Entering GVC Commodity-Based Industry Through Design and Engineering: Comparing Brazilian and Algerian Experiences

Abdelkader DJEFLAT

DIM – Maghtech – Clersé -CNRS 8019 University of Lille

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ABSTRACT

Natural Resources (NR) sectors in African economies have been crowding out manufacturing and domestic capacities in Design and engineering (D&E) still in their infancy stage but with important growth potential in most manufacturing activities. As a core component of the innovation capacity building process, D&E capacity is a crucial driver of industrial and economic development (Bell 2007). While the strategy is to move up the value chain and develop backward and forward linkages to the commodity sector seems within the possibilities of oil corporations, the manufacturing of industrial equipment needed for the sector has shown serious limitations. The chances to enter Global Value chains in NR-based industries seems remote for African oil Corporations making their Ttransformation of the industrial sector nearly impossible. This contribution examines first how the weakD&E capabilities resulted in major difficulties entering the GVC of NR equipment manufacturing. The aim to establish possible theoretical and conceptual linkages between all three components NR, D&E capacity building and GVC. A comparative study is made between the successful penetration of the giant Brazilian Corporation Petrobras and the oil company Sonatrach in Algeria and lessons drawn. A sample of companies is investigated in Core and non-core activities of the oil sector.

Keywords: Global Value Chain (GVC), Natural resources, Design and engineering, Sonatrach, Petrobras

INTRODUCTION

Recent global dynamics with rapid growth in BRIC countries and especially growth of manufacturing activities in China have triggered an increase in the demand for natural resources worldwide. This has been reflected in high rates of growth in several of the low-income countries highly specialized in natural resources. On top of this impressive growth of commodity export, the commodity boom in African economies has brought massive imports of technology in various sectors of industry, broadly defined, as we will see later. However, a closer analysis of the structural change and the pattern of economic transformation in the African countries raise critical questions about the sustainability of this phenomenon. Growth in Africa recorded for the last decade was predominantly based upon exports of hard commodities and on capital inflow in the form of transmittances and donors' support. It has not translated into the kind of broad-based economic and social development that is needed to lift millions of Africans out of poverty and reduce the wide inequalities seen in most countries (UNCTAD 2012). Published figures indicate that FDI in the Manufacturing sector in Africa for example did not exceed 26% of total FDI contributing very little to employment, with a loss in their share of global manufacturing output. Another conclusion is that income from export of natural resources has not been converted into knowledge assets shown by the R&D ratio as percentage of GDP for a sample of African countries and the emergence of innovation systems has met several constraints (Djeflat 2011). This situation is similar to natural resources (NR) based Latin American countries who failed to develop strong diversified economies as a result of a weak knowledge base and with an institutional set-up that did not support the processes of learning (Ferranti et al 2002) These include Venezuela, Argentina, Peru, Mexico, Colombia to mention few of them. Most of the negative impact observed relates to cases where there is export specialization in 'hard commodities' such as oil and minerals substantiated to some extent the "resource curse" belief. Yet both historical and current developments illustrate that it is possible to move from dependence on natural resources to a more diversified and knowledge-based economy as shown by Scandinavian countries such as Finland and Norway for example and that Africa could benefit from this unprecedented window of opportunity for learning and building economies driven by knowledge and innovative capabilities. The new era is also marked by further advancement of the global division of labor also when it comes to the production and use of knowledge and the issue of integrating Global Value Chain (GVC) dynamics is getting a great of importance for growth and development (Gereffi and Kaplinsky 2001). The new developments open up new opportunities for producers in Africa to link up with GVC but they make it even more crucial to build local capacity and to link local capacities to a innovation capabilities (Djeflat & Lundvall 2016). One of the strategies could be to move up the value chain and develop backward and forward linkages to the commodity sector exploitation as a core activity: this will no doubt maximize direct and indirect job-creation but the effects remain limited. The other strategy which is entering the GCV of non-core activity has much higher impact in terms of industrialization of the sector, diversification of the economy, in addition to employment creation and balance of payment surplus seems more sustainable. While moving into non-core activities may include different outsourced inputs, the Brazilian experience, through its Giant company Petrobras (Dantas and Bell 2011) signals that producing petroleum equipment needed by the sector is quite feasible and could inspire the commodity sector in Africa. Indeed, Petrobras has become world leader in oil and gas off shore equipment, using a GVC penetration strategy while operating, its NR sector in the conventional manner. This experience cannot be found in Africa whose oil and gas companies have reached significant experience and age: this is the case of NPCC in Nigeria, Sonangol in Angola, Star Africa in Ghana, and Petro SA in South Africa and SONATRACH in Algeria. the giant oil and gas company SONATRACH (ranked first company in Africa in 2022), while moving successfully in some downstream activities such as petrochemicals first find it difficult to move further in the GVC of its core activity and failed many attempts to move into producing equipment: 400 million US US dollars are paid annually for the acquisition of wellheads for example[1] and this has been going on for more than fifty years. A close look at the Brazilian experience shows that one of the key enabling factors was building design and engineering capabilities which interacting with knowledge networks. Identifying the policies and institutions that were conducive to promote engineering design capacity is a critical activity of the capacity building effort in the Brazilian experience seems critical. Comparatively, these capabilities seem to be missing in the Algerian company and in several others in Africa. Several questions could therefore be raised Meanwhile: How did the Brazilian company move into a non-core activity such as producing equipment and successfully penetrate the GVC? What was the role and the importance of D&E? What was the experience of Sonatrach to enter non-core GVC activities and what was the place of D&E? How could African countries diversify their economies through entering non-core industrial activities and could D&E facilitate this strategy?

To answer these questions, **our** methodology combines both a case study of the main petroleum company Sonatrach and a statistical analysis of a sample of firms which can be based upon a combination of desk and field research pursued by the author. The desk research involved looking at the broad literature on Sonatrach and mainly its published annual reports (websites of Sonatrach and the different subsidiaries, annual reports, and press releases). The fieldwork was undertaken in 2015 (between May and August). It involved ten companies: five were affiliates of Sonatrach in downstream core activities and five from partners from non-core lateral and downstream activities (see table 1). The sub-sample was made of 80% public sector, while 20% are private which give a bias towards the public sector and reflect the reality of the dominant posture of the public in the NR sector. A semi-structured questionnaire was used and direct face-to-face interviews conducted. The emphasis was put at the practice of DE at the enterprise level: Finally, it must be noted that this fieldwork is part of a much broader field work undertaken to assess

[1]https://www.algeriepatriotique.com/2017/03/15/lalgerie-va-fabriquer-des-equipements-petroliers/

the importance of the D&E in the Algerian industry (Djeflat 2015).

