).

3. Offshore wind: a supply-chain overview

The vast majority (85%) of the offshore wind market currently lies in Europe, namely in the United Kingdom, Germany, Denmark, Belgium and the Netherlands. The only other existing major offshore wind market globally is China, which is extensively composed of

Table 3
Key actors in European offshore wind farm construction by segment (Dutch actors indicated in bold).
Source: (4C Offshore Ltd., 2018c).

Owner ^a	Wind turbine manufacturers ^b	Wind turbine installers ^b	Monopile manufacturers ^b	Foundation designers ^b	Foundation installers ^b	Inter-array cable manufacturers ^b	Inter-array cable installers ^b	Grid connection cable manufacturers ^b	Grid connection cable installers ^b
Ørsted (Danish) (3.87 GW)	Siemens-Gamesa (German/ Spanish) (66%)	A2Sea (part of GeoSea-Danish) (32%)	EEW (German) (27%)	Ramboll (Danish) (36%)	van Oord/MPD (Dutch) (33%)	JDR (UK) (34%)	VBMS (part of Boskalis-Dutch) (36%)	NKT (Danish) (28%)	VBMS (part of Boskalis-Dutch) (31%)
Vattenfall (Swedish) (2.22 GW)	MHI-Vestas (Danish/ Japanese) (18%)	Van Oord/MPD (Dutch) (25%)	SIF (Dutch) (19%)	Ørsted (Danish) (20%)	GeoSea/Deme (Belgian) (26%)	Nexans (French) (25%)	Siem Offshore (Norwegian) (15%)	ABB (Swedish-Swiss) (26%)	Deep Ocean (Norwegian) (10%)
E-on (German) (1.44 GW)	Senvion (German) (7%)	Fred Olsen Wind Carrier (Norwegian) (15%)	Bladt (Danish) (15%)	COWI IMS (Danish) (9%)	Boskalis (Dutch) (8%)	Prysmian (+ owns Draka) (Italian) (18%)	Deep Ocean (Norwegian) (9%)	Nexans (French) (20%)	Tideway (Belgian - part of DEME) (10%)
Iberdrola (Spanish) (1.26 GW)	Adwen (German) (5%)	Seajacks (British) (7%)	Bladt/EEW JV (Danish/ German) (14%)	Atkins (British) (5%)	Seaway Heavy Lifting (Dutch) (11%)	NSW (German) (13%)	CT Offshore (Danish) (8%)	Prysmian (Italian) (16%)	Prysmian (Italian) (9%)
Innogy (German) (1.11 GW)	General Electric (American) (2%)	GeoSea (part of DEME-Belgian) (5%)	Sif/Smulders JV (Dutch/ Belgian) (13%)	Other (30%)	Other (22%)	Other (10%)	Van Oord (Dutch) (8%)	NSW (German) (6%)	Jan de Nul (Belgian) (7%)

N.B. Data is based on total installations, including signed contracts for wind farms currently under development.

^a owned capacity in GW.

^b % market share.

Chinese companies (4C Offshore Ltd., 2019). Other major markets are forecast to take off in the near future, notably in the United States, Taiwan and South Korea, as well as other European countries, such as France and Poland (4C Offshore Ltd., 2018b). The following summary about the European offshore wind industry is largely taken from the 4C Offshore Wind Global Market Overview Report – October 2018 (4C Offshore Ltd., 2018c). This summary is designed to provide a broad overview of the key actors present in the offshore wind industry. Offshore wind farm construction is broadly organized into four industrial segments and is dominated by a few dominant actors in each sector. The key industries are: offshore wind turbines, foundations (mostly monopiles), cables (inter-array and sub-station to grid) and construction and installation, which includes key vessel segments (particularly jack-up and heavy-lift vessels). These actors are all major diversifiers from the oil and gas, shipping, maritime, dredging and/or cable industries (Mäkitie et al., 2019). Many of the skills and assets needed for offshore wind are therefore strongly related to these core industries. Finally, wind farms are owned and managed by a few dominant companies that finance the upfront costs of the project, organize construction activities and contract the appropriate firms. Table 3 provides an overview of the dominant companies active in the European offshore wind industry. Naturally, there is an extensive sub-supply chain, such as ship builders, vessel owners (such as crew-transfer-vessels and surveyors), crane manufacturers, energy consultants, geological surveyors, ports and component manufacturers, which are not indicated in the table; however, many of these actors are included in our data collection. These companies are also often diversifiers from related industries.

The offshore wind industry is hence a highly concentrated industrial cluster situated primarily in Northern Europe and dominated by heavy industry incumbents. The Dutch have a large share of every offshore installation segment as well as monopile manufacturing. The table below is based on completed projects and signed contracts, but not on projected changes, which will likely alter market shares because companies have gone out of business, restructured or have been acquired by other companies. For example, GE (American) has 1.8 GW of envisioned contracts for its turbines while Adwen (German) no longer produces turbines. Boskalis (Dutch) acquired VMBS cable-laying and Deme (Belgian) acquired GeoSea, which also owns A2Sea wind turbine and foundation installation. Further, rapidly growing markets outside of Europe, particularly in south-east Asia and the USA, may witness the rise of new actors not yet dominant in the current supply chain.

As the industry matures and processes become more tailored and streamlined, a number of innovative developments are underway or have begun to take shape. Specialized vessels, quieter pile-driving hammers, wave motion-compensated equipment, innovative foundations, new installation techniques, radical turbines and numerous digital solutions are all under development by both startups and established actors.

