

ANALYSIS OF CAPACITY UTILIZATION OF PAKISTAN'S OIL REFINERIES



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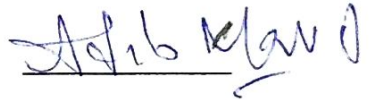
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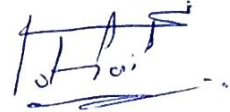
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DEDICATION

To my beloved mother, whose unconditional love, sacrifices, and prayers have been the foundation of all my achievements, and to my dear sisters, whose support, encouragement, and guidance have inspired me throughout this journey. Their unwavering belief in me has been my guiding light and source of strength.

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Abstract

Oil refineries in Pakistan operate below their optimal refining capacity, increasing reliance on costly imports of refined petroleum products, widening the trade deficit, depleting foreign exchange reserves, and limiting domestic value addition. Understanding the economic and operational drivers of capacity utilization (CU) is critical for enhancing efficiency and competitiveness. Despite policy interest, empirical research on the macroeconomic determinants and structural barriers to optimal CU in Pakistan's refining sector remains scarce. This study adopts a mixed-methods approach. A Panel Autoregressive Distributed Lag (ARDL) model is applied to annual data from 1996 to 2023 to evaluate the relationships between macroeconomic variables and CU. Results indicate that crude oil prices and exchange rates have a significant negative long-run effect on CU, suggesting that rising input costs and currency pressures reduce operational efficiency. Conversely, GDP growth and refined product imports are positively associated with CU, reflecting increased domestic activity and demand. Scenario-based analysis shows hydroskimming refineries yield limited benefits, even at higher utilization levels, while transitioning to deep conversion technology with moderate expansion in capacity can generate substantial import substitution and export surpluses. To achieve this, the study recommends targeted fiscal incentives for refinery upgradation, such as tax holidays and duty-free equipment imports to enhance investment returns, and exchange rate risk-mitigation measures for crude procurement. Establishing a unified National Refining Policy with clear timelines for refinery upgradation plans is critical to reduce import dependence, stabilize foreign exchange reserves, and ensure sustainable growth in Pakistan's refining sector.

Keywords: Oil Refineries, Capacity Utilization, Refinery Upgradation, Economic Benefits

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CHAPTER 1

INTRODUCTION

1.1 Background

Energy consumption is a key driver of economic growth and fostering sustainable development, particularly in developing economies. In this context, numerous studies highlighted the positive relationship between energy consumption and economic growth in Pakistan (Ahmad et al., 2012; Chaudhry et al., 2012). In a recent study, Rehman et al. (2021) emphasize that the dominant role of oil within Pakistan's energy mix serves as a primary fuel source for the industrial and transport sectors. Despite the widely acknowledged linkage, Pakistan's energy sector grapples with inefficiencies that undermine its economic growth and energy security. The key concern is the persistent underperformance of the oil refining sector over the past two decades. Although the sector possesses an installed refining capacity of 20.8 million tons per annum (MTPA), Pakistan's oil refineries have consistently operated at suboptimal levels, utilizing only 60% to 65% of their nameplate capacity (Ahmed, 2023; Khan, 2022).

The issue of suboptimal capacity utilization (CU) of oil refineries has created a widening gap between domestic supply and demand, compelling the country to rely heavily on costly imported refined products to meet the demand of a steadily expanding economy (Memon, 2018; Vitharana & Kandegama, 2020). Rather than advancing energy self-sufficiency, this pattern curtailed the opportunity for import substitution and value addition within the petroleum supply chain. According to the Ministry of Finance (2023) report, refined imports now account for nearly one-quarter of the country's total import bill, increasing fiscal vulnerability, widening the trade deficit, and exposing the country to external price shocks and supply disruptions.

This challenge is amplified by the country's escalating demand for energy. According to the statistics of the Hydrocarbon Development Institute (Pakistan Energy Yearbook 2005 & 2021), Pakistan's final energy consumption increased by 87.5% over 16 years, from 2005 to 2021 and demand projections indicate that oil will be the most widely consumed energy source by 2035, accounting for 38.26%, followed by natural gas at 36.57% and electricity at 16.22%. As the Global demand is expected to grow by 24% over the next decade, particularly in developing countries, many developing countries are expanding refining capacity. Encouraging domestic

production and streamlining operations to capture more value from their energy sources (Mayasari & Dalimi, 2019)

Simultaneously, the global energy landscape is undergoing a profound transformation in response to the escalating threat of global warming, and economies worldwide are transitioning toward low-carbon energy systems. These decarbonization pathways focus on scaling up renewable energy generation, enhancing energy efficiency and conservation, and adopting technologies for clean hydrogen production, bioenergy integration, and carbon capture and storage (CCS) facilities (IEA, 2024; IRENA, 2021). The refining sector is central to these transitions, as mandated global standards for cleaner fuels, particularly Euro V and Euro VI specifications, are common standards used in developed countries, which mainly differentiate based on the level of Sulphur content, 10 ppm (parts per million). To align with these international standards, the Pakistan refining sector must have advanced refining facilities, such as hydrodesulphurization and deep conversion, to produce cleaner fuels.¹ However, this transition requires significant capital investments in refinery modernization for cleaner fuel (Nasution et al., 2005). Many developing economies modernized their refinery infrastructure, diversified feedstock's, and adopted advanced conversion units and hydrodesulphurization technologies to enhance efficiency in producing low-sulfur, clean fuels. In Asia, for instance, China and India have modernized their infrastructure and increased utilization rates, with China reaching 83% and India 90% in 2020, through upgrades to technology and diversification of inputs.²

However, Pakistan continues to grapple with technological stagnation. It's predominantly outdated hydro-skimming refineries lack the capacity to produce cleaner fuel in response to changing demand patterns. This structural inefficiency and push for cleaner fuels, along with the changing dynamics of the country's energy mix, have significantly affected the CU of oil refineries in Pakistan. This is particularly evident in the power sector, where the use of furnace oil has decreased following a shift to liquefied natural gas (LNG) for power generation.³ Although the recently announced Pakistan Brownfield Refinery Policy 2023 is a crucial pathway to upgrade local refineries to meet global climate commitments, such as Euro V/VI fuel specifications. In transitioning towards low-carbon energy solutions, regulatory

¹ SAARC Energy Center, 2021

² British Petroleum Statistical Review, 2020

³ Ministry of Energy, 2023; Pakistan Economic Survey, 2023

frameworks focus more on eliminating carbon-intensive fuel production and promoting cleaner alternatives.

In this context, the underutilization of available refining capacity is not merely a technical or operational issue; it is a strategic economic challenge. This issue undermines energy security, contributes to fiscal vulnerabilities, and limits Pakistan's ability to participate in the global transition towards cleaner fuels. Addressing this challenge requires a coherent policy approach that considers future demand trends, technological upgrades for enhancing the refineries' CU to produce high-demanding fuels. This study responds to this critical policy gap by examining the macroeconomic determinants of CU, evaluating the potential benefits in terms of imports bill from enhanced utilization, and exploring the structural barriers impeding upgradation/modernization. By doing so, the study aims to provide evidence-based policy insights that can strengthen refining sector performance, reduce import dependency, and contribute to Pakistan's long term energy security.

1.2 Problem Statement

Pakistan's oil refining sector consistently operates far below its installed capacity, resulting in a persistent structural imbalance between refining output and domestic demand. Although the sector has a nameplate refining capacity of 20.8 MTPA, actual utilization has averaged only 60% over the past decade (PACRA, 2024), resulting in domestic output of 10.4 million tons against demand of 21 million tons (OCAC, 2023). This persistent underutilization is primarily due to outdated hydroskimming configurations that lack advanced conversion units, constraining product yield flexibility. Consequently, Pakistan meets nearly half of its petroleum demand through costly imports, which in 2022–23 reached USD 11.87 billion, over 51% of the total petroleum group import bill, thereby worsening the current account deficit and depleting foreign exchange reserves. Beyond macroeconomic pressures, underutilization reflects missed opportunities for domestic value addition, import substitution, technology-driven efficiency, energy security, and petroleum prices for consumers (SAARC Energy Center, 2021).