Table 1: List of companies in the sub sample

Name of companies	**Position in the value chain of NR**	**Sector**	**Status/ownership**
1- SDE (société de distribution de l'électricité et du gaz de l'est)	Non-core downstream	Electricity and gas distribution	Public
2. SONELGAZ	Non-core upstream and dowstream	Electricity and gas distribution	Public
3. ENIP – Sonatrach	Core downstream	Petrochemicals	Public
4. RMK – Sonatrach	Core downstream	Petrochemicals	Public
5. LNG- Sonatrach	Core downstream	Gas liquefaction	Public
6. RTE – Sonatrach	Core downstream	Oil refining	Public
7. PETROFAC	Core upstream	Petroleum engineering company	Public
8. TRAPTACT	Non-core downstream	Plastics and printing	Private
9. STE GENERALE GENIE MECANIQUE (SGGM)	Non-core lateral	Industrial engineering & Metallic construction	Private
10. SIDER	Non-core lateral	Fabrication of steel pipes for the oil industry	Public
Total :	10 companies		8 publics and 2 private

The author

Section 2 looks at the global value chain and Natural Resources sectors with a view of establishing possible theoretical and conceptual linkages namely in the face of a dominant literature on GVC and the manufacturing and distribution sectors. Section 3 examines in the specific role of Design and Engineering as an entry point into global value commodity chain (GVCC), and the linkages with learning and competence building in Africa. Section 4 examines empirically the case of building D & E in the petroleum equipment industry in Brazil and Algeria, focusing on the experience of the giant company Sonatrach and the difficulties met entering to the CVCC. Section 5 discusses the results before some concluding remarks.

Global Value Chain, Natural Resources economies and the learning process: conceptual framework.

Global value chain and Natural resources:

The value chain analysis developed by Gereffi and Kaplinsky (2001) indicates a new pattern of global interaction where firms in less developed countries can enter into value chains and use their participation to upgrade their knowledge base in all sectors, including sectors that exploit natural resources. Moving from exploitation of natural resources to manufacturing, packaging, distributing and branding can be described as "climbing the ladder". However, deepening capabilities to explore new original features and varieties at each stage of the global value chain is also important and clearly requires learning, creating and acquiring higher level skills and more complex technological capabilities (Pietrobelli and Rabelloti 2010). On this basis, the learning potential and the knowledge content in natural resource based sectors seems important and the creation of upstream and downstream manufacturing seems possible. Marin et al. (2009) analyze the recent and prospective forces driving innovation towards the "decommoditisation" of the natural resources themselves as well as the conditions that are making it more likely to weave networks of innovation up and downstream as well as laterally from the natural resource base, constructing a production and innovation network in non-core sectors.

The key difference between successful and less successful growth policies seems to lie in the nature of the learning process that promotes the economic potential of access to natural resources (Wright 2013). A crucial issue is how natural resource related activities make use of and master new technologies and knowledge to improve production processes (De Ferranti et al. 2002). The notion of 'upgrading' has been very influential, above all amongst scholars and policy makers interested in the patterns of industrialization in developing countries (Ramirez 2018). Diversifying technological capabilities and skills base through integration into GVC, deepens industrial structure and opens up opportunities for lateral migration into other sectors. Thus resource-based industries export success stem not so much from high levels of initial skills and capital: it rests mostly on the strength of the kind of relationship with international partners. Governance patterns is crucial for understanding the opportunities for suppliers to move up the value ladder, moving from the low end to competitiveness, where competition is based mainly on price and squeezing wages, and the barriers to entry are low (Pietrobelli and Rabellotti, 2007, Morrison et al 2008). Gereffi et al. (2005) identify five modes of GVC governance: markets, modular, relational, captive, and hierarchy (figure 1).

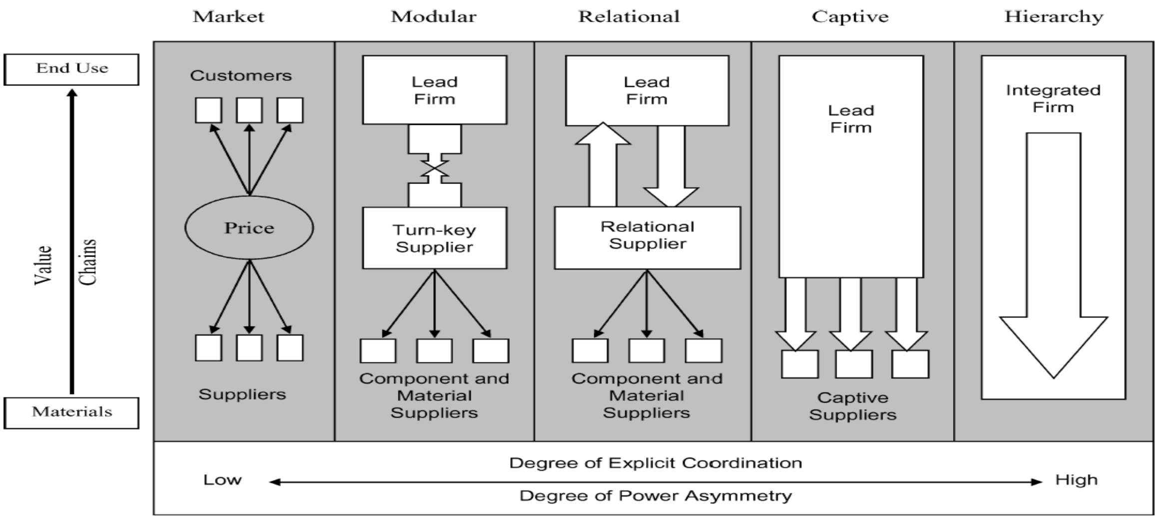

Figure 1: Stylized linkage patterns/governance and types of value chains

Source: Gereffi, Humphrey, and Sturgeon (2005:89).

Often the relation of LDC firms with Global VC players is arm's length. Inclusion in a GVC provides information about the global market's requirements in terms of products, processes, technology and standards. three types of GVC: arm's length, modular and relational GVC.