4. Method

Our research is predominantly composed of semi-structured interviews. As mentioned, we have two primary actor types: established firms and young firms, plus networking organizations. In total, we conducted 28 semi-structured interviews in 2018–2019 with Dutch firms and organizations (please see Appendix 1). In addition, we spoke with more than 30 actors in the Dutch offshore wind industry at two international wind energy conventions. Our interviews cover the majority of the Dutch offshore wind supply chain. Semi-structured interviews provide for a standardized set of topics, whilst allowing for an open-ended discussion. Interviewees signed informed consent agreements; the interviews were then transcribed and coded in NVIVO and all quotes below have been anonymized and were verified by the interviewees for accuracy. Our results are further corroborated and supported by publicly available documents, including press releases from offshore wind companies or organizations and industry news journals – such as Offshore WIND and 4COffshore.

To analyze the Dutch offshore wind innovation system and international market access mechanisms, the interviews cover a wide range of topics, including perception of and engagement with the TIS functions over the course of the actor's engagement in the offshore wind industry. For example, the function 'entrepreneurial activity' investigates engagement in offshore wind projects and product testing. Knowledge diffusion underscores R&D collaborations with companies, universities or interactions with formal and informal networks. We also probe companies on international market access facilitating and hindering mechanisms and strategies, including firm specialization, piggy-backing, networking or capitalizing on demonstration sites. As such, our time period covers the entire period in which a given actor was active in offshore wind, starting from their first year of entry, often in the early 2000s. Table 4, below, lays out the key interview topics and examples of the subtopics.

Table 4
Description of the interview script.

Topic	Key points/examples
Background information	<ul style="list-style-type: none"> ● Company expertise ● Share of offshore wind in portfolio ● Background of company experience in other industries (if applicable) and entry into offshore wind ● Size of company
Accessing international markets	<ul style="list-style-type: none"> ● Reasons for entering/diversifying into offshore wind ● First international offshore wind project ● Strategies to get contracts ● Difficulties in getting contract ● Change in strategies over time ● Role of a growing domestic market
Knowledge development	<ul style="list-style-type: none"> ● In-house R&D ● Collaboration with other companies and universities ● Participation in or benefit of demonstration zones ● Development process of new products
Resource mobilization	<ul style="list-style-type: none"> ● Mobilization of human and financial resources ● Sufficient resources ● Acquiring new resources ● R&D funding programs
Internal competition over resources	<ul style="list-style-type: none"> ● Competition for human and financial resources between company departments/segments
Networks	<ul style="list-style-type: none"> ● Use of and leveraging formalized networks to access international markets/get contracts ● Leveraging informal networks ● Leveraging networks from past work experience ● Networks to share and diffuse knowledge
Governance and politics	<ul style="list-style-type: none"> ● Perception of current Dutch policy ● Perception of current international policies ● Collaboration with or lobby the government for certain policies
Additional drivers and barriers to market access	<ul style="list-style-type: none"> ● Language or cultural advantages (or barriers) ● Benefits or issues with other industry players ● Unexpected mechanisms or barriers
Concluding remarks	<ul style="list-style-type: none"> ● What the interviewee would like to see changed in the industry or policy ● How to further stimulate offshore wind ● Future of offshore wind

5. Results

We present our results by dividing our findings between established and young companies. Amongst young companies, we evaluate the ability and ways in which young firms utilize each of the three international market access pathways. Tables 5 and 6 summarize our findings. Interviews are coded in the following way: Established large enterprise = ‘ELE’ + interview # (for example [ELE1]); established SME = ‘ESME’ + interview # ([ESME2]); young SME = ‘YSME’ + interview #; startup = ‘SUP’ + interview #; networking organization = ‘N’ + interview number.

5.1. Established enterprises

In line with our hypothesis and corroborated by the literature, established firms face fewer obstacles to enter the international offshore wind market than younger companies.

One of the key mechanisms for established firms to access international markets is their long history in related industries (for example, oil and gas and maritime). While many established firms continue to broaden their offshore wind portfolio (further diversifying within offshore wind), their entry point was very close to their core set of expertise [ELE1–7 and ESME1–4]. Due to the high level of relatedness, proving technology or shifting resources was not a demonstrable challenge towards accessing international markets. Not only did their skills and expertise line up with the needs of the growing offshore wind industry, these Dutch firms were often amongst the few global actors able to provide the services needed, particularly in Denmark, the United Kingdom and Germany. Hence many of the established Dutch companies were able to directly enter the international offshore wind market without ever needing to build experience initially on a domestic project. According to one ELE:

Well from our point of view, it’s quite easy [to get into offshore wind] because not only we have track record in offshore oil and gas, but also our clients have track-records in offshore oil and gas, or major offshore construction projects...And they’re all moving to offshore wind, because it’s quite a logical step from a technological perspective. [ELE1]

Another ELE stated:

[Interviewee] The first renewable job, that was [early 2000s British project]. They were looking for support, offshore support...We didn’t know anything about that market. We just stepped in and we started to do some testing offshore, that we were able to carry out the type of work they were requesting. So, we had to operate the transportation and installation. The full management of that

for the foundation piles. [Interviewer] And how did you convince [*the contractor*] to contract you? [Interviewee] It was about timing. About our performance profile, about our safety records, our quality systems. Safeguarding schedules. That's what are we very good in. And we had already a bigger relationship from oil and gas with them, so that helped as well. But we convinced them that we could do it. We won it in competition. So, we were the best bidder. [ELE5]

Further, every ELE we spoke with has a large, global presence with existing multinational networks of contacts, offices and reputation and a turnover in the hundreds of millions of Euros. For example, one ELE stated:

Because we're actually based all around the world. We have a big office in Singapore, we have a big office in the Middle East. We're big here. We have two or three offices in Africa. And even in Europe we have one head office in [*the Netherlands*], but there's an office in UK, there's an office in Norway. So, we are all around the world. [ELE3]