From the theoretical standpoint, chronic underutilization reflects structural and economic inefficiencies. While the production theory posits that firms operate below optimal capacity when faced with high marginal cost or a rigid production system, such as outdated technology (Samuelson & Nordhaus, 2009; Varian, 1992). In this framework, firms determine the optimal level of output where marginal cost equals marginal revenue. Pakistan's refineries mostly

operate as hydroskimming units, which lack the advanced conversion technology needed to adjust product yields to market demand.

To address these gaps, the present study employs a panel ARDL framework to examine the impact of key macroeconomic variables on refinery capacity utilization. It further evaluates the economic benefits of enhanced capacity utilization through technological upgrading, particularly the transition toward deep conversion refineries. A qualitative assessment complements the econometric analysis by exploring institutional constraints, technology adoption barriers, and modernization challenges that hinder capacity optimization. By integrating industrial theory, energy economics, and modernization perspectives, this research provides a theoretically grounded and empirically informed basis for policy recommendations aimed at strengthening Pakistan's refinery sector and ensuring long-term energy security.

By integrating econometric, scenario-based, and thematic approaches, the research provides evidence-based insights to inform a coherent policy framework for refinery modernization, capacity optimization, and long-term energy security in Pakistan.

1.3 Research Gap

The existing literature on petroleum refining has predominantly been examined through the lenses of engineering, environmental sustainability, and industrial economic perspectives. Limited attention has been given to the economic aspects and capacity utilization of petroleum oil refineries. The literature on capacity utilization has primarily focused on the manufacturing, food, and beverages sectors (for instance, Bashir, 2021a; Agbakahi, 2022; Adeyemi & Olufemi, 2016; Shiamwama et al., 2021; Iheukwumere et al., 2021). Similarly, Ghodduzi et al. (2021) explored the dynamic relationship between capacity utilization, crude oil prices, and product demand. While Akpan et al. (2012) assessed the impact of macroeconomic variables on capacity utilization in manufacturing industries. More recently, Ezie and Obumnek (2023) investigated the impact of specific macroeconomic factors on oil refining output, highlighting the importance of the exchange rate, interest rate, and government expenditure. Joshi et al. (2021) explore the refinery performance factors, identifying refinery complexity, capacity utilization, and distillate yield as key determinants. However, empirical studies examining these dynamics remain limited in the context of Pakistan's oil refining sector.

The existing literature on the Pakistan oil refining industry mainly focuses on firm-level financial indicators such as capital structure, profitability, and financial leverage (Ali et al., 2012; Shabbi, 2018). However, this suggests a noticeable lack of empirical studies into how

macroeconomic variables impact capacity utilization. No empirical study exists (to the best of our knowledge) that systematically examines macroeconomic factors that influence capacity utilization in Pakistan's oil refining sector.

Additionally, the existing literature overlooks technological limitations, potential import substitution opportunities, and the economic implications of adapting production patterns to current demand dynamics. Although Mumtaz et al. (2021) emphasize the importance of refinery investment and import substitution, their analysis lacks quantification of product yield and specific import savings of the most demanding products. It does not provide a structured analysis of the transition from hydro-skimming to deep conversion technology as prescribed by the Brownfield Refinery Policy (Ministry of Energy, 2023).

A significant policy gap persists, as current studies insufficiently examine how sectoral performance interacts with ongoing government policies, including the Oil Refinery Policy 2023, which aims to incentivize brownfield upgrades. These policy frameworks are central to understanding technology adaptation barriers, investment decisions, and modernization efforts, yet their implications remain empirically and theoretically unexplored in existing literature. This gap limits the policy's ability to design evidence-based strategies that address structural inefficiencies and optimize capacity utilization.

In response to these gaps, the present study empirically analyzes macroeconomic variables on refinery capacity utilization in Pakistan's oil refineries using the ARDL framework. Additionally, it contributes to the literature by computing the economic benefits of optimal capacity utilization through technological upgradation, particularly the transition from hydroskimming to deep conversion. Furthermore, this research also incorporates a qualitative assessment to identify the issues of underutilized capacity and explore the institutional and policy-related barriers that impede refinery modernization/upgradation. This study will contribute to the existing literature on oil refineries and set the stage for future research in this sector in Pakistan.

1.4 Research Objectives

The objectives of the study are:

- To investigate the impact of major macroeconomic variables on the capacity utilization of oil refineries in Pakistan.
- To compute the economic implications of enhanced capacity utilization in Pakistan's oil refineries, with a specific focus on the potential reduction in the import bill.
- To identify the key issues contributing to the underutilization of refining capacity in Pakistan's oil refineries.
- To explore the barriers that impede modernization and technological upgrades in Pakistan's oil refineries.

1.5 Research Questions

Based on the above objectives, the following research questions are designed for the analysis:

- How do macroeconomic variables influence the capacity utilization of oil refineries in Pakistan?
- What are the economic implications of enhanced capacity utilization in terms of potential reduction in import bills?
- What are the key issues that contribute to the underutilized refinery capacity?
- What barriers impede the modernization and technological upgrading of oil refineries in Pakistan?

1.6 Significance of the Study

The oil refining sector is an important component of Pakistan's energy infrastructure and industrial economy, holding substantial potential to contribute to economic growth and industrial competitiveness. However, it has persistently operated at suboptimal capacity. Despite having an installed capacity of 20.8 MMT, local refineries are operated at around 55-60 percent of their installed capacity (Pakistan Energy Yearbook, 2023). This underutilization has compelled the country to import refined products, which now constitute the primary component of Pakistan's energy bill, amounting to USD 12.6 billion in 2023. This dependence not only strains foreign exchange reserves and widens the current account deficit but also demonstrates the missed economic opportunities in terms of domestic value addition, employment generation, import substitution, and industrial linkage. Moreover, prolonged

underutilization prevents refineries from achieving economies of scale, thereby weakening their financial sustainability and overall competitiveness.

Within this context, this study is significant as it addresses a critical gap in the academic and policy literature by being the first to empirically investigate the macroeconomic determinants of refinery capacity utilization in Pakistan. While previous work has largely focused on broader energy sector dynamics, this research links macroeconomic variables directly with refinery-level performance and further explores the structural and institutional barriers that hinder modernization. The findings will hold immediate policy relevance for the Ministry of Energy, Petroleum Division (MoEPD), and the Oil and Gas Regulatory Authority (OGRA). By quantifying the impact of macroeconomic determinants on refinery utilization, the study will generate evidence for designing targeted interventions that can optimize capacity and improve efficiency. Moreover, the study also contributes by estimating the potential economic benefits of upgrading refineries from outdated hydroskimming configurations to advanced deep conversion units, which allow the production of higher-value products. These projections are particularly valuable for the formulation of Pakistan's new refinery policy framework, including the design of tariff protections, fiscal incentives, and investment facilitation measures to support modernization and capacity enhancement.

The significance of this research also extends to industry stakeholders and investors, who will benefit from its insights into the financial and strategic viability of upgrading refinery infrastructure. By identifying the barriers that have historically hindered refinery modernization, the study provides a knowledge base that can inform investment decisions, reduce risks, and improve competitiveness within the sector.

In conclusion, this study will contribute to academic literature and to practical policymaking, industry development, and national economics. It will also serve as a policy reference for formulating long-term strategies aimed at prioritizing domestic production to reduce import dependency and strengthening the refining sector's performance. By offering a comprehensive assessment of both the macroeconomic and operational dimensions of refinery underutilization and modernization, it will provide actionable guidance for policymakers, industry stakeholders, and investors, ultimately supporting sustainable growth, energy security, and industrial competitiveness in Pakistan.

1.7 Organization of the Study

This study is organized into seven chapters. Chapter 1 presents an introduction to the topic, highlighting the research gap, objectives, and significance of the study. Chapter 2 reviews the existing literature relevant to the current topic. Chapter 3 provides an overview of the refining sector, its historical development, and current status. Chapter 4 outlines concepts and theoretical approaches to capacity utilization, as well as descriptions of variables. Chapter 5 presents the empirical methodology for quantitative and qualitative analysis. Chapter 6 provides an analysis of results and a discussion of the findings. Finally, Chapter 7 presents the conclusion and policy recommendations.