In modular, – lead firms put pressure on their suppliers to innovate and keep abreast of technological advancements but do not become directly involved in the learning process. It is a buyer driven process. This requires an understanding of learning processes at three different levels: 1/ the learning process for upgrading the knowledge base within natural resource based industries (micro level) 2/ The learning processes allowing industrial transformation and diversification through the development of upstream, downstream and lateral activities (meso/network level) and 3/ the policy learning to tackle the 'the Dutch Disease' and institutional weaknesses in terms of rent seeking (macro/institutional level) (Djeflat & Lundvall 2016).

In captive chains, lead firms intervene actively in the learning processes of suppliers that lack competencies, but their support is usually confined to a narrow range of tasks such as simple assembly (Pietrobelli and Rabelloti 2010). In this case, there is a risk that the suppliers will get locked into a position in the value chain because lead firms do not promote development of strategic, core capabilities within the smaller firms, and in fact sometimes prevent it (Djeflat 2001). However, this does not prevent learning through spillovers and imitation, which allow small LDC firms to capture the knowledge about adaptive change and innovation needed to stay in the value chain. Pietrobelli and Rabelloti (2011) argue that the governance of the GVC influences how learning takes place, and different mechanisms of learning and innovation are likely to dominate in different types of chains.

The challenge is not always about moving into more advanced functions but is often about deepening the specific capabilities required to explore new opportunities in the value chain stage in which the firm is currently engaged (Morrison et al., 2008). It implies acquiring new, superior functions in the chain, such as design and engineering which are higher-value-added activities[2](Schmitz 2004) that and this depends on firms capabilities to make investment in design, engineering and product development. However, the demand for entering GVC remains also important. Some may argue that Small and medium countries have no interest at entering GVC and no positive correlation is found between GVC participation and growth of employment in exports (Hardman 2020). Other ways of learning and having access to GVC is through international networks OECD (2013) which contributes upgrading capabilities. These networks take the form of knowledge and innovation networks (GIN). GIN refers to new ways in which MNCs are organising their value-adding processes across organizational and international borders (Dunning and Lundan 2008; Cantwell 2017) The growth of knowledge-seeking technological alliancesre presented a significant change in the strategy and management of innovation; (Teece 2010, Ramirez). For developing and emerging countries it is often easier to penetrate a GVC through networks activities than building a complete value chain.

GVC and Design & Engineering in NR economies

The importance of Design and Engineering in penetrating GVCs.

The importance Design and engineering (D&E) activities constitute what might be considered the 'core' of STI systems in advanced industrial economies (Bell 2007).

The importance of engineering to a country's development is stressed by Grochocki et al. (2018) could be indicated by the research efforts made in D&E; It is apparent that with the exception of Brazil and Mexico, the 15 largest economies in the world are those that publish the most in engineering. The constant use of external engineering and consultancy services, and the marginalization of the local competencies, namely of the university and local research centres, have greatly contributed to that situation (Djeflat and Lundvall 2016).

The D&E is an important stage in the Innovation capabilities issue. It often comes through an upgrading process. Several attempts have been made to categorize D&E functions: As stated by P. Intarakumnerd[a] and T. Virasa (no date specified), in newly industrializing countries, other capabilities such as acquisition and absorptive capabilities, investment capability, and adaptive and design capability are more important than R&D. Strengthening the knowledge base in fields of D&E and promoting learning may be seen as a pre-requisite both for building strength in the natural resource based industries and in manufacturing in general. This simple reality has not been clearly perceived by African countries as in other parts of the Developing World until recently (Bell 2007). This has led gradually to wide gap between advanced and LDC economies with regards to D&E capabilities. Those manufacturers who have had the chance to integrate global value chain seem to have good prospects for upgrading their design, marketing and branding as a combination of learning by exporting and organizational successions. John Humphrey and Hubert Schmitz (2002) distinguish four stages 1/Assembly of imported goods 2/ more domestically integrated goods (Original equipment

[2]The other types of upgrading include process upgrading is transforming inputs into outputs more efficiently by reorganizing the production system or introducing superior technology; product upgrading is moving into more sophisticated product lines in terms of increased unit values;

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manufacturing: OEM) 3/ designing products sold under the brands of foreign supplier and 4/ Designing products under original design manufacturing (ODM) through the integration of manufacturing expertise and design of own brand name expertise. This indicate that D&E play a key role in the GVC strategy. As an illustration, East Asian and Pacific Garments manufacturers for example moved from mere assembly of imported inputs to selling and branding their own merchandise for both internal and external markets relatively easily using abenign escalator type using Bell's expression[3]. More difficult was the move into designing their products and selling them under their own brand name (Fig.2) They had to overcome relatively high barriers of entry into DE as a component of the GVC. Johnson (2014) argues that lead firms usually TNCs exert more power in the distribution of value creation and because such upgrading encroaches on their core competencies.

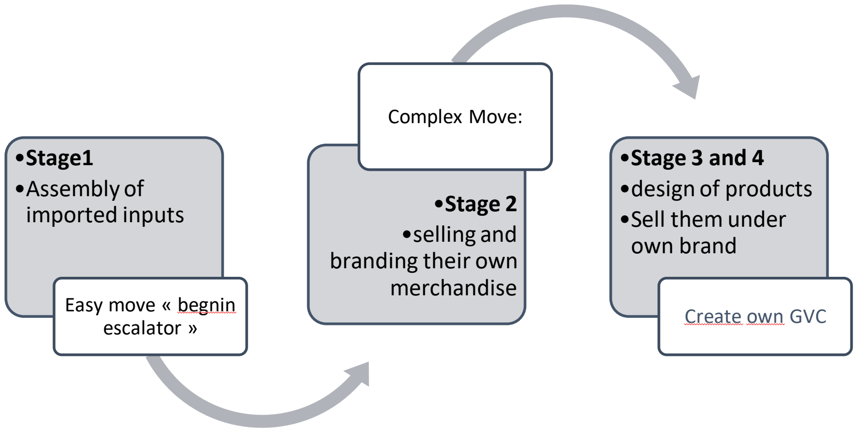

Figure 2 : From the easy upgrading « begnin escalator » to more complexe move

Source: the author drawn from Hubert and Smith (2002) contribution

With these conceptual tools and theories, let us look how Natural Based industries in Africa could enter a new era of GVC access and growth.

