

Chapter 15 - Collaborative Innovation in the Norwegian Oil & Gas Industry: Surprise or sign of a new economy-wide paradigm?

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Introduction

This book tells the story of the improbable rise of internationally competitive, Norwegian suppliers of sophisticated subsea equipment, advanced seismology and other capital goods to the offshore oil industry. By venerable consensus in development economics, the production of commodities based on natural resources, whether in agriculture or mineral extraction, is the last place to look for accumulation of the general-purpose capacities that underpin economic growth. When, exceptionally, such capacities do arise in commodity production, multinational firms produce them, or swiftly wrest control from upstart innovators. Up to now, Norwegian suppliers have succeeded against the odds both because of peculiarities in the oil industry's technological trajectory, and the infant-industry protection of domestic producers. But continuing reliance on an exhaustible natural resource like oil makes this unlikely success fragile and fleeting, and prudence suggests that the supply industry diversifies into more robust pursuits before good fortune turns bad.

The story of the oil-field supply firms' success makes an important contribution to another, more general narrative: the emergence at the frontier of production in all sectors of the economy – in the production of resource-based commodities as well as industry and services – of a model of collaborative innovation. This model takes as its starting point a world – ours – in which the speed and uncertainty of technological and market change make it impossible for even the most capable actors to master by themselves the skills needed to remain at the forefront of development. Given this uncertainty even the leading firms come to depend upon shifting constellations of suppliers, large and small, to deploy and develop technologies changing so rapidly that their strengths and weaknesses can only be determined in use.

In this new model of production the master skill is the capacity to collaborate in adjusting general technologies to particular contexts, and then learn from those adjustments how to advance general understanding. Because this model of production is inherently collaborative, its development goes hand and hand with the creation of new forms of contract that facilitate joint innovation among rapidly changing groups of partners. Because this model of production is taking hold in all sectors of the economy, it implies that the possibilities for acquiring the general purpose capacities that are the building blocks of growth are broader than development economics has assumed.

The upshot is that firms and (parts of) national economies that excel in these disciplines of collaborative innovation thrive, regardless of whether formal ownership of productive assets is national or foreign, and regardless of whether those assets are deployed in natural resource based activities or not. From the perspective of this emergent model the success of the Norwegian supply industry is not an accidental exception to the exceptionally unpromising conditions of skill acquisition in a resource-based industry in a small country. It is rather a paradigmatic illustration of how the collaborative capacity to use ever deeper knowledge of the local circumstances of production can become a springboard to lasting global success.

The argument proceeds in two steps. First we recall the incremental, but cumulatively transformative development of the technology of off-shore oil extraction in which Norwegian capital goods suppliers have played an important part. Both the summary statistics for the global industry and the detailed studies of Norwegian developments presented in this book show that the epicentre of innovation is no longer the international oil companies but rather the suppliers of oilfield services and equipment.

These changes are of a piece with developments in industries as different as automobiles and pharmaceuticals. In these industries too, the locus of innovation has shifted. For much of the last century, leading firms in these and many other industries dominated research and development in their domains, and produced key components and other inputs themselves or under contract with suppliers working to detailed specifications they provided. In this sense, they were vertically integrated, whether they formally owned their suppliers or not. As in the oil case, these industries have, in their own way, also undergone technological transformations so broad in scope and

unpredictable in direction that no firm can expect to be a pioneer in all. Firms that owned their suppliers have divested them out of fear that the internal producers could easily become obsolete or superfluous; and lead firms expect to collaborate with new generations of independent suppliers in developing innovative technologies.

To understand how collaboration is organized under these conditions we look, in a second step, at the contractual relations governing the co-development of innovative products in these same industries. Here we encounter a paradox. Lawyers understand contract as an exchange of precise promises: I give, so that you will give in return – *do ut des*. But when no one can say for sure what is feasible – when innovation is necessary – a detailed and binding division of labour would be a self-deluded and self-defeating speculation. The same uncertainty or inability to anticipate future states of the world that makes collaboration between independent parties indispensable to innovation makes it impossible for conventional contracting techniques to manage the effort.

Faced with this dilemma firms have adopted novel forms of interacting. Instead of attempting to specify the outcome – what each party must actually contribute to realize the common purpose – they agree to set terms for collaboration. The formal contracts create governance processes – for instance regular meetings to review progress towards milestones, and procedures for resolving conflicts over how and whether to proceed – that allow each party to assess the capacities and good faith of the other while refining ideas of what the eventual product should be – or whether it is feasible at all.

The Norwegian oil industry has adopted ‘front end engineering and design’ (FEED) contracts of this general type to govern collaboration with large general contractors in designing the system of production in a particular field. This is a crucial stage of development when the innovative integration, in view of basin-specific conditions, of established and novel technologies can determine the profitability of a venture – and trigger further cascades of technical innovation as ambitious designs are realized. We discuss these relatively recent and little studied contracts against the backdrop of closely related innovations in contracting in the pharmaceutical and automobile industries.

Norway, a small country on the European periphery and long dependent on the export of natural resources, has a fertile tradition of development economics (Nurkse, 2009). Like the larger body of thought with which it is intertwined, that tradition sees manufacturing industry as the high road to the acquisition of general purpose capacities, and the exploitation of natural resources as more of a curse than a blessing. The similarities between the emergent patterns of innovation in oil and gas, automobiles and pharmaceuticals is at odds with this tradition of thought. By way of conclusion we doubt the utility, today, of distinguishing natural resources as a distinct sector of the economy.