The ELEs we spoke with expressed positive attitudes towards the promising and up-and-coming overseas markets and have already witnessed some success. For example, the Dutch incumbent Jumbo recently signed a contract to transport a number of heavy offshore wind components overseas – including monopiles and transition pieces – to the Taiwanese offshore wind farm, Yunlin (*Offshore WIND*, 2019). As two ELEs state:

There is so much experience in oil and gas exploration, and now we are building offshore wind as an industry. And we should utilize the knowledge that we have for the last decades for offshore oil and gas to also help in offshore wind...And by doing that, we can set the pace, we can be a show case for other countries like the US, like Japan, like China, like Taiwan...I mean we get so many delegations from South Korea, busloads of Japanese people, Korean people. I think every 6–8 weeks, we have a group of foreigners here to just be lectured about what is important in offshore wind. [ELE1]

And there is Taiwan, now five and a half gigawatts, but at the end of the year they might announce another ten gigawatts. So, in the short time to 2030, we'll be very, very busy. [ELE5]

While established SMEs do not necessarily have offices around the world, they all have a stable business portfolio, existing contacts, resources dedicated to R&D, capitalize on their core expertise and are not at risk of bankruptcy in the event that an R&D innovation fails [*ESME1-4*]:

It must be said that I hit the ground running because I had a, together with [*name omitted*], which is sitting here, we had our own company before we came here, did exactly the same... So, we already had all the business cards in the book. [ESME3]

And actually, since ten years we've been active in offshore wind. Starting with offshore sub stations, because oil and gas platforms are comparable, at least in a sense, to an offshore (wind) substation. So that was how we entered, and I think that's typically how most engineering companies come from offshore engineering, like us, and enter the offshore wind business. [ESME2]

When established enterprises need to conduct R&D to modify or develop a product for offshore wind, they have the necessary financial, human and technical resources. In the event that an established company does not have a skill or asset, it works within traditional market mechanisms to acquire, partner or merge with another company. For example, van Oord acquired the offshore wind assets and technical base from Ballast Nedam, another Dutch engineering firm, and Boskalis acquired VBMS, a Dutch cable-lay specialist (*Boskalis*, 2016; *Van Oord*, 2014). According to our interviews, [*ESME3,4* and *ELE4,6,7*] were all part of a merger, acquisition or spin-off during their transition into offshore wind.

Some established companies entered the offshore wind market via the creation of one of the few domestic one-off offshore wind farms. For example, van Oord's first offshore wind project was on the Dutch Prinses Amaliawindpark, which began construction in 2006 (*4C Offshore Ltd.*, 2018a; *Van Oord*, 2008). However, no established firm we spoke with indicated that developing a domestic market for offshore wind was an essential step [*ELE 1-7* and *ESME1-4*]. That is to say that, while occasionally a company may have won a first contract on one of the few domestic wind farms, they felt that they could have entered the offshore wind market anywhere in the world.

An interesting finding is the use of international RD&D networking organizations, even for some established firms, to develop products, access demonstration sites and establish consortia. For example, the established SME SPT worked with the Carbon Trust in the United Kingdom, along with a consortium of international companies to develop a new suction-bucket foundation technology that was tested full-scale on a number of British offshore wind projects by DONG Energy (now Ørsted) (*Carbon Trust*, 2014; *Offshore WIND*, 2017). Both established and young small and medium enterprises (see below) cited the open and supportive nature of international research programs, and particularly as products reached more expensive, higher technology readiness levels.

Networks that are open to international collaboration prove beneficial even for established firms, and particularly for the smaller established firms that have legitimacy and skills, but fewer resources and capital to deploy large-scale testing and demonstration. This is an example of international entrepreneurial experimentation, knowledge development and knowledge diffusion that was not predicted in our original hypotheses, but proves to be an important international market access mechanism.

In this respect, we conclude that both large and small established firms that stem from related industries access international offshore wind markets in similar ways even when there is a limited to non-existent home market; this is due to highly related existing expertise, established informal networks, a global reputation and occasionally local or international networking and RD&D organizations.

Table 5
Enabling international market access flows for established enterprises.

Mechanism	Subsets	Explanation	Power of mechanism
Firm specific resources	<ul style="list-style-type: none"> ● Financial ● Human 	<ul style="list-style-type: none"> ● Numerous offices around the globe ● Large number of employees ● Ability to invest and divert resources ● Ability to internally support and prove new technology 	<ul style="list-style-type: none"> ● Very powerful and heavily relied upon by all established firms
Mergers and acquisitions	<ul style="list-style-type: none"> ● Acquiring skills, knowledge and assets 	<ul style="list-style-type: none"> ● Grows the company portfolio under the same brand name 	<ul style="list-style-type: none"> ● Powerful, used when needed
Reputation and legitimacy	<ul style="list-style-type: none"> ● Global brand name ● Long track-record 	<ul style="list-style-type: none"> ● No need to market the company name ● The industry trusts the company 	<ul style="list-style-type: none"> ● Very powerful and heavily relied upon by all established firms
High degree of relatedness	<ul style="list-style-type: none"> ● Related to core assets and skills ● Minimal investments 	<ul style="list-style-type: none"> ● Proving technology is easier ● Investments in-line with pre-existing competences ● Direct application of products and services with minimal modifications 	<ul style="list-style-type: none"> ● Very powerful and heavily relied upon by all established firms
Formal networks	<ul style="list-style-type: none"> ● Industry conventions/meetings ● National networks ● International networks 	<ul style="list-style-type: none"> ● Forum to bring business leaders together ● Time and energy advantage more than establishing new contacts ● Brings together partners interested in working on a new idea to address a problem 	<ul style="list-style-type: none"> ● Medium benefit, useful and convenient, but not essential ● Access to foreign RD&D organizations more beneficial for established small and medium enterprises
Existing informal networks	<ul style="list-style-type: none"> ● Know who to call ● Personal contacts 	<ul style="list-style-type: none"> ● Existing personal relationships and previous collaborations facilitate market entry 	<ul style="list-style-type: none"> ● Very powerful and heavily relied upon all established firms