GVC, Design and Engineering and the NR based industries in Africa.

Several studies have come out with some results of the D&E in Africa namely the Africa technological Gap, (UNTACD 2003), The African technological outlook (IDRC 2011) and other studies on STI in Africa. They all conclude that there is little D&E and that capital goods and design engineering are almost all foreign. Often, passive imports of equipment with relatively simple use with low levels of technical efficiency, while the role of foreign skills remains dominant. A general fact is that Industrial engineering as a distinct function to enter GVC is often absent. The lack of local research and design capability is one factor keeping African producers at the bottom of the quality chain, and outside complex product segments.

Few attempts were made in Africa in the seventies in some NR economies to disembody the D&E component from the technological package and integrate progressively the GVCC (Global Value Commodity Chain) (Djeflat. This situation has been changing substantially in the last decade with the restored growth: it is increasingly common for firms to participate in a GVC to access knowledge and learn how to innovate. To satisfy requirements related to product quality, delivery time, efficiency of processes, environment, labor and social standards imposed by a GVC firms specialized in different functions have to learn and innovate (Pietrobelli and Rabellotti 2010). This is happening most of the time in other sectors than the commodity ones. These dynamic Industrial non-NR sectors in Africa now include according to Nepad/APCI both traditional manufacturing and more advanced or high technology sectors such aeronautics, pharmaceuticals, digital industries etc. In spite of this remarkable progress over a relatively short period, several issues remain pending: excessive dependency and exclusion from GVCC in particulars (Unctad 2012).

[3]The term 'benign escalator' was used by Martin Bell in research meetings at SPRU and IDS.

Empirical evidence from the oil sector: the case of Petrobras and Sonatrach

As mentioned at the beginning, and in the absence of important work on the specific topic of D&E and GVC, we resorted to look for best practices in the developing world in order to learn by comparing. Petrobras through its explicit upgrading of D&E and highly successful strategy to penetrate the petroleum equipment and high tech services appeared to be an ideal case. We will look at Petrobras inn the first section and at Sonatrach case in the second section.

The case of Petrobras (Brazilian Petroleum Corporation) and the successful integration of NR based industries in GVC: the role of D&E.

The giant oil Brazilian oil company, Petrobras, is chosen not only because of its size and important which are similar to Sonatrach in Algeria, but also for the strategy it developed, almost unique in the Developing World to enter the GVC on the production of offshore oil equipment through the knowledge networks at the international level with the objective of developing domestic capabilities for the production petroleum equipment. While roughly starting in the same position as Sonatarch and many other NR corporations in the South, it has been successful in establishing itself as world technology leader in oil related technologies. Petrobras was created in 1953 ie: ten years before Sonatrach. Through Petrobras, Brazil is the only Latin American country to feature among the 20 most competitive countries in engineering, having been recognized for its strong engineering. Petrobras has implemented the "Deepwater Oilfield Exploitation Technology Innovation and Development Plan" since 1986, and formulated a detailed deepwater oil and gas development technology development plan.

Put in a historical perspective (Fig. 3), the Petrobras case shows the gradual building up of a successful GVC penetration in non-core industrial activities: namely production of advanced drilling equipment in deepwater seas. While it does not use a conventional GVC penetration strategy, its network penetration, can serve as a proxy to benchmark the research undertaken in this work. Examining in depth Petrobras, Dantas and Bell (2011) show that it went through several stages up to success: The first was stage was Passive Learning Networks: where the associated technological accumulation activities focused on assimilating acquired methods, equipment, services and operational know-how. Flows of essentially knowledge were largely unidirectional from suppliers to Petrobras, followed by bidirectional flows of operational knowledge between the company and partners. The division of labor in knowledge production between Petrobras and partners was highly imbalanced and asymmetric, with key R&D and basic design activities externally-located at partners level. The second stage was Active Learning Networks, where the changes involved pursuing the development of networks with the deliberate intention of strengthening corporate learning and seeking such relationships with supplier companies. Flows of more complex design and scientific knowledge, though predominantly one-way flows from partners to Petrobras. However, there was also a shift towards greater participation in knowledge production through arrangements whereby Petrobras' personnel learned from partners to do more complex technological activities. In the third stage Hybrid Forms took place involving some elements of Active Learning Networks and what we describe as Innovation Networks. Managers sought to establish collaborations partly with a view to carrying out innovation to develop equipment for new deep-water conditions, but primarily and more importantly as learning vehicles to build up design skills and knowledge. These networks were concerned with learning by trial and error by undertaking joint development activities. They involved some bidirectional knowledge design flows between the company and suppliers, but flows from Petrobras to partners were limited, and the participation of the company in knowledge production was restricted. In the fourth stage, Pure Innovation Networks stage emerged in association with four technologies out of the only targeted initially. Managers initiated new collaborations that were explicitly intended as mechanisms for undertaking innovation, and they involved joint R&D activities with partners. These innovation networks were characterized by bidirectional flows of design and engineering, and scientific knowledge and by increasingly balanced and symmetric arrangements for joint knowledge production in which Petrobras and partners undertook specialized and complementary R&D activities. The fifth and last stage is called The strategic Innovation Networks. In the networks associated with these areas of technology, the direction of knowledge flows started to involve not only bidirectional flows and unidirectional flows from partners to Petrobras, but also reverse unidirectional flows of complex S&T knowledge from Petrobras to partners. The technological activities in networks consisted of joint not only R&D activities and participation in the R&D efforts of others, but also technology exchanges with major oil companies and reverse technology transfer to suppliers.