The trend to vertical disintegration and collaboration

Developments in the oil and gas industry are not singular. They are part of a very general pattern. In one area of the economy after another – within natural resource based sectors and within manufacturing industry itself – the very direction of technological change has become unforeseeable. Knowledge of what works today is an unreliable guide to what will be required tomorrow. The common response to this uncertainty is the opening or dismantling of closed R&D and production systems and significantly more collaboration with outsiders in both.

To illustrate the broad scope of this claim, we examine the similarities between developments in oil and gas and two non-natural resource based industries in the United States, automobiles and pharmaceuticals. These industries differ not only from oil and gas; they are also different from each other. The US auto industry pioneered mass production and vertical integration to become an emblem of traditional manufacturing, while pharmaceuticals has become, in the wake of the biotechnology revolution, an emblem of the new, knowledge-based economy. We find that each industry has its own trajectory, but those trajectories are all marked by a degree of uncertainty that leads to vertical disintegration and collaborative innovation. The common response suggests a change in the general conditions of competition, not the idiosyncrasies of any particular pursuit.

Collaborative Innovation in Norwegian Oil and Gas

The extraction of oil and gas from deep reservoirs offshore under harsh conditions has been transformed in recent decades by new instrumentation and by innovations in subsea or ocean floor technology, as described in chapters 2 and 4 of this book. One of the most important advances in metrology is 4-D or time lapse seismology, which permits observation of a reservoir as it is being drained, revealing untapped reserves. The advances in subsea technology make it possible to separate solids and seawater from oil and gas at or near the wellhead; re-inject seawater into the formation to compensate for the decrease in pressure caused by the well flow; compress gas; and pump only the gas and oil – purified of the by-products of extraction, and often together, in a single, multiphase pipeline – to floating storage facilities or to onshore terminals. Used together with advanced metrology such subsea equipment, installed by robot, monitored from shore, and operating in the high-pressure but stable conditions beneath waves and weather dramatically lowers the cost of extracting oil deep offshore, substantially expanding the range of recoverable resources while reducing the risks of harm to human operators and the environment.

Geopolitical events reinforced the destabilizing effects of these developments on oil industry organization. Price shocks in the 1970s led the IOCs to reduce expenditures on research and development, and outsource many technically demanding tasks to oil service providers. The rise of national oil companies displaced the IOCs from reserves they had long exploited, and forced them to explore alternatives in less hospitable settings, whose accessibility often depended on technical innovation. This market, technological and geopolitical turbulence has made the IOCs more dependent on innovative suppliers and created opportunities for Norwegian firms – as pioneers in both 4-D seismology and subsea processing – to establish themselves first in the North Sea and then internationally.

The growing contribution of suppliers to technological development in the industry is significant enough to show up in aggregate statistics, despite many problems of measurement (chapter 3). A recent survey of senior managers in the oil and gas industry globally finds that 63% of the innovations actually put to use originated in service companies (Perrons, 2014, 309). Before the IOCs began to rely on outside suppliers to (co)develop technology, the 11 leading firms in the

industry accounted for more than 80 percent of total investment in research and development (Perrons, 2014). By the mid-1990s observers found that technology had ‘become so sophisticated, broad, and expensive that even the largest companies can't afford to do it all themselves’ (Leonard-Barton, 1995, p. 135). A dramatic increase in the market capitalization of service and technology providers is a further indication of their increasing centrality to the industry: Schlumberger, the biggest of them, has a market value greater than all but the very largest IOCs (Perrons, 2014).

The study of Norwegian suppliers (Chapter 3) reflects this trend. Oil-related suppliers outperform Norwegian firms generally and Norwegian firms in comparable sectors. In particular, the oil field suppliers scored high on measures of participation in research and development projects and less formalized collaboration with customers and other suppliers.

Social network analysis of all publicly funded, oil-related, Norwegian research projects shows these relations in higher resolution. In projects regarding the implementation of new technology on the Norwegian continental shelf (NCS), the supplier company is typically the project leader, and other actors cluster around it. Collaboration among suppliers is increasing. In short, suppliers play a lead role in innovation on the NCS (and by extension in global markets) and their reliance on each other is increasing.

Interviews with supplier managers from the Rogaland (Stavanger) subsea technology and service cluster and their large oil operator customer counterparts confirm the centrality of suppliers to innovation (Chapter 4). Virtually all the supply-firm managers agree that in-house knowledge accounted for at least 65 percent of innovative solutions. The oil operating company managers, interviewed less systematically, concurred, estimating that their companies contributed only between 15 and 35 percent of the know how that goes into collaborative innovations.

The precise balance of the contributions matters less here than the nearly unanimous agreement that innovation is no longer the exclusive domain of the oil producers. Innovation today is, instead, vertically disintegrated and collaborative, with suppliers often taking the lead in joint efforts. A brief look at changes in the automobile and pharmaceutical industries shows that this is a general outcome, even if the paths to it vary by industry.

Vertical disintegration in automobiles

The US automobile industry is a particularly useful reference point because it was for much of the 20th century the canonical example of the natural connection between mass production and vertical integration. The parts of a car were specialized to one another: each was good for a particular make or model. Manufacturers, fearing supply disruptions – particularly costly because production was capital intensive – made the bulk of almost all the parts they needed. They only resorted to outside suppliers for two reasons. One was to periodically check that the methods and technologies used internally were at least as efficient as those available on the outside market, and to take corrective action if not. The other was to hedge against unpredictable, short-term fluctuations in demand: outside supply could be increased or decreased as needed to ensure that internal capacity was utilized at a nearly constant, efficient rate.