CHAPTER 2

LITERATURE REVIEW

This chapter examines the literature on capacity utilization (CU) and the various factors influencing it across different sectors and industries. The review is organized into two sections. Section 2.1 discusses theoretical literature, while Section 2.2 presents an empirical literature review divided into subsections.

2.1 Theoretical Literature

Capacity utilization (CU) has long been regarded as a key performance and efficiency metric in the food, manufacturing, and refining industries. It reflects the extent to which installed productive resources are being used. Rather than treating CU only as a technical ratio, from an economic perspective, capacity utilization plays a crucial role in evaluating firm productivity, particularly when productivity improvement is necessary. For instance, in developing economies, where capital formation is often constrained, the efficient use of existing capacity becomes even more critical (Adeyemi & Olufemi, 2016). However, the concept of capacity utilization lacks a universally accepted definition. It is theoretically complex and varies across disciplines.

Early theoretical work by Cassels (1937) conceptualized capacity in terms of cost minimization, suggesting that optimal CU corresponds to the output level, distinguished between short-run and long-run excess capacity, linking it to the cost structures of fixed and variable inputs, suggested that optimal capacity defined at a point where average total cost is minimized, thus linking it to both technical and economic dimensions. Later studies develop on this economic view, framing CU as a decision variable shaped by firm response to market conditions, cost structure, and resource constraints rather than fixed technical limit, as argued by (Kemal & Alauddin, 1974; Pasha & Qureshi, 1984). Later, economic theorists like (Klein, 1960) and Padma (1991) noted the conceptual ambiguity of “capacity,” emphasizing the lack of a unified framework and the need for sector-specific models, arguing that sector-specific approaches are necessary to capture the capital intensity, market dynamics and product mix.

According to Afroz and Roy (1976), the theory of economies of scale posits that cost-minimizing firms are inclined to increase the utilization of their fixed capital when returns to scale diminish with increasing output. This direct describe that CU is endogenously determined, influenced by cost efficiency and market opportunities. Implying that low CU not

only increases output but also reduces per-unit capital service costs. Consequently, CU becomes directly associated with firm-level efficiency. The production theory, rooted in neoclassical economics, posits that output is a function of labor, capital, and materials, with technological efficiency playing a significant role (Samuelson & Nordhaus, 2009; Varian, 1992). According to this theory, firms determine optimal output where marginal cost equals marginal revenue. When external constraints such as rising crude prices or limited capital investment occur, firms may choose to operate below full capacity to mitigate losses. In the refining industry, this describes why external shocks such as crude oil price volatility, currency depreciations, and demand conditions push firms to operate below capacity.

Therefore, Technology Adoption Theory represents an important dimension to the theoretical foundation. Companies invest in new technologies when perceived usefulness outweighs adjustment costs, learning barriers, and uncertainty. Within refining contexts, investments in advanced conversion technologies (e.g., deep conversion, hydrocracking, catalytic cracking, isomerization) enhance yield efficiency and maximize CU by enabling heavy crude processing, producing high-demand products, and reducing operational bottlenecks. Conversely, failure to upgrade, as evidenced by hydro-skimming refineries, results in chronic underutilization and limited product flexibility. Hence, technological capability serves dual purposes: not only as a determinant of CU but also as an outcome, reinforcing links between modernization, competitiveness, and continued operational efficiency.

Furthermore, industrial economies' approaches to the technical change framework proposed by Richard R. Nelson and Sidney G. Winter (1982). In their evolutionary theory of technical change, emphasized that technological transitions are not merely incremental improvement but involve changes in the configuration of production units and organization and institutional structure (Geels, 2002). In the context of refining, this suggests that adopting advanced technology can shift a refinery's productive capacity and potential output. Hence, a technological shift requires capacity availability, a regulatory environment, and access to technical expertise, and then technological potential translates into actual CU.

CU is simultaneously a strategic choice and a company's outcome. Nikiforos (2013) argues that firms set their utilization levels based on expected costs, long-run investment strategies, and profitability. It means that CU is integral to capacity planning, competitive, and modernization decisions. Empirical studies in industrial production and energy-intensive sectors support this cyclical sensitivity (Kerstens & Managi, 2012a) have used this theory to

model output efficiency and input optimization. It is observed that fluctuations in aggregate demand are the main drivers of short-term variations in production and employment (Keynes, 1936; Mankiw, 2015). It is particularly relevant to cyclical sectors, such as oil refining, where demand is highly responsive to macroeconomic trends. During economic booms, increased income levels, industrial activity, and transportation fuel consumption drive refineries to operate closer to their maximum capacity. Conversely, economic downturns lead to reduced consumer demand and industrial slowdown, causing refineries to scale back production (Hamilton, 2009a). Additionally, excessive imports of refined petroleum products have been identified as external demand-side pressures that suppress domestic refinery output, further depressing capacity utilization in countries like Pakistan (Kiani, 2025). Furthermore, CU not only shows internal efficiency but also serves as an indicator of external market dynamics. Sequin and Sweetland (2014) highlighted that CU implicitly reflects the level of market demand. When demand increases, CU tends to rise; when demand weakens, CU falls, leading to higher operating costs and reduced competitiveness.

Coelli et al. (2002) and Johansen. (1968) further refined the definition of capacity, viewing it as the maximum output that can be achieved using fixed inputs while allowing variable inputs to adjust freely. CU is then calculated as the ratio of actual output to this potential output. In engineering terms, full capacity is assumed to reflect 100% efficiency. However, this definition assumes ideal conditions, while in practical and economic terms, particularly in developing countries, capacity utilization rarely exceeds 90% due to factors such as machine breakdowns, labor inefficiencies, supervision issues, and production wastage (Afroz & Roy, 1976).

Similarly, recent theoretical work treats CU as both a strategic choice and an outcome. Nikiforos (2013) notes that firms choose their level of utilization based on cost-minimization principles and adjust their production strategies accordingly. Thus, the rate of CU is not only an outcome of current production dynamics but also an input into firms' strategic planning and investment decisions. From a broader economic development perspective, persistent underutilization of productive capacity, particularly in countries like Pakistan, often signals structural inefficiencies, weak demand, changing demand patterns, and underinvestment in technological modernization. Bresnahan and Ramey (1993), in their study of U.S. automotive firms, and Fagnart et al. (1999), in Western Europe, found that even in developed countries, firms often operate with excess capacity due to cyclical fluctuations, cost uncertainties, or strategic flexibility.

Energy economics provides an important framework for understanding CU in oil refining. Refinery utilization responds to global crude oil prices, shifts in fuel demand, crack spreads, and regulatory changes. The principle of refinery margin optimization is straightforward: throughput decisions are based on the difference between what crude costs and what refined products bring in. When margins shrink due to higher crude prices or strong import competition, CU tends to fall. The field also emphasizes the role of feedstock availability, energy security risks, and refining complexity—think hydro-skimming versus deep conversion on CU, where the techno-economic configuration becomes a core driver of how efficiently a refinery operates. The macroeconomic perspective provides further explanation of Keynesian theory (Keynes, 1936) highlight the sensitivity of CU to the business cycle. Exchange rate predicts that the currency depreciation raises the domestic cost of imported crude, that reduce refinery profitability and also lowers CU. An open economy macroeconomic models highlight the role of trade deficits, import of refined products, and GDP growth rate, factors particularly relevant to Pakistan’s refining sector, and also making refinery CU sensitive to broader macroeconomic stability.

In summary, theoretical literature converges on the view that capacity utilization is a multifaceted construct shaped by cost structures, technological capabilities, strategic behavior, and macroeconomic conditions. For oil refineries operating in developing economies, these dimensions intersect to produce persistent underutilization, often rooted in structural constraints, price volatility, weak demand, and outdated technologies. This theoretical foundation provides the analytical basis for examining Pakistan’s refining sector, where CU reflects not only operational efficiency but also systemic issues in technology, market structure, and macroeconomic stability, challenges that the present study seeks to investigate in depth.