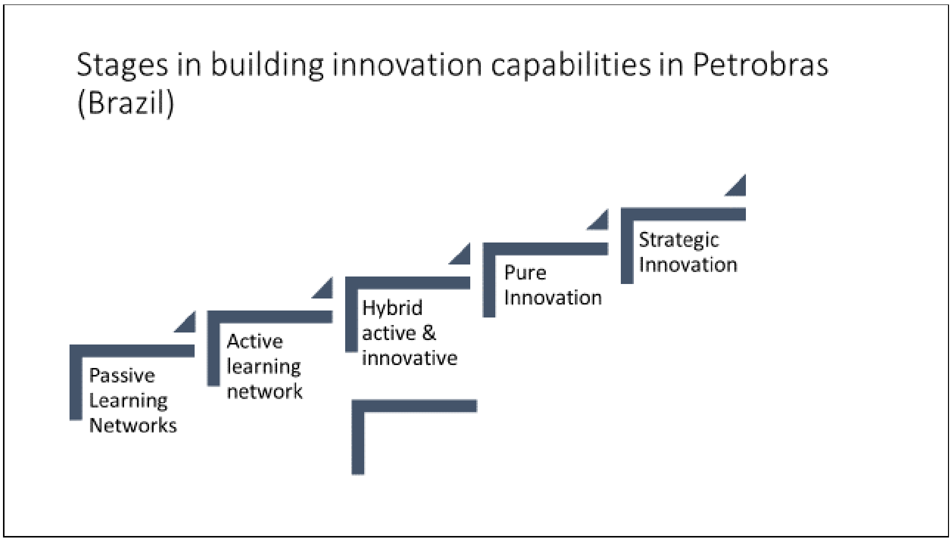

Figure 3: Dynamic approach in building competences in the penetration of GVC of Petrobras

Source: the author using material in Dantas and Bell (2011)

Table 2: Stages and components of the learning process in the D&E capacity building using the GVC approach

Stages in the learning process	**Design and engineering function**	**Learning, Innovation and competence building**
In the Passive Learning stage	basic design activities externally-located	Key R&D activities
Active Learning stage	Flow of a more complex design and scientific knowledge	Personnel learnt from partners
In the hybrid stage	-some bidirectional knowledge design flows - flows from Petrobras to partners were limited	Participation of Petrobras in knowledge production restricted
Pure innovation stage	- bidirectional flows of design, engineering,	-bidirectional flows and scientific knowledge - for joint knowledge production -specialized and complementary R&D activities undertaken jointly with partners
In the Strategic Innovation stage	-bidirectional flows D&E of knowledge - unidirectional flows from partners to Petrobras	Reverse unidirectional flows of complex S&T knowledge from Petrobras to partners.

Source: built by the author from the work of Dantas and Bell (2011)

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Looking more specifically at the D&E function, the stage in acquiring design capabilities, The example of Petrobras in Brazil shows different kinds of capabilities were mobilized throughout the period: 1/ Assimilative capabilities 2/ Adaptive capabilities 3/ Generative capabilities and 4/ Strategic capabilities. More specific to engineering, the company needed adaptation of technologies, own design and absorption of design S&T knowledge. It appears thus that the D&E capability started with active learning stage: In 1984, the company interacted with the training and research component. Thus, COPPE (The Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering) the Post-Graduate and Engineering Research Institute of the Federal University of Rio de Janeiro) was frequently used to obtain design knowledge and design tools relating to offshore structures (Active Learning Network). In the mid-1980s, it established internal engineering projects to master the design of semi-submersible platforms (Adaptive Capabilities).

This was followed by several projects that hugely expanded these internal adaptive efforts. It collaborated further with COPPE to obtain knowledge about the normal design configurations and design parameters of semi-submersible platforms throughout until it reached the strategic innovation stage. This was done through training, hiring experienced personnel, in-house technical services, learning by designing and establishing and formalizing R&D activities. (see table 3) As shown below, the engineering function is present in all research and training Programs with COPE. It is targeted towards the needs of Petrobras in terms of technological and scientific knowledge. Since its creation in 1970, the Copp Foundation has administered more than 12,000 contracts and partnerships with national and international, private and state-owned companies and governmental and non-governmental agencies.

Table 3: The structure and syllabus of both research and training at COPPE

Research lines	Ocean engineering Civil engineering	Dynamic Positioning, Underwater Robotics, Control Systems and Automation	Ocean engineering Civil engineering
Offshore Structures and Systems	Ocean engineering Civil engineering	Remote Sensing by Radar	Civil Engineering
Geoacoustics, Seismic Waves Propagation, and Acoustics in the Ocean	Ocean engineering Civil engineering	Computer Systems Oriented to the Oil Industry	Civil engineering Mechanical engineering
Structural Integrity in the Oil and Gas Industry	Ocean engineering Civil engineering Metallurgical and materials engineering	Ocean Floating Systems	Ocean engineering Civil engineering
Material to the Oil and Gas Industry	Ocean engineering Civil engineering Metallurgical and materials engineering	Oil Systems	Civil engineering

Source: Cope UFRJ https://www.coppe.ufrj.br/en/node/4217

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In recent years, the discovery of huge deepwater oil and gas reserves has intensified collaboration between Coppe and Petrobras in new engineering specialties. The result of these research and development activities has been transferred to society through three main channels: 1) The training of human resources; 2) The production and publication of scientific papers (including the organization of international conferences, such as the OMAE -Offshore Mechanics and Arctic Engineering conference in 2001 and 2012; and 3) conducting consulting, research and development projects. In 2018 it celebrated 15 years of the installation of the largest ocean tank in the world, designed and built by Coppe[4]. (Table 3)

Coppe's historic partnership with Petrobras has become a model of a successful partnership between companies and universities. What is fundamental is also the co-evolution of COPPE and Petrobas in knowledge production and knowledge implementation, all that driven by the real needs of the company.

To adapt, design and understand S&T principles, the company neededthe creation of design and R&D facilities and resources (Bell and Dantas 2009). Nonetheless, it is reckoned (Dantas and Bell 2011) that there were several examples of failed steps, limitations, and reverses in making the transition to new network forms in the absence of prior capability changes. Two types of mismatch seem to have given rise to such discontinuities. One type involved the tentative move to new network forms in the absence of prior in-house capabilities required for the more complex types of problem-formulation and problem solving in the more complex form of network.

The difficult penetration of NR based industry GVC: the case of Sonatrach in Algeria

Sonatrach (the National Company for the Research, Production, and Transportation, Processing and Marketing of Hydrocarbons and their by-products) was created in December 1963, it is fully owned by the State (100% equity) and it the third largest oil and gas company in Africa in 2022.

The company operates in exploration, production, pipeline transportation and distribution of hydrocarbons and by products. The Sonatrach group employs 200 000 employees (in 2022) [i].

The international strategy of the company includes operations in several parts of the world namely: in Africa (Mali, Niger, Libya, Egypt), in Europe (Spain, Italy, Portugal, Great Britain), in Latin America (Peru) and in the USA. With a export turnover of 60 billion US dollars in 2022, and invested 5.5 billion US dollars in the same year(ABN News 2023)[5].Sonatrach ranked first company in Africa and 12th in the world.