The kind of geopolitical shocks that broke open the oil industry in the 1970s deeply unsettled US automobile manufacturers as well. Yet, despite fitful efforts to emulate Japanese competitors who were then demonstrating the potential of collaborative methods, the initial and for decades main US auto company response was simply outsourcing: divesting internal units and purchasing parts and components from independent suppliers, still working to detailed specifications, and often located in low-wage countries. Disintegration was dramatic and relentless. In the early 1980s, as outsourcing began, General Motors, the largest of the US companies, produced roughly 70 percent of its parts and components internally, and contracted for the remainder; by the early 2000s the ratio was reversed. This was, however, vertical disintegration in the narrow sense of increased reliance on outside markets but not in the larger sense of the term as including a shift to collaborative innovation: The automakers continued to dominate design and development in the global supply chains they created.

This hierarchical disintegration began to give way to increasingly collaborative relations after the turn of the century; and the process picked up speed as the global economy recovered from the financial crisis. As with the oil producers in roughly the same period, the automakers' inability to keep abreast of the proliferation of transformative innovations ultimately undermined

hierarchical control over technology in the supply chain. The growing importance of microprocessors in engine control and safety equipment such as airbags and anti-lock brakes, for example, made them increasingly dependent on novel technologies beyond their ken, and therefore on collaboration with outside suppliers who had mastered them. More recently collaboration with battery makers and the producers of other key components for electric cars crystallized the changing relation between the automakers and their suppliers. Whereas the supplier's traditional aim was to win the preference of one major customer, the situation is now reversed. It is the buyers who must compete for the preference of capable suppliers. As one manager puts it, becoming the supplier's 'customer of choice is increasingly an imperative' to assure the partner's best efforts in collaborative innovation (Trebilcock, 2017, 21).

... and in Pharmaceuticals

Where the shift to collaborative innovation came incrementally in oil and autos, in pharmaceuticals it came almost explosively, as the result of a technology shock. Large pharmaceutical firms built in-house research laboratories to improve the commercial production of penicillin before and during the Second World War. After the War these facilities were used to screen natural and chemically derived compounds for potential therapeutic activity. Progress in physiology, enzymology, cell biology led to deeper understanding of the biochemistry and molecular biology of many diseases, and insight into the mechanism of action by which some drugs achieved their effects: Random screening gave way to 'guided search' and 'rational drug design' as the precepts of investigation, but research continued to be highly centralized in large pharmaceutical companies (Malerba & Orsenigo, 1992).

It was the following wave of innovation, in genomics, genetic engineering as well as molecular biology, that, from the late 1970s on, ended the dominance of the internal research units and opened the way to collaborative investigation. The new science made it possible to grasp with much greater precision – though still incompletely – the chains of biochemical reaction by which particular cancerous tumours propagated, or sheltered themselves from immunological defences – and to devise counterstrategies. By the 1990s, universities, public research organizations,

venture capitalists, and successive cohorts of new biotech firms were collaborating and competing with multinational pharmaceutical corporations to develop and produce the new technologies.

Powell and his collaborators have used network analysis to trace the rapid evolution of the ties (including research and development collaborations, financing, and commercialization and licensing arrangements) among these various actors from 1988 to 1999 (Powell et al., 2005). In the early period there is a relatively clear division of labour. Small biotech firms, often start-ups, do innovative research; multinationals and first-generation biotech firms help finance the research and commercialize it by organizing the expensive tests on successively larger groups of human subjects needed to demonstrate the safety and efficacy of new drugs to regulators. There is a continual flow of 'new entrants as progress is made along a broad scientific frontier in which no single organization can develop a full range of scientific, managerial, and organizational skills' (Powell, 2005, p. 1188). As time goes on the actors with the most connections, at the centre of the network, are those with the most diverse set of collaborations, suggesting 'an open elite, accessible to novelty as the field expands' (Powell, 2005, p. 1189). The 'large' players, in other words, do not become central because of the number of their connections, but because they are good at playing, collaboratively, with others.

Leading figures in the oil and gas industry have noticed these trends toward vertical disintegration and increasingly close collaboration with suppliers and urged their peers to learn from them. A former chairman and CEO of Schlumberger, for instance, remarked recently that firms in the automobile and mobile phones industries had been quicker than firms in his own to 'recognize their subcontractors are an essential part of the product or product development, and involving them in a closer partnership relationship is an essential competitive advantage' (Finding petroleum, 2012).

As we will see in the next section this is just the direction in which contracting with suppliers in the oil and gas industry is going.

Contracting for Innovation

The sociology of work and industry is congenitally suspicious of contracts or formal agreements as descriptions of how work is done. A finding so common that it became an assumption is that even the most apparently routine tasks can only be accomplished by informal adjustments unforeseen in the instructions for the job (Fox, 1974). Because this is so, following rules to the letter is, as trade unions discovered, an ingenious strategy for stopping work while complying with formal obligations. Companion research in law and society found similarly that contracts between small and medium-sized firms are often a mere formality (Macaulay, 1963). When disagreements arise the parties react on the basis of shared norms of reciprocity – trust – inflected by understandings of their own history of past dealings. The contract stays, forgotten, in the drawer.