Finally, theoretical literature emphasizes that CU is not merely a technical measurement but a multifaceted economic concept, influenced by firm-level cost structures, market conditions, macroeconomic variables, and outdated technology. This theoretical foundation serves as a basis for analyzing Pakistan’s refining sector, where CU indicates inefficiencies and systemic issues in production (technology), market dynamics, and macroeconomic stability.

2.2 Empirical Literature

2.2.1 Capacity Utilization - Manufacturing Industries

Empirical studies on Capacity utilization (CU) in manufacturing industries reveal that capacity utilization is shaped by a complex interaction of supply-side constraints, demand-side dynamics, a firm's characteristics, technological capability, and institutional factors. Rather than being a technical measure, CU of a firm reflects broader structural and macroeconomic conditions that influence a firm's decision. Demand-side conditions consistently emerge as a key determinant of CU across multiple studies.

For instance, A study by Adeyemi and Olufemi (2016) found a positive relationship between CU, consumer price index, and fixed capital formation, whereas a negative correlation was found with electricity supply disruptions, implying that higher aggregate demand encourages firms to operate at full capacity. This study suggests that where demand is predictable, firms operate close to full capacity. This pattern is relevant for developing countries, where fluctuations in demand lead to suboptimal utilization levels. Similarly, Reneganathen et al. (1991) conducted a cross-industry analysis involving 73 industries. The results show a positive relationship between demand pressure, market concentration, and capacity utilization. Similarly, Balasubramanian (2022) used the ARDL model to examine the impact of industrial credit on industrial growth in India. The study established a relationship between credit and industrial output.

However, with the demand side factors are not sufficient to sustain optimal CU if supply side constraints persist. Ndemezo et al. (2018), Rwanda's food and beverage sector, demonstrated that limited access to raw materials, technological capability, and high taxes reduce CU. Their findings are similar to the earlier study by Pasha and Qureshi (1984) in Pakistan, who attributed low CU to energy shortage and limited access to raw materials. This suggests that demand can stimulate utilization, but inadequate infrastructure and input shortages cap operational efficiency.

Another critical factors discussed in the literature highlight the role of technological and institutional capability. Lieberman (1989) found that capital intensity influences CU, while Kim (1999) argued that firms' output decisions based on profit maximization behavior consider production factors and market dynamics. It indicates a measure of capacity utilization that

includes production factors, capital, compared with traditional engineering-based measurements. Krishna and Kodali (2014) state that firms need to anticipate market expectations, invest in technology, and have flexible production systems to align production capacities. This evidence underscores that CU is not merely an outcome of market forces but reflects strategic firm behavior.

Firm-specific characteristics also emerge as crucial determinants of CU. Rahmouni (2021) found that larger firms in Tunisia achieve higher CU due to economies of scale, while political instability and lower export constraint utilization. In the Asian context, Gajanan and Malhotra (2007) estimated the capacity utilization rate in the Indian manufacturing sector and found that changes in demand significantly influence capacity utilization, which is positively related to labor intensity in production. Goldar and Renganathan (2008) demonstrated that CU positively influences labor intensity and firm size but is vulnerable to import penetration. Similar evidence was reported by Shahverdi and Abdi Jalal (2015), a study of Malaysian palm oil refineries, where a locally owned firm outperformed a joint venture, indicating that ownership structure and firm-specific factors shape operational efficiency.

In Pakistan, the capacity utilization of the manufacturing sector has been studied by Kemal and Alauddin (1974), Pasha and Qureshi (1984), and Kalim (1998). An earlier study by Kemal & Alauddin (1974) identified high capacity utilization in industries with sufficient demand and technological advances. However, capacity utilization is considered an economic choice that responds to economic factors. Furthermore, the demand for products and raw materials was identified as the primary determinant of capacity utilization in Pakistan's manufacturing sector. According to Pasha and Qureshi (1984), capacity utilization was low due to both demand and supply side constraints, including electricity shortages and limited access to raw materials. Kalim (1998) identified load-shedding as the most critical factor affecting capacity utilization. The study also pointed out supply-side constraints, such as shortages of imported raw materials and skilled labor. On the demand side, the key challenges highlighted were domestic competition and export demand. This prior literature demonstrates that the Pakistan manufacturing sector has been constrained by structural and infrastructural weakness rather than demand and supply side considerations.

2.2.2 Capacity Utilization - Oil Refineries

The literature on oil refineries has long attracted scholarly and policy attention, indicating the strategic importance of the energy sector and industrial development. Unlike general

manufacturing industries, the petroleum oil refineries operate under a complex market structure, heavy intensive capital, a highly regulated environment, and are vulnerable to global market conditions. For instance, volatility in global crude oil prices is widely recognized as a critical determinant of refinery margin and operational efficiency. Baumeister and Kilian (2016) argued that changes in crude oil prices not only affect the cost of procurement but also transmit uncertainty through downstream operation, affecting a refinery's ability to plan production and utilization levels. Similarly, empirical findings by Hamilton (2022), confirm that persistent oil price shocks reduce refinery performance, especially in an import-dependent economy. These studies suggest that volatility in crude oil prices destabilized refinery operations, reduced predictability, and deterred long-term investment in the refining industry. Furthermore, Ezie (2023) examined how macroeconomic factors impact oil refining output, revealing that exchange rate, interest rate, and government expenditure all affect output.

Some early scholars underscore the role of the regulatory environment in influencing refinery survival and performance. A study by Mitchell and Mulherin (1996) demonstrated that regulatory subsidies often favor smaller refineries, increasing their chances of survival in a competitive environment. Similarly, Chen (2003) examines petroleum refineries' survival and growth dynamics in the U.S. under market deregulation in the 1980s. The findings show that refinery age and size positively impact survival probability while negatively impacting growth potential, implying that larger refineries are more durable yet may develop more slowly. Furthermore, the study emphasizes the effect of regulatory subsidies, which benefit smaller refineries in developing technological adoption. Dunne et al. (1995) found that refineries that have adopted new technology dramatically boosted growth in surviving refineries, implying that innovation is insufficient without a conducive policy environment. These studies highlight how technological adoption and regulatory regimes interact to shape the refineries' utilization outcomes; highly protective regulation can shield inefficiency while competitive deregulation compels refineries to expand throughout capacity and upgrade technology.

The operational efficiency and market dynamics have also explored as critical determinants. Dalei and Joshi (2023) examined the operational efficiency and found that utilization rate and distillate yield are significant drivers for operational efficiency. This finding aligns with a study conducted by Iheukwumere et al. (2021) identify leading factors such as governmental interference, underfunding, and poor maintenance as the leading causes of the low capacity utilization in the refineries, which operate below 20%, despite repeated technical interventions. These studies suggest that persistent underutilization of refining capacity has been linked to

systematic inefficiencies. Ogbuigwe (2018) examine that Nigeria import half of its fuel needs, despite possesses surplus install capacity which is operated at around 15% because of governance and institutional failures undermine operation efficiency. Similarly, Agbakahi (2022) extended the argument and attributed low utilization to price distortion by government manipulation in the form of subsidies that disincentives productivity.

Ghoddusi et al. (2021) found a long-run relationship between crack spread and refinery capacity utilization, indicating that the long-term crack spread is strongly related to capacity utilization (CU). Chesnes (2015) examines the impact of refinery outages on future refinery investment and prices of petroleum products. Considers how high market profitability and planned refinery outages influence utilization rates. In the European context, Herce et al. (2022) assess the energy efficiency of ten Italian oil refineries based on data from mandatory energy audits. They find that the specific energy consumption (SEC) varies systematically depending upon each refinery's capacity, product mix, and complexity. Furthermore, Ruble (2019) noted that the U.S. refining industry faces competitive pressure, emphasized the future challenges of demand for petroleum products and competition from new refineries in the Middle East and Asia.