5.2. Young SMEs and startups

5.2.1. Blocking mechanisms

As we have seen, established companies are able to fairly easily access international markets. However, the story becomes less clear when focusing on young SMEs. Young firms are intrinsically at high risk of failure, a situation that is exacerbated by the capital-intensive nature of offshore wind and the lack of a home market, or at minimum, a protected niche-space. The lack of a home market therefore adds to the difficulties that many younger firms face because they are not able to benefit from the regional proximity of local markets or given access to demonstration zones. Every high CAPEX, young SME discussed challenges associated with limited resources [SUP1-5 and YSME1,3-5].

Specifically, for us, and also for offshore wind, the amount of finance you need, that's just crazy. Like, if you do a smart box, and you do some kind of energy management system, you can do your whole go-to-market stuff, and you can do a test, and deliver the first product. But with offshore equipment it's impossible. [SUP1]

One of the largest hurdles is bringing a technology from the R&D phase to full-scale demonstration. Young firms often attempt to introduce an innovative product or service to the capital-intensive offshore wind industry, which means that a customer has to be certain that a product will function. Every young firm we spoke with, with the exception of two low CAPEX young SMEs, faced – or still faces – high barriers to market entry and proving technology [SUP1-5 and YSME1,3-5]. In the absence of potentially powerful demonstration zones, as explained in Section 5.2.2, below (*via local niche-market formation*), the burden is on investors to develop a product and assume all the risk. The absence of investment thus hinders young companies' abilities to grow and sell their products to the international market.

They [*potential investors*] all want to be second. All companies that want to use a new technology want to be the second user, when the major risk is gone. And that's the biggest problem, because we're now going to do an offshore full-scale test. We got that financed also with a subsidy, but still we had to put in significant money ourselves. [SUP3]

Despite successful scale-tests, government R&D funding and significant personal investments, one startup continues to struggle with developing a full-scale demonstrator:

[Interviewer]: You haven't done a full-scale mock up yet? [Interviewee]: No. That's part of the problem...in big infrastructure. So, projects require that they have about a four-year lead time, then the operator gets a license, then it takes another year to select the type of turbine and the type of foundation for the specific area. And then they start building, which takes another two years. Then commissioning, etc. So, for small companies... Absolutely, things are very difficult. Because you don't have the financial redundancy to actually keep yourself going. At least if you are a one trick pony like us...But financing innovation in SME companies is the hardest part.] [SUP2]

With limited resources, no global reputation nor a proven technology and operating in a conservative and highly capital-intensive sector, demonstrating new technology in real-world circumstances is extremely challenging.

5.2.2. Enabling mechanisms and strategies

Nonetheless, as predicted, there is some hope for younger firms to access international markets. Based on our data, we confirm that each of the three international market access pathways was – or is being – exploited by one or more young SMEs throughout their development process via a variety of mechanisms, strategies and tools.

5.2.2.1. Via established firms. According to publicly available documents and corroborated by our interviews, piggy-backing and partnerships are indeed a successful international market access mechanism. For example, the young startup, Barge Master, was able to work with the Dutch ELE, Boskalis, on a first project, albeit an offshore oil and gas project, to gain experience and run full-scale tests of its wave motion compensated platform in real world conditions (Barge Master, 2013). Similarly, private investment from a local ELE, when it occurs, is a very powerful mechanism for a company to enter the market. For example, the innovative Dutch startup, Fistuca – which is developing a quieter pile-driving hammer – was acquired by the Dutch ELE Huisman, which then funded full-scale manufacturing and onshore testing (Offshore WIND, 2015). According to two startups:

We attracted an investor, so you can understand that that doesn't come for free. It's a very capital-intensive business. [SUP3]

We follow the large Dutch and Belgian contractors, they contract worldwide and we are basically in their slipstream. [YSME5]

With access to resources, manufacturing capacity and an international reputation and network, a young SME has a much higher chance of success if it links up with an ELE. Having geographic proximity to these larger companies facilitates this process in large part due to logistic simplicity and a high density of potential investors. Indeed, every Dutch ELE mentioned in Section 3 is based, or has an office, in or near the Rotterdam area. Our results show that interviewees [SUP3,5 and YSME5] directly capitalize on local ELES to help them develop their products and (begin to) access international markets. Local culture, language, legal setting, regional cohesion and local networking events provide companies with a natural 'in' when it comes to bidding on sub-supplier contracts or gaining the investor confidence necessary to take the risk on a novel and unproven concept.

I think as a SME your range is very local. So, we have more than enough companies to talk to in a range of fifty kilometers geographically. So far, I have the feeling that that's where we'll be able to find our investor. There could be a very interesting party in the north of Germany. But as a small company you don't easily reach out to travel there. [YSME3]

While the Dutch seem to be very internationally minded and do not express a distaste for interacting with non-Dutch firms, the pure logistics and density of firms in the Netherlands helps develop a local network and access potential partners.