Sonatrach operates through several subsidiaries and shareholdings in various fields of the energy and mining sectors at the national level and worldwide. Sonatrach manages its subsidiaries through five Holdings bound to its Activities.

1/The Petroleum and Para-Petroleum Services Holding linked to Upstream Activity, 2/ The Sonatrach Investment and shareholdings Holding linked to Pipeline Transportation Activity, 3/ The Refining and Hydrocarbon Chemistry Holding linked to Downstream Activity, 4/ Sonatrach Hydrocarbon Valorization Holding linked to Marketing Activity and finally and 5/ Sonatrach External Industries Activities Holding (AIE) running Non-Oil activities.

Attempts to climb the GVC ladder.

Several efforts have been made throughout the period to enter GVC through several channels.

[4] https://www.coppe.ufrj.br/en/node/4217

[5] https://algeriebrevesnews.dz/2022-sonatrach-fait-le-plein-60-milliards-de-dollars-dexport/

Table 4: The diversification plan of SONATRACH through downstream activities in the Global value Chain.

Downstream Activities in GVC (6)	Construction companies : core-activities (3)	Core Oil/Gascore-services companies (6)	Non-core oil/gas services (3)	Oil equipment manufacturing (0)
Hydrocarbon refining and distribution: NAFTAL. (petrol and gas-oil) Petrochemicals industry) (ENIP). Plastics and rubber industry (ENPC). Fertilizers (ASMIDAL). Helios SPA (Helium) COGIZ (Industrial Gas)	ENGTP (Great oil works) ENGCB (Civil engineering and construction) (1998) ENAC (pipelines)	ENAGEO (Geophysics) ENAFOR&ENTP (Drilling) ENSP (wells service) ENEP (Oil Engineering dissolved in 2003) CERHYD (Hydrocarbon Research Center)	Compagnie des assurances des hydrocarbures CASH.SPA SOMIK (industrial Maintenance) SOTRAZ (Transportation)	Contract signed between and General Electric to produce locally oil/gas equipment (drilling/control) 2015

Source: Ministry of Energy and Mining – Algeria.https://www.energy.gov.dz/?article=liste-entreprises-secteur-hydrocarbures

Entering the Petroleum GVC (PGVC) through downstream core activities:

Through product diversification

Sonatrach managed to upgrade its capabilities through downstream core activities in the oil and gas sector. This diversification into the GVC made it possible to contribute to the increase exports of few MIG (manufactured Intermediate goods) and contribute to the balance of payments. Two types of MIG can be identified: those specific to oil and those specific to gas. The MIG specific to oil include oil refining for the production of petrol, fertilizers for agriculture such as ammonia, plastics and solvents, liquefaction, These activities are away from crude oil exporting. Those that are specific to gas include plastics and solvents, helium and ethylene, methanol and fertilizers[ii] .

Sonatrach entering the petroleum GVC went as far as creating joint ventures with foreign partners: this was the case of the production of MIG for the plastics industry notably through its propylene plant jointly owned with the German giant BASF with a capacity of 420,000t /year of Algerian propane for 12 years. More than 20 private companies were created in the plastics sectors in all parts of the country. This diversification along the GVC was closely linked to the product. It happened in a relatively concentrated way in the eighties as shown in table 2.

Downstream core activities include the development and exploitation of the natural gas liquefaction units, LPG separation and refining. Sonatrach had no difficulties in developing several of its down-stream activities. Increasing thus domestic added values: As a result, 17 companies were created in the five years plan 1980-85 in charge of both core and non-core activities. This was also part of the company diversification strategy.

As shown in table, From the oil production, it went into first transformation: 1/ and built installations for gas and petroleum liquefaction and for oil refining and the production of fuel for gas liquefaction plants (in Arzew and Skikda), two-petroleum liquefaction plants (Arzew) and five refineries of crude oil (in Algiers, ArzewSkika and Hassi Messaoud[iii]. 2/It then moved to second level transformation by developing plastics trough propylene processing, petrochemicals, fertilizers and helium: four companies were created and an important of these by-products was exported mostly to Europe, the US and East Asia successfully competing against big international firms. 3/Core

Entering the GVC through building D&E capabilities

Sonatrach appears to have had an early awareness of the need to have access to the imported technology. In the eighties, several attempts were made namely in human resources development and in the institutional instruments for acquiring technology from abroad in order to give a higher access to the acquired technology mostly in the form of plants. The D&E was present and the need to have local value chain were present. Two major phases could be: the first relatively easy phase where the begnin escalator seems to have worked and the second phase which seemed complicated and where a malign escalator (moving backward) seem to dominate (see figure 8).

The begnin escalator

-At the first level, in all six companies in charge of downstream activities, the D&E component was embodied in the equipment and bought in a turnkey package. The attempts of Sonatrach to use disembodied engineering with the hope of climbing the GVC did not often succeed. Regarding this last aspect, it started by innovating in the contractual and the managerial fields. It thus replaced the turnkey contract by the product in hand and the 'dis-embodied engineering" contract to give the possibility to its engineers and technicians to participate to the design of the equipment. This was not sustained in time however, partly as a result of drop of oil prices in world market in mid-eighties (Djeflat & Lundvall 2014). It also resulted from the lack of a clear strategy to integrate the GVCC.

Djeflat and Lundvall (2016) show that Innovation has been the weakest and largely missing in the sense that oil and gas exploitation draws upon generic knowledge, which does not require locally engineered knowledge intensive solutions. Moreover, this move was not supported by any policy to build D&E capabilities namely through research and innovation. Sonatrach started research activities through its Laboratoire Central des Hydrocarbures[iv], which became Centre de Recherche-Développement (CRD) in 1987. The areas of research were mostly geology, geophysics and drilling. Moreover, the creation for its downstream activities of the Centre d'Études ET de Recherche en Hydrocarbures (CERHYD) in charge of petrochemicals, transformation of oil products, composite materials and environment did not perform adequately: most of the work conducted was problem solving and consultancy work. Real research activities did not represent more than 10% to 15% of total activities. Finally, proper R&D and Innovation structure were effectively created in 2020 after several previous failed attempts[6]. This indicates that pressure on the locally born solutions; new products and services were not high on the company's agenda unlike the case of Petrobras. The DUI mode of acquiring capabilities was not recognized by the company. On various occasions, workers were able to find innovative solutions to solve technological problems and to engineer new parts, and spares using accumulated experience and knowledge. (Djeflat 1985).