Okoro et al. (2017) discuss the economic benefits of processing crude oil domestically and explore the possible impacts on the economy. The study contributes to understanding how local refining influences capacity utilization and economic growth. A technical report on Oil Refineries (2014) provides an overview of the global oil refining industry, outlining its present status and geographical shifts in refining capacity. It emphasized the need for upgrading capacity to process lower-quality feedstock to meet the demand for Low-Sulphur diesel and other high-value products. Bukari (2013) highlights the poor performance of Ghana's Tema Oil Refinery (TOR) due to inefficient management, political interference in pricing, and low capacity utilization (CU) and recommends restructuring through privatization as a strategic policy alternative. Daferighe and Edet (2019) evaluate the determinants of the financial performance of Nigeria's oil and gas industry, considering both internal and external factors. The findings show that internal factors, such as capital structure, age, and size, significantly impact financial performance, while external factors have less influence.

Sallam and Sadraoui (2025) use PMG-ARDL to examine the nexus between energy efficiency and industrial competitiveness in the GCC countries, finding that energy efficiency improves competitiveness by increasing productivity and reducing operating costs. Similarly, the study

by Ezie (2023b) found a long-run relationship among macroeconomic variables; all variables are positively correlated with oil refining output. Using the ARDL with co-integration bound testing, revealing mixed integration order. In this study, the same rationale applies. The macroeconomic variables influence refinery CU exhibit mixed integration order, due to the nature of the data consisting of time series and cross-sectional units. Therefore, employ Panel ARDL to capture the short-run and long-run correlation between macroeconomic variables and CU, considered as an output performance measure of the oil refining sector.

Pakistan-specific literature remains limited and focused on financial and operational challenges. Existing literature is specific. Awan and Anjam (2015) explored HR inefficiencies. Shabbi (2018) found that financial leverage affects refinery profitability. Malik (2008) noted that domestic refineries in Pakistan are protected through import-parity pricing and deemed duties, which generate high margins but fail to optimize full capacity. The issue of duty-free imports and subsidies must be addressed for better management and efficiency in the refining sector.

In conclusion, prior literature has explored various factors such as macroeconomic volatility, technology, crude prices, and policy frameworks that determine capacity utilization (CU) in different industries around the globe. However, these remain underexplored in Pakistan's context. This study aims to fill a gap in the existing literature by investigating the macroeconomic determinants of CU in Pakistan's oil refining sector using the Panel ARDL method. Previous research has primarily focused on other industries, leaving a need for a detailed analysis specific to refineries. Although various factors affecting CU in refineries have been identified through industry analysis, they have yet to be empirically investigated. Moreover, the study also measures the technological and operational product mix of the refining sector to highlight the importance of modernization.

2.2.3 Evidence on Barriers to Modernization of Oil Refineries

Literature identifies a set of interacting institutional, structural, financial, and policy dimensions that collectively shape the oil refining sector capacity. Modernizing refineries is capital-intensive; the scale and structure of investment costs highlight that countries unable to overcome these constraints tend to increase import dependence, deteriorate competitiveness, improve product slate flexibility, and operate at efficient utilization levels. However, Clancy (2001) discussed that the regulatory and institutional factors amplify the technological and financial constraints. Some case studies underline that delayed implementation of emission

standards, unclear fuel quality rules, and uncertain federal regimes further perceived regulatory risk of refinery investments that undermine the ability of refineries in developing and transition economies to upgrade processing units (Narkhede & Gardas, 2018; Wijetilleke & Ody, 1985).

Oil refineries face multifaceted factors that hinder modernization. Most importantly, financial constraints are a significant barrier to refinery modernization/upgradation. Habrylevych and Nikytenko (2023) identify key challenges, including financial, institutional, and technological constraints, and develop a policy-oriented investment framework for the structural transformation of the refining complex in Ukraine. Also, emphasize that investment financing is essential for the optimal operation of refineries and has a significant impact on their ability to develop production capacity and competitiveness that contribute to the refining technology and production facilities. This allows for applying more efficient refining processes, reducing losses, and improving product quality.

Technological constraints represent another critical dimension of modernization challenges. Kim et al. (2022) provide a systematic review that identifies complex sociotechnical obstacles to decarbonizing refineries, indicating that technological modernization hurdles the industry must address. Aalto (2018) demonstrates that the modernization of Russia's energy sector struggles to finance and equip the refinery. The study notes that around 90% of technologies are imported, highlighting both technological dependence and supply chain disruption. Furthermore, the deregulation of the petroleum sector has emerged as a critical policy discourse. Olujobi (2021) found that the excessive government regulation in Nigeria's downstream petroleum sector discourages private investment. Ovaga (2010) highlights that reregulation would reduce market distortion and promote market competition, while Ayodele et al. (2013) urged that the dominance of government in pricing, supply, and investment as major structural challenge for the mid-stream and downstream petroleum sector.

In summary, the literature demonstrates that refinery modernization and upgrading, as a complex process, cannot be exclusively contextualized without recognizing the interplay of institutional, financial, technological, and policy-related barriers. Weak institutional capacity, fragmented governance, and regulatory inefficiencies undermine long-term planning and delay investment decisions (World Bank, 2022). Financially, refinery upgrades-particularly transitions from hydroskimming to deep-conversion technologies-demand substantial capital outlays, with volatile refining margins, high country-risk premiums, and increasing concern about stranded assets further limiting access to long-term financing (Akhtar et al., 2024;

Olaizola et al., 2022). In addition, policy uncertainty-from inconsistent fuel quality standards to vague long-term energy transition roadmaps-introduces significant strategic risk, discouraging investment in complex upgrading projects (Narkhede & Gardas, 2018; Wijetilleke & Ody, 1985). Collectively, these interrelated constraints emphasize that refinery modernization is not exclusively a technical challenge but one inherently constituted by the quality of governance, market conditions, technological preparedness, and policy stability.

CHAPTER 3

PAKISTAN OIL REFINING: AN OVERVIEW

This chapter provides a general overview of petroleum refining, focusing on its historical development, installed and operational capacities, current structure, technological state, and the main obstacles that prevent optimal performance.

3.1 An Overview of Petroleum Refining

The oil refining sector is a crucial component of the petroleum industry, playing a fundamental role in the country's energy supply chain. It is essential for ensuring energy security, which in turn facilitates economic growth and promotes overall economic development. Petroleum refineries transform crude oil into various types of petroleum products, primarily achieved through a distillation process that breaks down crude oil into distinct fractions based on their boiling points (Walls, 2010). The process is based on the selective reconfiguration of diverse products, including motor spirit (MS), high-speed diesel (HSD), jet fuel (JF), fuel oil, lubricants, naphtha, liquefied petroleum gases, and so on. These products are necessary for industrial, commercial, and domestic use, as well as for a wide range of businesses that have evolved from the petroleum refining process (Worrell & Galitsky, 2005).

In general, refineries are categorized into four types: topping, hydroskimming, conversion, and deep conversion refinery (ETSAP, 2014; Jing et al., 2020). Topping refineries are considered the most basic and simplest category. These facilities mainly consist of atmospheric crude distillation units (CDU) and basic support plants. Their technical capacity to alter the yield pattern of the feedstock is highly limited, and they end up with simple extraction of crude oil into naphtha, distillates, light gas, and residual or heavy fuel oil.

Hydroskimming refineries are more advanced configurations compared to the topping refinery. It is typically designed and equipped with catalytic reforming, various hydrotreating units, and product blending units. Catalytic reforming enables the upgrade of naphtha into gasoline components, and nitrogen is produced as a byproduct for use in hydro-treating units. Simultaneously, hydro treating units enable the removal of impurities, including nitrogen and sulfur. This type of refinery is common in countries with low domestic demand for gasoline, where the primary focus is on producing middle distillates.

Conversion or cracking refinery is the next stage and represents a more complex process, including advanced processing units such as vacuum distillation, catalytic cracking or hydrocracking, and an alkylation unit. These facilities possess the capability to improve the yield pattern of crude oil by converting heavier fractions into lighter, higher-value products. Despite these technological advancements, conversion produces a certain proportion of lower-value products, such as residual fuel and asphalt, due to limitations of crude composition and conversion efficiency.