This research implies that as uncertainty increases, and with it the need for collaboration under unforeseeable circumstances, trust will become more important as the foundation of cooperation, and contracts even less. Thus successful collaboration between Japanese automakers and their suppliers – instead of vertical integration – was often attributed to a national culture of reciprocity that mitigated the risks of opportunism (Holstrom & Roberts, 1998). Conversely it has been argued that the continuing failure of US automakers to adopt the plainly superior Japanese methods is rooted in the persistence in the US industry of an unwritten, relational contract – a de facto social pact – that grew from old practices and obstructs introduction of new ones (Gibbons & Henderson, 2012; Helper & Henderson, 2014).

But there is paradox here too. As the trajectories of technological development become less predictable, and results in one domain prove applicable far afield, collaboration will often be between near strangers, who presumably do not share social norms. ‘open elite’ at the centre of the biotech networks – the most detailed picture of collaboration under uncertainty that we have – succeeds because it remains ‘accessible to novelty as the field expands’ – committed to seeking out and working with promising strangers. As the level of uncertainty rises, moreover, the nature of tasks change and past performance is a poor predictor of the capacity to meet new obligations. Established partners may intend to meet their responsibilities, but be unable to do so. The very uncertainty that makes collaboration more important thwarts not only traditional contracting but also pre-contractual reliance on social norms as a coordinating mechanism as well.

The novel contracts and contract governance mechanisms (we explain the difference in a moment) emerging in the oil, biotech and automobile industries are an apparently successful legal adaption to the new constellation of requirements. Compared to unspoken relational contracts they are remarkably formal. They require the parties to set general goals; define milestones on the way to them; review interim results regularly to identify problems, redirect efforts to revised goals – and perhaps abandon the project. In egregious cases of ‘red-faced cheating’ – secretly channelling the ongoing results of collaboration with an external partner to a parallel internal research unit – courts will sanction breaches of the agreement.

But compared to traditional contracts they seem like informal arrangements, not contracts at all. The parties’ only obligation is to collaborate without engaging in red-faced cheating. Neither party must produce any determinate result, either in the course of the collaboration or, *a fortiori*, at the end of it. Even collaboration that results in a potential product creates no further obligations. The buyer will have an actual or *de facto* option to purchase the result, but can choose not to exercise it (in which case the seller will have actual or *de facto* option to make use of the product.)

How can such non-binding agreements further collaboration under the demanding conditions of uncertainty? The answer is by using the formal requirements of explicit collaboration to generate the informal norms that make mutual dependence under changing circumstances workable and tolerable. The information exchanged under the formal contractual provisions allows the parties to evaluate one another’s capacities and good faith – to observe if the capable stranger can become a reliable partner and the trusted partner is capable of new tasks – while simultaneously evaluating the prospects of the particular project and joint efforts generally. As collaboration progresses each party relies increasingly on the capacities of the other, deterring opportunistic defection even in the absence of an explicit commitment to purchase anything in advance. In this way the formal contractual obligations – regular review and deliberate consideration of the interim results – create the conditions in which informal norms and self-interested calculations bind the parties to continue promising collaboration in good faith. Because they have the explicit aim of encouraging collaboration whose outcome cannot not be defined in advance, we will call contracts of this general kind contracting for innovation (Gilson, Sabel & Scott, 2009).

Pharmaceuticals

As the shock of technological innovation came earlier and more abruptly in pharmaceuticals than in oil or automobiles, it is not surprising that contracting for innovation is most developed there. In a typical agreement, a large pharmaceutical company with, say, expertise in a particular pathology's metabolic pathways, collaborates in a search for therapeutic compounds with a small biotech company that has developed tools for identifying molecular classes likely to correct the metabolic defect without producing toxic side effects. If a promising compound is found, the large pharma company takes charge of clinical testing and other regulatory obligations.

Typically the agreement provides for a research period of roughly a year, which may be extended by agreement of the parties, to fully explore the possibilities of a solution. During this period the large firm will usually pay the smaller partner's research costs, and make additional payments for achieving agreed milestones. The agreement allows for searching, and joint evaluation of the research results, yet avoids deadlock and protects both parties against opportunist use of the findings – without creating a binding obligation to produce any result at all.

A key institution created by these agreements is a joint research committee, composed of three or so managers or researchers from each of the partners, all directly involved in the project. This committee recommends continuation of the project, or not, during the research period, or extension of the work after the anticipated endpoint. Recommendations to continue require unanimity, so committee members with doubts about the project can easily request further information. In case of deadlock decisions are escalated to a high manager in each company. Knowing little of the day-to-day operation of the project, these managers decide its future on the basis of the record produced by the committee's deliberations. Holdouts who object without clearly demonstrable reasons run the risk of being disavowed by their superiors -- a prospect that deters self-interested obstinacy. If the big pharma company disregards the committee's recommendation for commercial reasons the agreement bars it from pursuing further similar research for an extended period. The pharma company has an option to purchase the rights to further development (paying a license fee to the biotech firm in case of ultimate success). If the

pharma company does not proceed, the biotech firm has a matching option to acquire the development rights at a lessor cost.

The US Auto Industry

The shift towards systematic collaboration came in the US auto industry not through revision of the terms of the contracts – which have remained lopsidedly in favour of the buyers for decades – but rather through the introduction of a new contract governance regime: rules for reciprocal performance review and procedures for responding to the problems and opportunities detected that together transform the effective operation of the underlying agreement.