-At the second level, the D&E was mostly linked to civil engineering and construction. The ENGCB entreprise was a limited liability State company entirely owned by Sonatrach. Created in 1998, it reached international quality standards and become in 2008 certified ISO 9001. Its capability building rests essentially on dedicated human resources: nearly 600 corporate executives, (10%) of total, nearly 1620 middle managers (27%) and nearly 3780 labor (63%)[7]. Through continuous training and upgrading of skills and learning by doing, it developed internal capabilities. Moreover D&E is performed through a bureau d'étudesd'engineering, d'architectures et de topographie. It managed to move successfully in Most of its activities include earthwork, industrial civil engineering namely reinforced concrete (for platforms), roads, airports and landing runways, hydraulics, and railways, buildings and drilling platforms. Its clients include Sonatrach but also its partners: namely JGC (Japan), KBR and STATOIL (USA), SNC-Lavalin (Canada), AGIP and SARPI (Italy), ABENER (Spain) and others. All contracts are arm's length. The big Civil engineering and construction groups are not involved[8].

The malign excalator

-At the third level, a specialized petroleum engineering company, ENEP, (Entreprise Nationale d'engineeringpétrolier) was created in 1983 in partnership with a US partner, Haliburton, one of the biggest engineering petroleum company in the world. However, the JV was dismissed as a result of dismal performances. In 12 years of existence, the company did not train a single specialist in the field of D&E for the petroleum industry (Malti 2012). The company was dissolved in 2003. (Fig.4)

-A fourth level, use local competencies (including in D&E) to produce oil and gas equipment. The new company was expected to start production in 2019 with the specific objective to help sonatrach producing its own drilling equipment locally. The company was suspended in 2022 for reasons not clearly established .

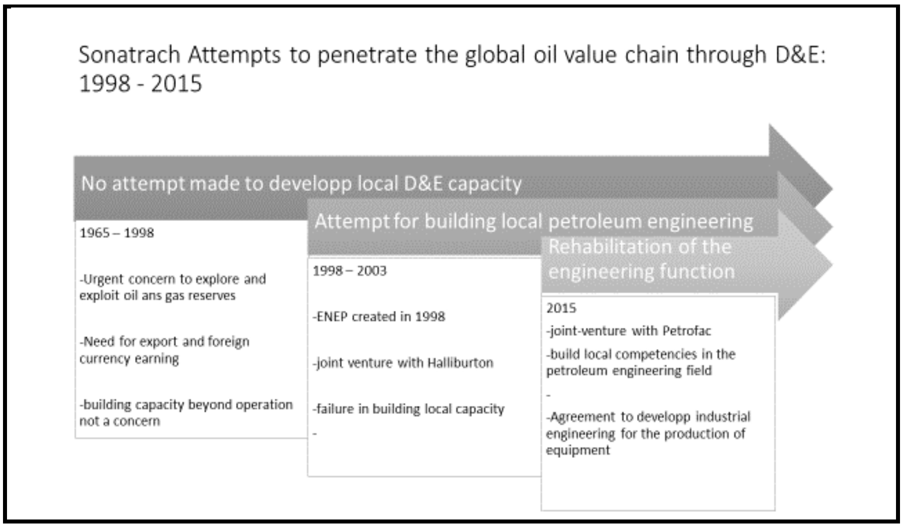

Figure 4: Failed attempts to penetrate the GVCC in historical perspective

[6]Declaration at the seminar on Mechanical Industries at Sonatrach , Hassi Messaoudhttps://www.gcb.dz/wp-content/uploads/2022/12/154.pdf

[7] GCB website http://www.gcb.dz/entreprise_atouts.html (visited february 2016)

[8] GCB website http://www.gcb.dz/references_projets-anciens.html (visited February 2016)

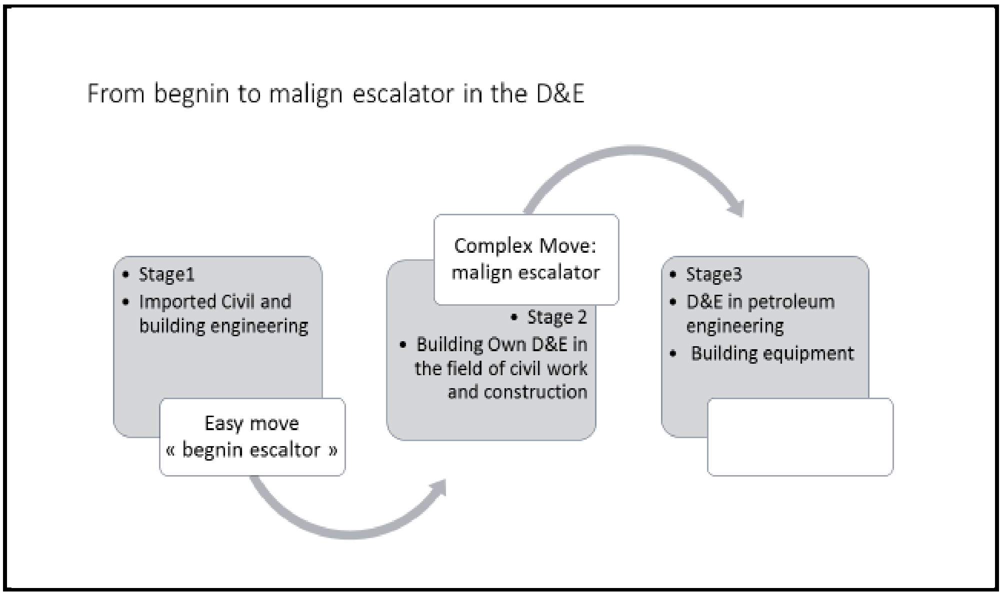

Figure 5: from begnin to malign escalator in the D&E in the experience of Sonatrach

The easy move to build own-capacity of basic engineering. To satisfy their needs of D&E, local firms use different sources. Nearly half of them (57%) use their own D&E services, which they developed over the years: they are both public (Sonelgaz, RMK, RTE) and private companies (TRAPACT). This is often basic and civil engineering. Bearing in mind the des-industrialization and de-engineering phenomenon, the score seems fairly high. More surprising is no doubt the proportion of private companies. This indicates that effectively, the upgrading of engineering succeeded allowing the company to climb the latter and that the “begnin escalator” (Bell 1999) has effectively worked.