Deep conversion refineries are the most advanced and complex category within the refining spectrum. These facilities are equipped with deep conversion units, which are designed to process the heaviest and least valuable fractions of crude oil, converting residual and asphaltic components into lighter, high-value products such as diesel, gasoline, and naphtha (EIA, 2020). By minimizing residual fuel output and maximizing the production of valuable fuels, deep conversion plants often prove the most profitable form of refinery, particularly in markets with stringent specifications and high demand for clean fuels (McKinsey, 2020)

The physical features of a refinery fundamentally determine its unique operational capabilities, and the economics of refineries will be examined in subsequent sections. Normally, the level of configuration is primarily shaped by its location, crude slate features, and the specification of the product quality (Mu, 2019). Additionally, the configuration of a refinery is influenced by industry standards and environmental regulations. The dynamic interplay and evolution of these factors driven the development and technological refinement of refineries over time (Gary et al., 2007). The economic performance of oil refineries is influenced by a range of factors, including refinery configuration, product prices, market dynamics, operational costs, and levels of capacity utilization.

3.2 Domestic Refineries and Contribution

Pakistan's petroleum industry holds strategic importance as it generates significant government revenue, adds value, and optimally utilizes port infrastructure. The growing population, urbanization, and increase in socio-economic activity also underscore the importance of oil refineries to meet the local demand. In addition to producing petroleum products, refineries contribute significantly to the country's GDP (through their output utilization in various sectors), employ hundreds of thousands of workers, add value to the economy, save foreign exchange reserves, and meet, on average, 57% of the country's annual demand (see Table 2.1).

Table 3.1: Domestic Refineries Contribution to Total Consumption

Year	Total consumption (mln MT)	Refineries Contribution (mln MT)	Refineries Contribution (%)
2019	20.0	11.8	61%
2020	17.6	9.35	54%
2021	20.7	11.07	55%
2022	22.7	10.9	48%
2023	16.7	9.4	56%
2024	15.2	10.6	69%

Source: OCAC: Pakistan Oil Report

3.3 Historical Development of Pakistan's Oil Refining Sector

Pakistan's oil refining sector has historically evolved to reflect strategic energy security goals and broader industrial development. Oil refining in the region dates back to the pre-partition era, when the Attock Oil Refinery (ARL) was established in Rawalpindi by the Attock Oil Company in 1922. Initially intended to process crude oil extracted from the Potohar region, this marked a significant foundation for future development in Pakistan's petroleum refining industry.

After independence in 1947, Pakistan faced tremendous obstacles in developing an indigenous industrial base, particularly in the area of energy infrastructure. With increased domestic demand for petroleum products and ARL's limited capacity, the government adopted a diversification and expansion strategy. This led to the establishment of Pakistan Refinery Limited (PRL) in Karachi in 1960. PRL, a hydro-skimming refinery, played a critical role in meeting growing fuel demand and facilitating port-based crude imports.

In 1993, National Refinery Limited (NRL) was established in Karachi to produce base oils for lubricants and fuel products. It became the first refinery to produce lubricants on a commercial basis. Furthermore, in 2000, the establishment of the Pak-Arab Refinery Company (PARCO) in Multan, a joint venture between the Government of Pakistan and Abu Dhabi, marked a significant milestone in the refining industry. It operates as a semi-conversion refinery, contributing significantly to the country's energy distribution (Ministry of Energy, Petroleum Division, 2023).

In early 2000, Bosicor, previously Byco Petroleum Pakistan Limited (BPPL), later rebranded as Cnergyico PK Limited, commenced operations in 2004. The company's two refineries in Hub, Balochistan, have a combined capacity of more than 150,000 barrels per day, making it the country's largest integrated refining complex. (Cnergyico PK Ltd., 2023).

Table 3.2: Status of Five Major Oil Refineries

Refinery	Year	Technology	Capacity (BPD)
PARCO	2000	Mild Conversion	120,000
	2010 (EURO II)		
	2011 (AABU)		
	2020 (upgrade)		
ARL	1992 (original)	Hydroskimming	53,000
	1999 (upgrade)		
	2016 (upgrade)		
NRL	1966 (lube)	Lube + Hydroskimming	70,000
	1977 (fuel)		
	2018 (upgrade)		
PRL	1962	Hydroskimming	50,000
	2015 (upgrade)		
Cnergyico I	2004 (Commissioned)	Hydroskimming	35,000
	2008 (Capacity enhanced)		
Cnergyico II	2015 (Commissioned)	Hydroskimming	120,000
	2017 (upgrade Isomerization)		
Total Capacity			450,000

Source: PACRA

In the 20th century, Pakistan's oil refining industry primarily developed through government initiatives and international partnerships. This development showcased the government's role in planning industrial growth and building energy infrastructure. However, in the early 21st century, private firms began to play a more significant role, accompanied by new regulations. One turning point in this process was the Petroleum Policy 1997, which aimed to address the country's rising energy demand and reduce import dependency. The policy provides incentives for private investment through tariff protection, tax incentives, and a guaranteed investment rate to investors. The policy established a structured framework for private participation in the refining industry (Government of Pakistan, 1997).

However, the refining industry has largely stagnated over the past two decades, with no significant projects initiated; only two new refineries have been established in the last forty years. All refineries in Pakistan are based on hydroskimming technology, which lacks the complexity required to convert heavier crude fractions into higher-value, lighter products. The only exception is PARCO, which is based on a mild conversion process. In the context of long-term energy security, environmental obligations, and financial constraints, the future trajectory of the refining sector will be based on its ability to innovate, diversify, and integrate into global value chains.

3.4 Market Dynamics of the Petroleum Sector in Pakistan

3.4.1 Supply –Demand Analysis and Import Scenario

Over the past decade, demand for crude oil and petroleum products has followed a fluctuating trend, reflecting shifts in sectoral demand consumption patterns and macroeconomic conditions. On average, demand over the past five years stood at 21.4 MMT; consumption reached approximately 25 MMT in 2016-17, which declined to 19 MMT in 2018-19 and further dropped to 18 MMT in 2022 as shown in Fig. 2.3. The decline was led by an overall contraction in economic activity, following the fiscal austerity measures adopted by the newly elected government.

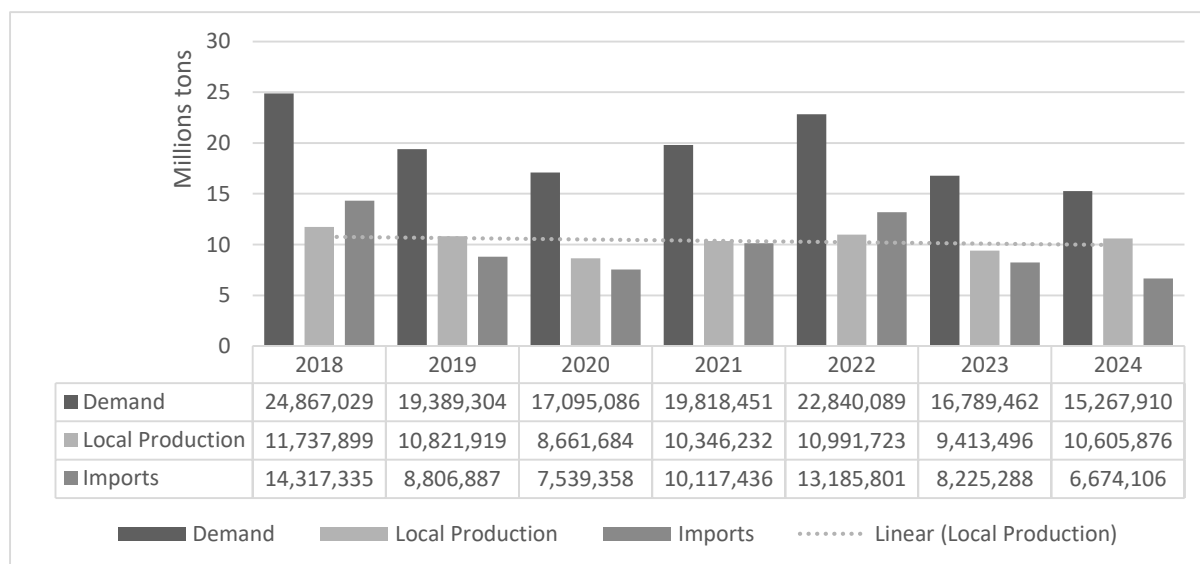


Figure 3.1: Total Demand for POL: Local Products and Imports

Source: OCAC 2022-23

In 2019-20, the decline in demand for petroleum products was due to the adverse impact of the global COVID-19 pandemic. In 2021, consumption reached a pre-pandemic level,

approximately 20 MMT. Domestic production in 2017 was 10 MMT, which increased to 12 MMT in 2018. However, in 2019, it declined to 9 MMT due to economic contraction and a decline in furnace oil demand. Additionally, lower demand from the transport and industrial sectors further contributed to the overall reduction in petroleum product consumption.