Until very recently US automakers, we saw, shifted all risks to suppliers, while buffering themselves against disruptions of supply. The ‘blanket order’ or master contract is used to assign the risk. Under a blanket order the supplier agrees to provide a specific part, at an agreed price. But the blanket order does not obligate the buyer to actually purchase anything. That obligation is created only when the automaker issues, often month by month, a purchase order for a certain number of parts, at the agreed price, for delivery during the following period. The supplier thus absorbs all the costs of fluctuations in demand (Macaulay, 1974). These practices survived the oil price shocks of the 1970s and the vertical disintegration that followed (Ben-Shahar & White, 2005).

But under the surface there was change. Japanese transplants’ success working with US suppliers demonstrated both the benefits of collaboration and domestic firms’ aptitude for it. Moreover, the differences in buyers’ capacity for and dedication to collaborative problem-solving and improvement – and their willingness to share the resulting gains – were becoming public knowledge. By the turn of the century suppliers plainly preferred some buyers to others. Beginning in 2001, an annual survey of suppliers’ experience with their customers was used to produce the Supplier Working Relation Index (SWRI), which publically ranks buyer performance..

As the pace of technological innovation accelerated after the financial crisis, and with it the need for collaborative innovation with capable suppliers, GM – at the bottom of the SWRI rankings – deliberately decided to establish itself as a reliable partner or preferred customer. Adding contractual language obligating the parties to make their best efforts in collaboration was impractical. Except in egregious cases, GM would not be able to verify to a court that a supplier had stunted in its efforts or withheld (emergent and tentative) understanding of technological prospects.

Instead GM introduced an information exchange regime, resembling the one centred on joint project committees in biotech, that makes the parties' capacities and intentions easily observable, even if not legally verifiable. In the new governance regime, GM gives suppliers monthly reports comparing target and actual performance on current operation measures such as quality and material cost, and annual reports on measures of collaborative performance such as responsiveness and engineering. Suppliers review GM in the same way. This regular, mutual review promptly alerts each party to the other's problems and allows both to make informed evaluations of the responses.

These measures produced a turnabout in GMs standing as a buyer, moving it from tied to last in the SWRI rankings to within striking distance of the leaders, Toyota and Honda. GM improved moreover in 5 of the 6 procurement areas included in the survey, providing further evidence of corporate-wide change (Henke, 2017). As the ratings rose, suppliers reduced their selling prices to GM, indicating that the new relation was yielding mutually beneficial efficiency gains (Trebilcock, 2017).

These results suggest that the information exchange regime, based on mutual monitoring, is the engine of contracting under uncertainty. The traditional system of non-binding, long-term blanket orders and binding but short-term purchase orders continues as it has historically. Unwritten, relational contracts cannot, by their nature, change in the short term. The only significant change in the relation between GM and its suppliers – and the most plausible explanation of improved collaboration – is the introduction of a highly formalized regime for continual reciprocal review, designed to induce, and braid with, informal mechanisms for resolving eventual disagreements – contracting for innovation.

Contracting for Innovation in the Norwegian Oil Industry

As noted at the outset, changes in the methods and organization of the oil industry generally, and in Norway in particular have been incremental. There was no single technological shock equivalent to the eruption of biotech in pharmaceuticals or the advent much more recently of electric cars in the auto industry. But cumulatively incremental change has produced wave after wave of reorganization in the oil industry, with corresponding changes in the forms of contracting, though earlier forms often coexist with later ones.

For the sake of exposition we divide oil operator - supply/service company developments from the 1980s to the present into three periods: an initial phase of vertical integration in our expanded sense of the term, where the operators direct the suppliers; a turn, beginning in the mid-1990s, to turnkey contracts, where a lead supplier or general contractor takes responsibility for coordinating the work of the others; and most recently, as recognition grows that the initial or front-end designs increasingly determine the economic viability of demanding projects, formalization of this stage of the design process in FEED contracts as a distinct, standalone and open-ended collaboration between the operator and a qualified partner. It is in this third and most recent phase of development, as the parties deliberately explore innovative solutions to highly specific problems without committing themselves to executing the project together, or to proceeding at all, that contracting for innovation comes to the oil industry.

In the first, vertical integration, phase, in the 1980s, the operator's engineering staff produced a technical description of necessary equipment. An outside engineering firm drew up detailed drawings based on this description; the operator then put the drawings out to bid, selected suppliers, and scrupulously monitored the execution of the plans, modifying them when necessary. To minimize the burdens of supervision and coordination major components were built sequentially, in the order of installation (Nelson & Braadland, 2014).

Nominally contracts fixed the relations between operators and suppliers. But given the inherent uncertainties of the situation – the limits to the *ex ante* specification of the final product; great imprecision in the estimation of design and production costs; and the difficulties of tracking and

measuring performance – these were, as Stinchcombe observed in a well-known study at the time, legal hybrids or ‘chimeras’ – contracts as hierarchical documents (Stinchcombe, 1985). Though the agreements spoke in the language of prices and incentives familiar from contract, they included provisions for adjusting the costs, prices and quantities agreed as circumstances changed, while imposing the buyer’s standard operating procedures on the supplier and providing for internal dispute resolution mechanisms in case of disagreements. The result, Stinchcombe found, is a relation between supplier and buyer that looks ‘very much like a hierarchy’ – an extension of the buyer’s internal order to the outside party – and very little like the arm’s length dealings typical of contracting in a competitive market (Stinchcombe, 1985, p. 126).