One local networking format that attempts to help establish these forms of connections is the Offshore Wind Innovators, which connects domestic startups with larger, domestic companies through investor pitches, awards, innovation challenges and marketing workshops. The award's tactic is designed to present a current challenge faced by the offshore wind industry to which startups are given the opportunity to pitch their ideas. The startups with the best ideas are given preferential access to present their innovative product to a large consortium of key players, thus opening more doors for collaboration. The award acts as a form of pre-validated legitimacy and vetting, thus increasing the visibility and stature of smaller companies and providing them with additional resources to take their concept to the next phase. Interviewees [SUP2,3,5 and YSME3,4,5] engage with the Offshore Wind Innovators to foster business connections and develop product legitimacy. Indeed, the four networking organizations we spoke with [NI-4] discussed the ways in which they help young SMEs connect with larger firms, for example via R&D consortia, award systems, visibility and increased legitimacy. Formal networking organizations are designed to help young SMEs overcome these challenges by connecting them with larger companies. These networking organizations bring young SMEs and ELES together in an informal and casual setting and are designed to allow discussions 'over a beer', hence greatly reducing barriers linked to establishing first contact. According to one young SME on the value of networking organizations and events:

We are part of the Offshore Wind Innovators and the Rotterdam Offshore Wind Coalition networks. The networks are of added value because we are able to meet and work with different companies. [YSME3]

These are direct examples of formal and informal networks that play a role in strong innovation system functioning and therefore supporting international market access.

5.2.2.2. Directly accessing international markets. Accessing international markets without going through local partners or waiting for a local market to form, while possible, is challenging and is facilitated by a number of different mechanisms. Local and international networking organizations play a key role in a variety of ways. For example, the Netherlands Wind Energy Association supports young companies at international wind energy conventions, such as by creating a visible 'Dutch Village' cluster. This brings young and established companies together in a single location at the same time and provides the space for investor pitches, knowledge sharing and marketing. Companies [SUP3 and YSME4,5] were present at the Dutch Village cluster of the offshore wind conventions.

We speak to them in trade shows, where they all go because they're in the field and they're in the market. We can talk to them at these locations, which is more convenient than having to go there specifically for a meeting. [SUP1]

This is a direct benefit of function 3, knowledge diffusion, of the TIS framework.

Additionally, one of the most powerful indicators of success with these young SMEs is if a high-level member has previously worked at an established firm in the industry before establishing his or her own firm. Indeed, interviews [SUP2-5 and YSME1,2,5,6] utilized contacts from previous work experience. For example:

[Interviewer]: How did you get a hold of these people? [Interviewee]: I was in the offshore oil and gas business for twenty years. [Interviewer]: So, you had previous contacts? [Interviewee]: I've negotiated hundreds of contracts for platforms, installation, construction, EPCI contracts. [Interviewer]: Did you use your past contacts? [Interviewee]: Yeah, because they're all in the same business. [SUP2]

The young SMEs with past contacts all indicated that this was a very beneficial tool for success and the startups were actively leveraging these connections. These contacts not only provide real-world insights into the industry and its needs, but also generate a long list of personal references and a high level of trust to take into the new business venture. A similar approach is to spin-off a part of a larger organization through a partial buy-out, which allows a new company to bring not only an existing informal network, but also a certain level of legitimacy and technological advancement; this mechanism was elucidated by [YSME5]:

And from that company we started also [*this company*]. [*It*] was just an idea that came up in two thousand and eight. We thought it was a good idea. Started patenting it. So, that was basically the start of the company. [YSME5]

An unforeseen, positive market access mechanism comes in the form of foreign networking and knowledge development organizations, coupled with foreign demonstration sites so long as the organization is open to foreign innovation and collaboration. Examples include the British Carbon Trust and the Danish Technical University and Aalborg University Wind Testing Centers (Denmark) (The Carbon Trust, 2008). Interview [SUP3] (and also [ESME2,4]) emphasized the benefits of international RD&D organizations to develop their products and run full-scale offshore tests. While not every company works with a foreign intermediary, this is a mechanism that some exploit and helps overcome some of the challenging domestic conditions, as explained below.

5.2.2.3. Via local niche-market formation. Demonstration zones represent one of the potentially most powerful mechanisms to overcome the 'valley of death' in terms of bringing technology to full-scale readiness and preparing it for deployment in the international market. Interviews [SUP1-3,5 and YSME 1,3-5] expressed a positive attitude towards more government facilitated and supported demonstration sites to enable and cover the additional costs of testing new technology in real-world circumstances. Borssele V, a designated innovation wind farm zone designed to do exactly that, is largely seen as a good idea with poor execution in terms of facilitating new innovative technologies. Our interviewees indicated that, due to the intense focus on cost reduction for offshore wind farms in the Netherlands, the subsidy rate for the innovation site was far below what a high CAPEX and disruptive innovation project would require. For example:

So, we had a beautiful bid, based on the conditions of Borssele five. We would absolutely win, ...Within the criteria we would really get three points per [*category*]... Like, it was all good. [SUP2]

Funding of an innovation site is also needed. Good funding of the project. Because I think for instance at the Borssele V as an SME it was not possible to find the funding for the offshore demonstrator. Only as a company that's already building there – Because they won Borssele three and four, they were able to put an innovative and financially feasible design for Borssele five. As [*a young SME*] we'd never be able to do that project. So, the subsidy or the financial rules for an innovation site are also very important. [YSME3]

According to one networking organization and corroborated by all four networking organizations [N1-4]:

I think if you do it well, then it has a big value. Borssele I think – It's called a test location and a demo site, but the conditions given by the government are not good enough I think, to attract disruptive innovations. [N2]

While publicly supported and funded demonstration sites have not been successful, the Netherlands does provide some access to semi-private/semi-public onshore sites: the areas are often (partially) government owned and controlled, but they are operated on a commercial basis; they are therefore provided at low cost, but do not financially support the development of innovative technology. For example, the Port of Rotterdam's Maasvlakte II and the Port of Eemshaven provide space for companies to test out full-scale products onshore. 2-B Energy is currently testing a 6 MW, two-bladed turbine at the Port of Eemshaven and Fistuca performed full-scale onshore testing at Maasvlakte II (Groningen Seaports, 2018; Offshore WIND, 2015). However, these sites largely provide the physical space for testing, not the finances necessary to actually run the tests. Private investments are still needed to bankroll these tests. Providing space is a positive and key step, but finances are limited and is (critically) still onshore. Harsh ocean conditions, complex installation procedures and high capital costs create high barriers to offshore testing.