Similarly, refined products imports increased from 13 MMT in 2016-17 to 14 MMT in 2017-18 but dropped to 10 MMT in 2018-19. In 2022-23, the imports reached the pre-pandemic level of 11 MMT. The total oil consumption is fulfilled through local refining production and imports of refined products. The imports of refined products have remained below 50% in the last 5 years. In 2024, the share of imports was the lowest, at 43%, while the average local refinery production contributed 58% from 2019 to 2024.

3.4.2 Refinery Capacity Utilization and Output Trend

The capacity and utilization trend of the oil refining sector are depicted in Fig. 2.4. Refinery capacity in 2019 was 19.41 MT, which increased to 21.8 MT in 2023. Despite the increase in capacity, the average capacity utilization remains at around 58%, which is substantially lower than the global average of 80-90%. As shown in Figure 2.2, the utilization rate has declined from 72% to 57%, primarily due to economic contraction and a gradual decline in furnace oil consumption. The existing configuration of refining capacity highlights product yield inefficiencies, technological obsolescence, and changes in demand patterns.

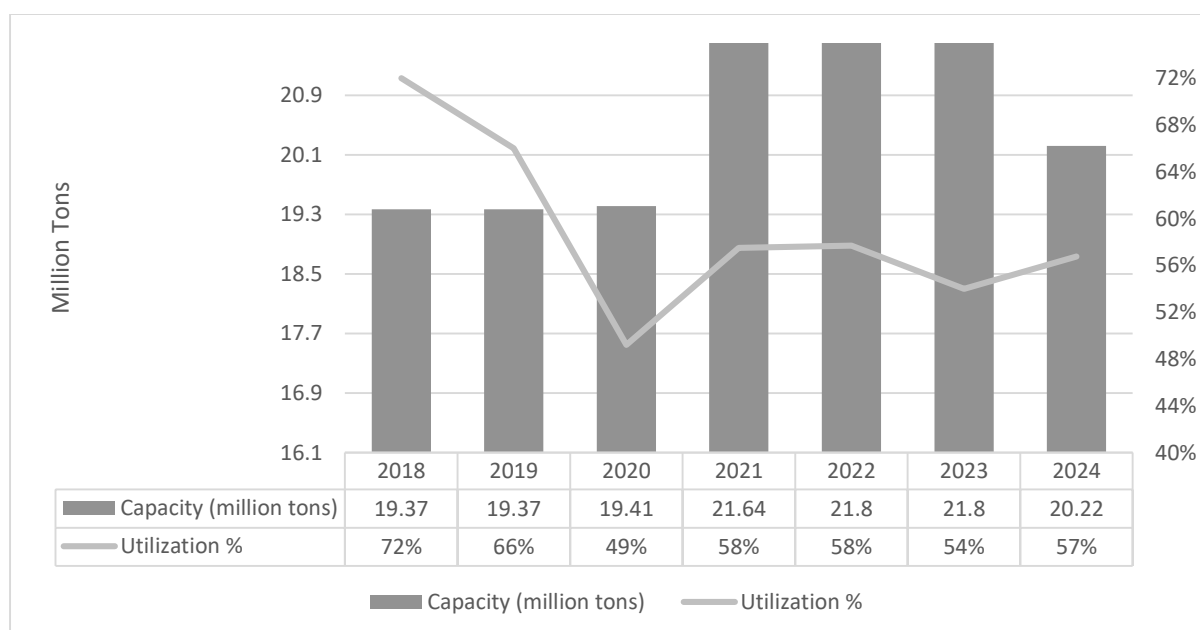


Figure 3.2: Refinery Capacity and Utilization

Source: OCAC 22-23

The current output of oil refineries, as indicated by product yield data from 2019 to 2024, demonstrates a sustained dependence on outdated hydroskimming technology and an inability to adjust product output. Despite a national policy shift from fuel oil-based power generation, furnace oil production remained high, averaging over 22%, with the highest value recorded in 2019 at 23.8%. This yield configuration reflects the technological constraints inherent in Pakistan’s refining infrastructure, which, in the absence of advanced processing units such as fluid catalytic cracking (FCC) and hydrocracking, faces challenges in converting heavier fractions into high-value products (MS and HSD), also known as positive margin products. The outcome is a suboptimal product slate, with MS and HSD yields averaging 20.3% and 37.1%, respectively. The increasing demand in the transport sector has resulted in significant imports of these products (OCAC, 2023).

Table 3.3: Output and Yield of Petroleum Products in Pakistan

	2019	2020	2021	2022	2023	2024
Throughput	12,795,046	10,079,439	11,843,833	11,997,710	10,414,786	11,475,828
Motor Spirit	2,274,711	1,978,989	2,521,510	2,496,327	2,211,665	2,376,701
High Speed Diesel	4,758,160	3,790,642	2,725,251	4,698,281	3,882,954	4,460,414
Kerosene	114,064	84,985	2,057,506	94,088	89,541	79,630
LDO	38,892	23,523	73,960	14,865	13,426	18,428
Furnace oil	3,047,477	2,344,108	2,679,652	2,472,115	2,107,700	2,518,929
Aviation Fuels	787,581	557,925	427,555	629,531	668,646	617,758
Naphtha	591,692	283,287	349,163	352,370	223,005	266,172
Liquefied Petroleum Gas	193,488	158,400	199,127	203,012	181,204	186,416
Yield Output (%)						
Motor Spirit	17.8 %	19.6 %	21.3 %	20.8 %	21.2 %	20.7 %
High Speed Diesel	37.2 %	37.6 %	23.0 %	39.2 %	37.3 %	38.9 %
Kerosene	0.9 %	0.8 %	17.4 %	0.8 %	0.9 %	0.7 %
Light Diesel Oil	0.3 %	0.2 %	0.6 %	0.1 %	0.1 %	0.2 %
Furnace oil	23.8 %	23.3 %	22.6 %	20.6 %	20.2 %	21.9 %
Aviation Fuels	6.2 %	5.5 %	3.6 %	5.2 %	6.4 %	5.4 %
Naphtha	4.6 %	2.8 %	2.9 %	2.9 %	2.1 %	2.3 %
Liquefied Petroleum Gas	1.5 %	1.6 %	1.7 %	1.7 %	1.7 %	1.6 %
Yield of Light Products	68.5 %	68.2 %	70.5 %	70.8 %	69.8 %	69.8 %

Source: Authors' calculation from the Pakistan Energy Yearbook, 2024.

The total crude processing (throughput) in Pakistan has remained relatively stable, fluctuating between 10 and 12 MMT per year, suggesting that improvements in capacity utilization are not leading to significant changes in product composition. The absence of deep-conversion capabilities and desulfurization units in local refineries is necessary to improve the yield pattern and reduce import reliance (Ministry of Energy, 2023). Implementing advanced conversion technologies would enhance the yield of high-demand light products and improve refinery economics.