The ‘supervisory’ role of the operator was most burdensome in the requirement that its engineering staff approve the work of the supplier’s engineers. In the most extreme cases nothing escaped review. ‘Sketches, drafts, preliminary specifications and drawings, final specifications and drawings, tender documents, technical evaluations of the bidders’ replies, technical changes proposed after contract start, and costs for all of these’, Stinchcombe found, ‘all have to be approved by the client’ (Stinchcombe, 1985, p. 157). These procedures, costly in themselves, also obscured responsibility for any decision. So complete was the system of approvals, Stinchcombe observed, that ‘every step on the way to an engineering contractor’s default has been approved and/or caused by a client directive’, making ‘the contractor’s responsibility for defaults very difficult to prove in court’ (Stinchcombe, 1985, p. 154). The very provisions of the contract that made them useful as instruments for collaboration under uncertainty rendered them useless as formal contracts.

This vertical integration model was workable, barely, so long as the price of oil was high and developments on the NCS was in some measure subsidized by infant industry protections. By the early 1990s, as competitive conditions tightened, the government convened major actors in the oil and gas industry, including the main trade association representatives of leading firms and regulatory authorities to investigate structural problems in the industry and suggest solutions. In addition to proposing the development of new technical standards for all firms operating on the NCS, this forum suggested a radical reform of supplier relations and the associated forms of contracting, which rapidly took hold.

The new turn-key model, and the engineering, procurement and construction (EPC) contracts in which it was embodied was in many ways the reverse of the previous one. Instead of selecting a series of suppliers, one after another, and carefully monitoring each as it executed detailed design drawings, the operator in the EPC model entered a single, comprehensive agreement with a capable systems integrator. The systems integrator then assumed responsibility for many of the tasks that had fallen to the operator in the vertical integration model: developing detailed plans from the functional specification of equipment requirements, selecting suppliers and supervising their work. Execution was now simultaneous, not sequential, so the systems integrator had responsibility for coordinating relations among suppliers with complementary tasks as well.

The EPC contracts seem to have contained the escalating supervisory costs of the vertical integration model, but the turn-key approach had limits of its own. Few systems integrators were capable, diversified and deep-pocketed enough to assume the risk of managing extremely large, complex and uncertain projects, even with the addition of contractual provisions limiting their liability to some share of the total project costs. The limited competition for EPC contracts reduced the pressure on those firms that did enter bids to keep prices low, and especially to contain demands for large risk premiums as a protection against costly, unforeseen developments (Nelson & Braadland, 2014).

The costs of uncertainty have proven to be an ongoing source of consternation in EPC contracts. Precisely because the systems integrator is in control of the project from early on, detection of what the operator sees as problems may be delayed; and delay can substantially increase the costs of modifications and trigger recriminations about liability. The standard form EPC contracts therefore elaborately specifies the system integrator's obligations to notify the client of difficulties in order to escape or limit liability – an indication that the 'supervisory' problems of the hierarchical model had been transformed, not definitively resolved (Beidvik, 2011).

In practice the operation of the EPC contracts seems to depend, as the older sociology of industry would lead us to expect, on the prior relations of the participating firms and the *ad hoc* governance arrangements they create to manage particular projects. When the participants are familiar with each other and on easy terms – when trust is high – they may agree to form an 'alliance' or some other arrangement for pooling project experience, identifying problems and

devising joint solutions. When trust is low they may create multiple and competing governance mechanisms, which each participant or faction uses to advance its interest against the others (Olsen et al., 2005).

But these idiosyncrasies aside, as novel technologies are deployed in harsher and harsher environments on the NCS, EPCs appear to be reaching their limit as the master coordination instruments in large oil projects. Two related problems stand out. The opening ‘pre-project’ or FEED stage of development, where innovative, basin-specific solutions are thoroughly explored, is becoming increasingly important to a project’s overall success. A study of significant cost overruns and delays in large off-shore projects traced their cause back to deficiencies in this stage: Faulty or incomplete exploration of possible solutions evidently cannot be compensated by improvisation later; on the contrary, initial shortcomings cascade, increasing costs and delaying completion (Oljedirektoratet, 2013). But the skills needed for this initial, wide-ranging exploration are not obviously those of the traditional systems integrator. Indeed, as the range of technologies implicated in reservoir development increases, and thorough evaluation of them becomes more crucial to a project’s success, the less well equipped are traditional turn-key experts, with their habitual approaches to problems and long-standing connections to capable but not always the most innovative suppliers, to collaborate in, let alone lead, the decisive pre-project work.

The third and most recent development in contracting in the Norwegian oil and gas industry begins to address both problems in ways that recall the contracting for innovation models in pharmaceuticals and autos. The key change is to make FEED an independent project or group of projects, rather than a stage in an integrated EPC contract. Under vertical integration the operator was chiefly responsible for design decisions; in the EPC model the systems integrator has substantial, often decisive control. In this emerging third model, operator, integrator and specialized suppliers all aim to collaborate fully in investigating possibilities. FEED projects can be executed in sequence, with each project refining the more general design produced by the preceding one. They can be nested as well, so that a FEED project examining overarching designs gives rise to FEED evaluations of various components on which possible solutions will depend. Besides allowing for a more comprehensive and thorough canvass of alternatives, treating FEED as a standalone project helps reduce the likelihood that conceptualization of a

solution is subtly influenced by consideration of the capacities of the firms that will execute it. The commitment to collaborate in the search for solutions does not entail a commitment to act together on the results. Once a plan is devised, the operator is free to enter an EPC contract with the FEED partner, choose another turn-key provider, or oversee some aspects of the project directly while delegating responsibility for the others by entering one or more EPC contracts of limited scope.