And then we found a location on the Maasvlakte in Rotterdam...which is sort of a barren field... It's a strange place to be but it's excellent for these types of setups. [SUP5]

The young SMEs that were able to perform offshore testing essentially bankrolled their own ‘private’ demonstration sites, often in collaboration with other, local ELEs [SUP3,5 and YSME4,5]. For example, the Delft Offshore Turbine installed its hydraulic-based wind turbine in the waters of the existing Princess Amalia offshore wind farm and was financially supported by a private consortium, R&D grants and research institutes (4C Offshore Ltd., 2018d). Two startups we spoke with were able to ‘create’ their own offshore demonstration site:

[Interviewee]: We’re now preparing for the offshore demonstration. [Interviewer]: Ok, you found an offshore demo site? [Interviewee]: We created an offshore demo site. [Interviewer]: How did you do that? [Interviewee]: That’s the good thing of the Dutch government: They’re very proactive in supporting tests in the way that they don’t create additional hurdles like you typically see in Germany. So, if you spot a site that could be interesting in the North Sea you can proactively approach Rijkswaterstaat [Ministry of Infrastructure and Water Management] ... And then they just come up with a strategy that you need to follow...And well, we complied with the request that they gave us, so yeah. That’s it. [SUP3]

While entrepreneurs are able to find offshore locations and receive administrative support from the government, financing these sites remains a challenge. The failed Borssele V innovation test site demonstrates that the government is not willing to fully financially back potentially disruptive innovations at higher technology readiness levels, leaving companies to find their own means.

However, in an attempt to counteract the poor-performing entrepreneurial experimentation function, the Netherlands has established a number of RD&D support organizations, such as the GROW research, development and demonstration offshore wind network, which is funded by 100 million Euros of funding from the Top Knowledge Sector Offshore Wind (TKI Wind op Zee) program. Our results show that some, but not all, of the startups and young SMEs leverage this RD&D network [SUP2,3,5 and YSME 4,5].

Subsidies and development funding, R&D funding... I can’t compare to other countries, but for us it’s been very valuable. Definitely. Without these types of funding, you’d not be able to bring to market any technology in the offshore. Because we’ve had funding for developing this [product], which is a higher risk product – Or a higher risk technology. The chance of success is not very high, because it’s new. [SUP1]

One startup [SUP4] intentionally steered clear of government sponsored R&D programs, citing bureaucratic complexity and burdensome application conditions, including the high share of required upfront private financing (RVO, 2019). While capitalizing on government sponsored R&D grants, many young small and medium enterprises still mentioned difficulties linked to the amount of personal capital and bureaucratic complexity required to receive funding support, which further hinders their ability to advance technology at higher technology readiness levels.

The problem with R&D funding from the Dutch government is that they often ask for a counter finance. So, you have to have a certain budget. And let’s say that seventy percent of your costs are internal hours. You’re allowed to calculate with sixty Euros per hour...And if you calculate with the standard rate...they give you for example sixty percent which is thirty-six Euros subsidy per worked hour...However, the government wants you to show that you can counter-finance, so you need to show that you got twenty-four Euros. Although you’re not going to spend it, but you got it somewhere...And the funny thing is that the government sort of asks you to show your counter-financing, even if you’re probably not going to need it. And that’s one of the rather difficult things in financing right now with Dutch government subsidies. [SUP3]

That’s a challenge: Getting this funding in. I know that I’m of course biased in this, but this is really not helping innovation. It’s just taking us too much time to get funding. [SUP5]

Other young SMEs [SUP1 and YSME3] leveraged different knowledge diffusion and development mechanisms, such as from incubators, to acquire funding and increase the product’s technological readiness and visibility.

[Interviewer]: What do they [networking organizations] do for you? [Interviewee]: They create opportunities for publication, marketing. For us it’s publicity they’re creating. And they’re also making the connection with companies that we’re not aware of, or companies where we’re having a hard time finding the right person. These network organizations do have the right contacts within the different organizations. So, I think those two are important benefits of these networks. [YSME3]

It becomes clear that knowledge development and diffusion perform well in the Netherlands, help companies develop their products and in some cases, even assist in full-scale testing. However, as was mentioned previously, translating this knowledge into full-scale entrepreneurial activity remains a major challenge.

Unlike for larger, more established companies, no high CAPEX young SME rolled-out its first commercial product on a commercial Dutch offshore wind farm. These singular, one-off wind farms are not the moments in which new, innovative firms are able to capitalize to develop products and subsequently enter the international market. Young SMEs benefit more from demonstration zones, collaborations with large, local players, local networking and research organizations or occasionally in partnering with international organizations; they subsequently demonstrate products in local or foreign waters. Hence, entrepreneurial activity becomes rather fragmented, complex and expensive. As commercially viable young enterprises recently went through the startup phase and still experience similar challenges, we can confirm that their responses are very similar to those of startups.

Table 6 summarizes our results for young SMEs.

Table 6
Enabling international market access flows for young SMEs.