-The limited importance of partnering in the field of D&E: What is surprising is the limited role of foreign partners in developing D&E capabilities of local firms. This role seem not to be well perceived: One of the reason is that not many companies have a significant experience with foreign partners as we have seen earlier. Other companies showed a certain mistrust in the training provided by foreign partners: they argue that foreign partners do not provide all the necessary know-how to prolong the dependency of the client stressing the role of gatekeeper of the lead firm in the GVC.

-The second result regards the involvement of the foreign personnel in the engineering function and in D&E in particular. It is common for companies in the south to hire the services of engineers, technicians and experts to compensate for their limited technological capabilities in various fields. Quite surprisingly, in our sample, the involvement foreign expatriates in the D&E function was nil (100% of responses). The reason is industrial Design and engineering, it is often embodied in the package and marginalize the role of local technical and scientific personnel.

-The weak linkages with the local training system. Unlike Petrobras where the relationship with COPE (for training and research was intimate and lasted over several decades in a co-evolutionary perspective, in the case of Sonatrach the relationship with the education and training system was strictly limited to recruitment of graduates and internships. Thus some companies such as petrochemicals, recruit locally trained engineers while others prefer in house trained engineers or those trained abroad. While others had a negative perception of locally trained engineers.

-The relationship between the D&E and R&D functions is of crucial importance and determines the extent to which collaborative work and interactive learning was used to enter the GVCC and the GVPC in particular. Two types of situations exist: in the first one, old and well-established companies from the public sector (energy, Gas liquefaction, petrochemicals, oil refining) seem to have relatively close relationships between D&E and R&D department and services. In the second type, more recently established companies such as plastics seem to have distant relationship between the two functions or no relationship as they have no R&D department or services. In other words, they are not involved in formal research.

-The majority (60%) reckon not involving workers in the D&E function. Workers are mostly involved at the implementation stage as pointed out by the LNG company. One of the reasons for not involving workers is attributed to the incapacity of the firm to organize workers implication. This is the result of an excessive centralization of decision making at the head office of the company. This is an indirect recognition that they are capable of doing it if they were given a chance. For example, in a public lamp company, one of the technicians managed to improve the productivity rate of the 'filamant' production process from 60% to 120%, through redesigning and re-engineering the process. In the face of total ignorance and lack of recognition of his achievement by top management of the company, he stopped proposing new incremental changes he had in mind. The DUI is therefore not

DISCUSSION

Unlike Petrobras, where successful entering into the GVCC, occurred, in the case of Sonatrach, we have seen that the company and the sector have been able to have a marginal participation into the value end of chain essentially through oil and gas processing. It remained largely excluded throughout the period from the oil equipment industry global value chain in spite of enormous investments, countless contracts and partnerships and massive learning opportunities. This result, which tends to accredit the resource curse hypothesis, is to put in relative terms however. Firstly, because of the experience of Petrobras, which we used as a proxy to benchmark the analysis and which, relates to knowledge and industrial international networks. It is indeed easier to participate to networks where the basic ingredients are shared values, exchange of services, cooperation and strategic mutual interests. In global value, the power relations of the lead firms and the governance structure tend to prevail and entry barriers are a great deal higher. It is therefore more complicated for a firm with little to enter GCV. Secondly the oil equipment industry global value chain appears to present further difficulties due to the excessive power position held by suppliers in oligopolistic positions in the Market. This explains why the move from civil engineering to industrial petroleum engineering was the most difficult stage in the oil processing industry GVC as seen earlier. Hilburton, for example, did very little to impulse building local capabilities in 13 years of partnership. On the contrary, it seems to have discouraged if not obstructed the design & engineering Sonatrach. Because such upgrading may indeed encroach on its core competencies as highlighted by Johnson (2014). The power relation contained in GVC in the sense that it had the power to exert its power in the distribution of value creation and furthermore on investment, international currency, and technical and organizational learning in the value chain.

This power position and efficient obstruction was made possible, because of Sonatrach, not being able build prior in house capabilities through learning, competence building and innovative capacity, which Petrobras could deploy. It also happened to Petrobras when it suffered two types of mismatch and failed to move to new network forms in the absence of prior in-house capabilities required for the more complex types of problem-formulation and problem solving in the more complex form of network. The consequence of such a mismatch was some form of failure in the attempt at collaboration, or at least the limited participation of the company in the collaborative activities.

This importance to build local learning capabilities in the field of D&E in order to integrate successfully the GVCC is also the result of important and continuous drive to mobilize the learning and competence-building sphere. Thus the success of Petrobras in the sphere of D&E can be explained largely also because COPPE was frequently used to obtain design knowledge and design tools relating to offshore structures (Active Learning Network). It collaborated further with COPPE to obtain knowledge about the normal design configurations and design parameters of semi-submersible platforms. Sonatrach hardly mobilized the local learning and research sphere universities, high schools and research labs. Most needs were satisfied through continuous and permanent use of foreign design and engineering companies, even when these demands were within the grip of the local knowledge sphere. This handicap is also the result of the marginalization of local competencies and the formidable reservoir of DUI accumulated over the years by engineers and technicians has to be put in much broader perspective: indeed, the priorities were given to the sphere of operation and not knowledge accumulation and innovation in spite of the enormous budget et efforts made in training and upgrading the competences of engineers and technicians. In more general terms, the economy suffered a deficit in terms of engineers. The needs programmed for each development plan were far from being met.

Local productive structures could hardly reach 2000 employed engineers, while the needs were of the order of 11 500 engineers for, the first dour year plan and 18 500 engineers for the second five plan (1980-1984) In addition to that, the engineers assigned to the function engineering were for two-thirds foreigners. During the First Five Year Plan, the engineering market representing 7 to 10 billion Dinars per year butnational capacities could satisfy only 23% of the needs. Significant differences however exist from one sector to another, Buildings and civil engineering could satisfy 80% of its needs heavy industry engineering need satisfaction did not exceed 20% (Djeflat 1992).

The limited attempts to enter the GVC for petroleum equipment. Is also another handicap. While Petrobras entered the field in its early days, Sonatrach expressed no real interest, and this is also a major obstacle for internal D&E capabilities.

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