To all appearances FEED projects have been proliferating in recent years, and are playing an increasingly prominent role in project design. Observers agree that they involve close collaboration between operators and FEED teams, often with participation of key specialist suppliers. ‘Early involvement’ and ‘tight collaboration’ with suppliers in the framework of a FEED agreement is credited with halving the capital costs of developing the Johan Castberg field in the Barents Sea, lowering the breakeven price of recovering oil in the reservoir from \$80 to \$35 per barrel (Barstad, 2017). Use of FEED contracts yielded similar reductions in capital expenditure in the giant Johan Sverdrup field in the North Sea, again because of the early involvement of key actors and improved handoffs from one stage of the project to the next (Statoil, 2013).

Though these results are suggestive, we still lack detailed accounts of the institutional mechanisms by which the collaborative exploration of uncertainty is organized. These might be set out in the formal terms of the FEED contracts, on the lines of the research agreements in biotech, or contained in the governance routines that determine how the contracts are applied in practice, as in the recent developments in the US auto industry. If, as we are strongly inclined to believe, the introduction and spread of FEED contracts in the Norwegian oil and gas industry marks a shift towards contracting for innovation, we would expect to see that collaboration depends not primarily on trust born of prior association but, instead, on the ongoing mutual review of performance and joint resolution of the problems this scrutiny reveals.

Conclusion: Turning the page in development economics?

That innovation in the Norwegian oil and gas industry closely resembles the pattern in automobiles and pharmaceuticals is further evidence, if more is needed, that it is time to turn the page in development economics and rethink the role of natural resources in growth. The idea that distinguishes development economics as a discipline is that manufacturing industry, alone among economic activities, allows, indeed induces the accumulation of general skills through learning by doing. Once firms in a developing economy enter the market for particular industrial goods, their productivity is assumed to inexorably increase, resulting in ‘unconditional convergence’ with the frontier of performance. In natural-resource based sectors and services, in contrast, innovation is infrequent and usually the product of breakthroughs by powerful, foreign actors, not local learning. It is a short step to the conclusion that natural resources, in the form of mineral deposits or arable land, are more often a curse than a blessing, stunting learning, subjecting a developing economy to the dictates of international capital markets and – in the case of oil bonanzas and the like – attracting waves of inward investment that discourage domestic manufacturing by raising wages and overvaluing the exchange rate.

The idea of unconditional convergence is literally history: it was true of earlier cohorts of industrializers, such as Japan and Germany, but it is not true of more recent ones, including China, a manufacturing giant (Diao et al., 2017). It is well established that industry plays a smaller role in modernization of developing economies today than it did in the past (Rodrik, 2016). It is a commonplace that entering many low-skill industrial activities leads nowhere. The notion of a resource curse has been refuted so many times that it will soon enter that intellectual nether world where ideas are invoked only to be rejected (Hallward-Driemeier & Nayyar, 2017).

But the study of innovation in the oil industry compels us to go further. The striking similarities between developments there – and by extension in other natural-resource based activities – and in very different industries, old and new, defy the claim that today, at least, there is any fundamental difference between them. In all, innovation is so pervasive and fraught with uncertainty that it can only be mastered by collaboration – and by collaboration institutionalized in similar ways.

These findings imply that the idea of natural resources as a separate compartment of activity is a false distinction. As the increasing rate and scope of recovery on the NCS shows, the application

of knowledge to natural resources produces new knowledge – and new resources. It is as misleading to think of those resources as given once and for all by a nature beyond our reach as to think of knowledge as renewing itself in a separate world of abstractions sealed away from material entanglements. Knowledge creates resources just as experience creates knowledge (Ville & Wicken, 2012; David & Wright, 1997).

This continuing to and fro between theoretical word and practical deeds today takes the form of collaborative innovation. Contracting for innovation is one of its principal instruments. It allows trusted partners to verify that the capacities they have are the ones needed, and to renew them if not; it allows relative strangers to build trust as they explore uncertainty together. It allows partners, old and new, to bind themselves legally without entangling cooperation in formalities that defeat collaboration. Contracting for innovation is thus a kind of flexible joint or connector that facilitates the recombination of the pieces of the learning economy across all sectors.

Taken together the breakdown in the distinction between natural resource based activities and the rest of the economy and the rise of collaborative innovation in response to increasing uncertainty make the prospects for development both more and less forbidding than development economics suggests. The conditions are more forbidding because there is no longer a manufacturing highroad to development – difficult perhaps to enter, but effortless to travel – and because trusted partners may prove unreliable while the need to rely on strangers increases. But the conditions of development are less forbidding because now there are as many paths to growth as there are areas of economic activity, even if none is an easy passage, and cooperation with strangers can be made less risky, and more likely to lead to trust than habit tells us.

Norway, by the quirks of its history, has been a pioneer in exploring the landscape of our new possibilities, and developments there, by turns surprising and predictable, help show us the way to make the most of them.