Mechanism	Subsets	Explanation	Power of mechanism
Via established firms			
Partnerships	<ul style="list-style-type: none"> ● Piggy-backing ● Mergers and acquisitions 	<ul style="list-style-type: none"> ● Geographic access to a cluster of established, local actors with legitimacy and resources to go global and are willing to take the risk on a new company ● Established companies work with younger companies to develop the product and advance the technology readiness level 	<ul style="list-style-type: none"> ● Extremely powerful, but challenging to achieve. Piggy-backing allows companies to test products full-scale and partnerships provide private investments and resources needed to test and develop products. When engaged, this mechanism works extremely fast.
Local networking organizations	<ul style="list-style-type: none"> ● Networking ● Business-to-business ● R&D ● Facilitate access to demonstration sites 	<ul style="list-style-type: none"> ● Networking organizations help companies at large conferences or conventions ● B2B networking organizations connect young and established firms in a local space and help build legitimacy ● R&D organizations financially support product development, collaboration and knowledge diffusion 	<ul style="list-style-type: none"> ● Beneficial in terms of making contacts, but limited in facilitating full-scale testing. Funding available, but becomes weaker as the product advances the technology readiness level ladder; very accessible.
Local context	<ul style="list-style-type: none"> ● Language ● Culture ● Geography 	<ul style="list-style-type: none"> ● Access to a wide range of companies in a small geographic space facilitates access to meetings ● Speaking the same language 	<ul style="list-style-type: none"> ● Beneficial in terms of having a large consortium of ELEs and established firms nearby, which can help facilitate piggy-backing or private partnerships, but plays less of a critical role than other mechanisms
Directly accessing international markets			
Local and international networking and research organizations	<ul style="list-style-type: none"> ● Domestic networking organizations ● Large-scale and open international networking organizations 	<ul style="list-style-type: none"> ● Brings together a consortium of young and established firms in an international context ● Similar to a local networking organization, but on a larger scale 	<ul style="list-style-type: none"> ● Somewhat beneficial for networking, as they help startups and young firms link up with potential investors and partners ● International networking and RD&D organizations can be extremely helpful when available and provided they are open to foreign collaboration
Informal networks	<ul style="list-style-type: none"> ● Previous work experience ● Cold-calling 	<ul style="list-style-type: none"> ● Bringing in contacts/established network from previous positions in other companies ● Creating an informal network by calling everyone who might be interested 	<ul style="list-style-type: none"> ● Very beneficial. Individuals who can take contacts from previous work experience provides higher levels of trust and a larger network to leverage
Via local market formation			
Demonstration zones	<ul style="list-style-type: none"> ● Public ● Private ● Semi-public/ semi-private 	<ul style="list-style-type: none"> ● Public demonstration sites are created and supported by the government and are designed to directly (financially and spatially) facilitate full-scale testing of products ● Private sites are sought out by private consortia and require private financing ● Semi-public/private: Site is provided for free or very cheap, or permitted by the government, but limited/no financial support 	<p>All demonstration sites are extremely valuable when available:</p> <p>Public demo site:</p> <ul style="list-style-type: none"> ● Extremely high potential, but poorly executed in the Netherlands <p>Private demo site:</p> <ul style="list-style-type: none"> ● Very useful, but requires private financing in offshore conditions. Dutch government is bureaucratically, but not financially, supportive. <p>Semi-public/private</p> <ul style="list-style-type: none"> ● Very useful, but onshore. Further, only space is provided, not finances.
RD&D networking organizations		<ul style="list-style-type: none"> ● Organizations financially support RD&D, connect companies to other companies and help find and finance demonstration sites 	<ul style="list-style-type: none"> ● Beneficial, particularly in helping to access and finance demonstration sites and find potential project partners. But many conditions and complications remain, including counter-financing requirements and bureaucracy

6. Discussion

By decoupling technological generation from technological diffusion within the national boundaries of a technological innovation system, we are able to understand the necessary conditions in which a science-technology-push strategy can support international market access. As previously demonstrated by (Wieczorek et al., 2013) and elaborated upon in the global innovation system

framework (Binz and Truffer, 2017), we have seen that it is possible for an innovation system to develop across a group of countries: a lack of a commercial home market can indeed be compensated for by a commercial market in other countries. This research has elucidated the mechanisms, strategies and innovation system conditions for which this is possible. We can therefore conclude that a science-technology-push approach supported by a strong innovation system can be fruitful in the absence of a home market under certain conditions.

First and foremost, a market-pull strategy (commercial market formation) needs to exist somewhere, implying that not all governments can take a late-mover approach. Second, it is fairly straightforward to develop a core supply-chain to service a foreign market so long as there is a strong, highly related industry characterized by a number of diversifying established large and small enterprises. These companies are able to access international markets through a high degree of relatedness, competitive advantage, extensive resources and existing multinational networks. Although the Netherlands is a lag market compared to Denmark, the United Kingdom and Germany, this has not hindered its ability to leverage its industrial resources to participate in the growing international market for offshore wind. Further, we can conclude that the different institutional conditions amongst European countries, including differing energy policies, subsidy systems, R&D mechanisms, environmental regulations and local content restrictions demonstrate that this is truly an international market; this also means that it is not enough to simply be European to access these different markets. Our results also indicate that up-and-coming markets in the United States, Taiwan, Japan and Vietnam are promising for the Dutch market, and Dutch companies have already won numerous contracts.