References

- Beidvik, O. (2011). Leverandørens varslingsplikter etter NF 07/NTK 07 konsekvensen av manglende varsel. MA, Faculty of Law, University of Oslo, 2011.
- Ben-Shahar, O. & White, J.. (2005). Boilerplate and economic power in auto manufacturing contracts. *Mich. L. Rev.* 104: 953.
- David, A.P. & Wright, G. (1997). Increasing returns and the genesis of American resource abundance. *Industrial and Corporate Change* 6(2): 203-245.
- Diao, X., McMillan, M. & Rodrik, D. (2017). *The recent growth boom in developing economies: A structural change perspective*. No. w23132. National Bureau of Economic Research.
- Fox, A. (1974). Beyond contract: Work, power and trust relations. *Faber & Faber*.
- Gibbons, R. & Henderson, R. (2012). Relational contracts and organizational capabilities. *Organization Science* 23(5): 1350-1364.
- Gilson, R.J., Sabel, C.F. & Scott, R.E. (2009). Contracting for innovation: vertical disintegration and interfirm collaboration. *Colum. L. Rev.* 109: 431.
- Hallward-Driemeier, M. & Nayyar, G. (2017). *Trouble in the Making?: The Future of Manufacturing-led Development*. World Bank Publications, 2017.
- Helper, S., & Henderson, R. (2014). Management Practices, Relational Contracts, and the Decline of General Motors †. *Journal of Economic Perspectives*, 28(1), 49–72.
- Holmstrom, B. & Roberts, J. (1998). The boundaries of the firm revisited. *Journal of Economic perspectives* 12(4): 73-94.
- Leonard-Barton, D. (1995). *Wellspring of knowledge*. Harvard Business School Press, Boston, MA.
- Macaulay, S. (1963). Non-contractual relations in business: A preliminary study. *American sociological review*: 55-67.

Macaulay, S. (1974). The Standardized Contracts of United States Automobile Manufacturers. 3-21 *Int'l Encyclopedia Comp. L.* 18.

Malerba, F. & Orsenigo, L. (1992), Regularidades en las actividades de innovación: una investigación preliminar para cuatro países europeos. *Ekonomiaz*, 22(01), 10-29.

Nelson, T. & Braadland, M. (2014). EPC som kontraktstrategi i offshore-prosjekter [EPC as contract strategy in offshore-projects]. *Magma* 2014.

Nurkse, R. (2009). *Trade and Development*. Vol. 1. Anthem Press, 2009.

Olsen, B.E., Haugland, S.A., Karlsen, E. & Husøy, G.J. (2005). Governance of complex procurements in the oil and gas industry. *Journal of Purchasing and Supply management*, 11(1): 1-13.

Perrons, R. K. (2014). How innovation and R&D happen in the upstream oil & gas industry: Insights from a global survey. *Journal of Petroleum Science and Engineering* 124: 301-312.

Powell, W.W., White, D.R., Koput, K.W. & Owen-Smith, J. (2005). Network dynamics and field evolution: The growth of inter-organizational collaboration in the life sciences. *American journal of sociology*, 110(4): 1132-1205.

Rodrik, D. (2016). Premature deindustrialization. *Journal of Economic Growth*, 21(1): 1-33.

Stinchcombe, A. (1985). Contracts as hierarchial documents. Stinchcombe, A. & Heimer, C. (eds.), *Organization Theory and Project Management*. Bergen, Norway. Norwegian U. Press.

Trebilcock, B. (May/June 2017). How They Did It: Supplier Trust at General Motors. *Supply Chain Management Review*.

Ville, S. & Wicken, O. (2012). The dynamics of resource-based economic development: evidence from Australia and Norway. *Industrial and Corporate Change* 22(5)

Additional sources

Barstad, S. (05.12.2017). Statoil bygger ut gigantfeltet til halv pris [Statoil building on giant field for half price]. *Aftenposten* (News media). Retrieved 26.02.2018

<https://www.aftenposten.no/norge/i/P390mb/Statoil-bygger-ut-gigantfeltet-Johan-Castberg-til-halv-pris>

Finding petroleum. (07.08.2012). Andrew Gould - take advantage of service industry competition. *Finding Petroleum*. Retrieved 26.02.2018

<http://www.findingpetroleum.com/n/Andrew-Gould-take-advantage-of-service-industry-competition/07029379.aspx>

Henke, J.W. (15.05.2017) 2017 N.A. Automotive OEM Study Shows General Motors Jumps to Third Place, Nissan falls to last, in Supplier Relations. *CISION PR Newswire*. Planning Perspectives Inc. Retrieved on 9/26/17. <http://www.prnewswire.com/news-releases/2017-na-automotive-oem-study-shows-general-motors-jumps-to-third-place-nissan-falls-to-last-in-supplier-relations-300457268.html>.

Oljedirektoratet. (2013). Vurdering av gjennomførte prosjekter på norsk sokkel.

<http://www.npd.no/Global/Norsk/3-Publikasjoner/Rapporter/Vurdering-av-prosjekter.pdf>.

Statoil. (20.12.2013). Aker Solutions tildelt rammeavtale for prosjektering på Johan Sverdrup [Aker Solutions awarded framework agreement for engineering on Johan Sverdrup]. Retrieved 26.02.2018 <https://www.statoil.com/no/news/archive/2013/12/20/20DecFEEDSverdrup.html>.