Supporting young, innovative firms, on the other hand, is more challenging; as the science-technology push approach focuses on supporting research at a basic level, fissures occur when innovators try to develop full-scale products and achieve commercial success, a key criterion of the TIS 'entrepreneurial experimentation' function. This is largely due to the high capital costs required for product development and a weak high-technology readiness level support system. While the science-technology push approach without a domestic market successfully supports some components of an innovation system, particularly in knowledge development and diffusion, it often suffers from a deficit at the entrepreneurial activity and resource mobilization level. This is a particular issue in such a capital-intensive industry. Therefore, partnerships with local and international firms, domestic and foreign networking organizations and the creation of full-scale demonstration zones are some of the key innovation system mechanisms needed to help facilitate market access. Further, the development of an innovation system without a commercial home market will face higher barriers without the presence of established firms forming the backbone of the industry; a country interested in developing an innovation system that possesses limited related skills will likely need to create a protected niche-space and commercial market in addition to science-technology push support mechanisms to succeed. Finally, outsourcing the commercial market formation function to other countries can only be successful as long as the other innovation system functions are performing well, thus mandating the need for robust and well-supported knowledge institutes, knowledge networking organizations, well-supplied R&D grants and adequate protected niche-spaces. Hence, it becomes possible to decouple technological generation from technology diffusion within national boundaries so as to facilitate societal transitions under a unique set of circumstances.

Finally, the close geographic proximity, free-trade and free movement of goods and people within the European Union may provide some ease of access to these individual markets. However, the institutional conditions of the individual European countries do not automatically translate into market access or create a singular market. Since the North Sea region comprises 85% of the global offshore wind market, it is yet to be seen whether our notions of international market access are applicable to the overseas international audience, such as in the United States, South Korea or India, or whether similar phenomena will occur within other regions, such as amongst United States East Coast states. However, initial indicators do show that Dutch actors are already involved in the first overseas international projects and delegations from numerous countries regularly visit Dutch companies, indicating a high degree of legitimacy. Further research is therefore required once offshore wind projects have been commissioned around the globe to truly understand the capacity of Dutch actors to access overseas international markets and whether differences can be highlighted between the European international market and the overseas international market. Further research, including comparative studies with other countries that also have limited offshore wind markets and yet also participate in the international market, such as Spain and Norway, may prove enlightening.

7. Conclusion

This research has attempted to elucidate the conditions for which industry formation is possible in the absence of a domestic market. Informed by in-depth interviews with actors in the Dutch offshore wind innovation system, we can conclude that it is possible to support industry formation for both startups and established actors under a unique set of circumstances. In reflecting on our market access flow-chart, we indeed see that established firms are much closer to international market access than younger firms. Their ability to leverage resources, utilize informal networks and capitalize on a high degree of relatedness from their core industries renders international market access relatively simple. Thus, when a local innovation system is well populated by established firms, domestic market formation is less essential.

Younger firms, on the other hand, are much further away from international market access and therefore need to employ a different series of strategies, utilize different mechanisms to gain access to these markets and are much more dependent on a well-functioning innovation system. We can confirm that all three of our potential market access flows were and are utilized by young

firms to attempt to gain access to international markets. Local policy support for R&D, product testing and access to resources have high potential to support new innovations. Young firms are able to capitalize on the high density of established large enterprises to piggy-back on or partner with. Finally, full-scale, offshore demonstration sites hold extraordinary potential for young, innovative companies. Hence, it becomes possible to support industry formation without investing in expensive home market policies if there is a strong and open international market, a high density of local and related established large enterprises and a robust and well performing innovation system.

A key conclusion of our research is that highly related incumbents that are already in possession of critical knowledge and experience are able to engage with an international innovation system in the absence of a domestic market, whereas younger firms with limited resources and experience are much more dependent on local innovation system building. This is a phenomenon we expect to be applicable to multiple innovation systems and industries. Further, we also understand that not every country can be a late-mover and bypass the initial home market formation stage, implying that the successful build-up of a domestic industry is highly dependent on other formative countries. The new markets in the United States, Taiwan, Vietnam and others will also prove to be interesting cases in the near future. Therefore, we argue that the case of the Netherlands is not a single-case anomaly, but rather representative of concerted innovation system build-up coupled with the strong backbone of highly related incumbents – a situation that we expect could be expressed across multiple countries or industries with similar contexts. Hence, we understand that successful industrial formation is highly dependent on strategic innovation system development and targeted government policy, particularly in the absence of a domestic market for an emerging technology.

Declaration of Competing Interest

None.

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Appendix 1

Code	Actor type	Date of interview	Interviewee's position in company
ELE1	Established large enterprise	30.5.18	Head sale's manager
ELE2	Established large enterprise	5.6.18	R&D manager
ELE3	Established large enterprise	19.6.18	Commercial manager
ELE4	Established large enterprise	9.7.18	Business development and acquisition manager for offshore
ELE5	Established large enterprise	12.7.18	Head of business development
ELE6	Established large enterprise	5.12.18	Head of offshore wind business unit
ELE7	Established large enterprise	11.12.18	Business developer
ELE8	Established large enterprise	27.3.19	CCO
ELE9	Established large enterprise	27.5.19	Former CEO
ESME1	Established SME	29.6.18	Business manager
ESME2	Established SME	18.7.18	Manager of renewables
ESME3	Established SME	25.7.18	Commercial general manager of wind
ESME4	Established SME	15.11.18	Managing director
YSME1	Young SME	16.7.18	CEO and founder
YSME2	Young SME	19.7.18	CEO and founder
YSME3	Young SME	24.7.18	Project leader
YSME4	Young SME	23.11.18	Head of offshore wind business unit
YSME5	Young SME	30.11.18	CEO
YSME6	Young SME	27.3.19	Co-founder
SUP1	Startup	16.7.18	General director
SUP2	Startup	17.7.18	CEO and founder
SUP3	Startup	26.7.18	CEO and founder
SUP4	Startup	29.11.18	Head of technical development
SUP5	Startup	6.12.18	Project developer
N1	Networking organization	7.6.18	Coordinator
N2	Networking organization	25.6.18	Manager/coordinator
N3	Networking organization	20.12.18	Director
N4	Networking organization	20.12.18	Former director

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