3.4.3 Product Pricing Mechanism

Historically, petroleum prices in Pakistan were subject to stringent government regulation, with decisions frequently made by the government, often relying on political rather than economic considerations (Malik, 2008). Although regulatory reforms were introduced, a market-based pricing mechanism for imported products, the government recovers customs duties, which become part of the landed cost. Conversely, the pricing formula provided to local refineries is based on the import parity principle, allowing them to set the price of fuel equal to the calculated landed cost of imported fuel. To make the ex-refinery price equivalent to the import parity cost, the customs duty on imported fuel is incorporated into the ex-refinery price, and this component is referred to as deemed duty.

The pricing mechanism for petroleum products has certain implications for petroleum refineries. In 2000, the government implemented pro-market reforms in the petroleum sector, restricting its role to policymaking exclusively. The government then modified the guaranteed return formula for refineries to an Import Parity Price (IPP) formula. Before these reforms, all local refineries were operated under a completely regulated pricing mechanism. PRL, ARL, and NRL refineries operated under a fixed return formula that limited returns to between 10% and 40% of their equity, commonly referred to as the 10-40 formula. PARCO, which began operations in 2000, had a different formula because it promised a minimum of 25% return over eight years. In 2002, the government aimed to initiate deregulation in the oil sector by developing a new pricing formula for local refineries, excluding PARCO. This formula eliminated the 10% guaranteed return and introduced tariff protection through customs duties on imports of Jet fuel, Light Diesel Oil (LDO), and High-Speed Diesel (HSD). This concept originated in India, where tariff protection for oil refineries had been in place for some time. ARL, PRL, and NRL were required to allocate more than 50% of their profit after tax beyond

their respective paid-up capital into a special reserve, as funds for the upgrade of these refineries are intended to offset potential future losses.

As part of its deregulation policy, the government authorized the Oil Companies Advisory Committee (OCAC) in 2001 to review, establish, and announce petroleum product prices on a fortnightly basis, under the approved pricing formula. From July 2001 to April 2006, the Oil Companies Advisory Committee (OCAC) conducted a review and announced the ex-depot prices of motor spirit (gasoline), kerosene, and light diesel oil on a fortnightly basis, in accordance with the approved formula. In 2002, the Oil and Gas Regulatory Authority (OGRA) was established as the regulator responsible for setting prices and implementing regulations in the oil and gas sector. Furthermore, the pricing framework for petroleum products has shifted towards deregulation. Since 2011, the ex-depot and ex-refinery prices of many products, including MS, LDO, HOBC, and jet fuels was deregulated, allowing refineries and Oil marketing Companies to set and announce these prices (Malik, 2021). Later in 2012, the ex-refinery price of HSD was also deregulated, whereas the ex-depot price of HSD had been deregulated since 2001.

Table 3.4: Price Structure of Petroleum Products

At 01-01-2024	Ex-Refinery Price	Custom/Excise Duty	Petroleum Development Levy	OMC Distribution Margin	Dealers Commission	Inland Freight Equalization Margin (IFEM)	General Sales Tax (GST)
Motor Spirit	168.05	17.56	60.00	7.87	8.64	5.22	00
Kerosene	180.17	-	0.05	1.58	-	7.03	-
High Speed Diesel	178.55	17.86	60.00	7.87	8.64	3.29	00
Light Diesel Oil	159.16	-	-	1.61	-	4.98	-

Source: *EYB, 2024*

Following the deregulation process of petroleum products, the Economic Coordination Committee (ECC) retained the authority to approve the pricing parameters that govern these calculations. OGRA no longer determines prices; its role is limited to computing the IFEM, notifying prices, and monitoring compliance within the deregulated market. Under the prevailing pricing mechanism, the ex-refinery price is calculated by averaging the international Free-On-Board (FOB) prices from the Arab Gulf markets. The final price of petroleum products is made up of six major components: Inland Freight Equalization Margin (IFEM), Customs/Excise duty, Oil Marketing Companies (OMCs) margin, Petroleum Development Levy (PDL), Dealer Commission, and General Sales Tax (GST)⁴. An illustration of the Price Structure is given in Table 2.4.⁵

3.5 Key Issues in the Pakistan Oil Refining Sector

The oil refining sector in Pakistan faces significant challenges that undermine its long-term financial viability and competitiveness. The underutilization of refining capacity is a crucial issue that directly affects a country's energy security and operational efficiency. This underutilization of refining capacity is largely driven by outdated technology and a structural decline in demand for specific petroleum products, most notably furnace oil (FO). Historically, FO served as a primary fuel for electricity generation in thermal power plants. However, the country's shift towards cleaner and cost-effective fuel, particularly Liquefied natural gas (LNG), has sharply reduced FO consumption. Between 2016 to 2021, the furnace oil (FO) consumption plummeted from 9.6 to 3 million tons. Given that refinery configuration, produce a significant portion of FO, up to 30 to 40% of the total output (OCAC, 2022). The declining demand for FO has compelled oil refineries to scale back operations, manage excess inventory, and operate well below optimal capacity.

Moreover, Pakistan's oil refining sector is constrained by outdated technology and is inadequate to meet the evolving requirements of the modern petroleum market. Most refineries operate as hydro-skimming units – the least sophisticated processing technology. These units have limitations in processing heavy crude oil fractions to lighter, high-value petroleum products such as motor spirit (MS), high-speed diesel (HSD), and jet fuel. As a result, these refineries generate a disproportionately large volume of low-value residual fuels, for which

⁴ In the Finance Act of 2024, the sales tax was removed on major petroleum products, and the status was changed from zero-rated to exempt supplies.

⁵ The prices are in Rupees per liter.

domestic demand has sharply declined and has minimal export potential (TDAP, 2022; PACRA, 2023). Compared to advanced deep conversion refineries that can produce 80-90% light products, Pakistan's current hydroskimming units yield only 30-40%, forcing the country to rely heavily on imported high-value products. For instance, domestic refineries meet only 30% of motor spirit demand. This technological gap undermines energy security by heightening a country's exposure to global oil prices and exchange rate fluctuations.

Further, the refining sector struggles to align with international fuel quality standards. Even though the government mandated Euro-V dual imports in 2020, local refineries were unable to achieve this standard because of the substantial upgrade costs. The expected cost of converting a hydro-skimming refinery to a deep-conversion unit is between USD 1.2 and 1.5 billion, which remains exorbitant for many operators, given their current financial health and the regulatory uncertainty in the sector (SAARC Energy Center, 2021). Overall, technological obsolescence remains a significant obstacle to optimal performance. Without substantial investments in modernization, the sector will continue to lag behind global standards, remain reliant on expensive fuel imports, and contribute to overall energy insecurity.

The unpredictable regulatory environment and frequent alterations in taxation laws, price structures, and import duties create uncertainty for investors, leading to a reactive rather than strategic approach in Pakistani policymaking (Kiani, 2023). For instance, planning and refinery margins have been adversely affected by the absence of a transparent and definitive pricing system for petroleum products. The lack of a long-term refinery development strategy further postpones investment choices on capacity expansion and technological advancement. Despite the government initiatives of the Pakistan Oil Refining Policy 2023, its implementation remains in preliminary stages, and previous occurrences suggest potential delays and reversals in policy (Ministry of Energy, Petroleum Division, 2023). The sector is improbable in attracting substantial domestic or foreign investment without sustained policy support.

CHAPTER 4

THEORETICAL FRAMEWORK AND VARIABLES DESCRIPTION

Capacity utilization (CU) in oil refining reflects both internal operational efficiency and the extent to which external macroeconomic conditions facilitate or hinder optimal production. In the context of Pakistan's persistent challenges with underutilized refining capacity, understanding CU determinants provides essential insight for addressing performance inefficiencies. This theoretical framework draws on microeconomic production theory and macroeconomic aggregate demand theory to analyze the dynamics influencing the capacity utilization of oil refineries.

4.1 Determinants of Capacity Utilization

The capacity utilization of oil refineries, expressed as the ratio of the actual throughput to the maximum sustainable throughput, is a critical performance indicator that reflects economic viability and operational efficiency in the intricate landscape of petroleum refining (Haider, 1989). The interaction of macroeconomic variables with micro-level refining activities determines the utilization and sustainability of energy-intensive plants (Cabrera & Saray, 2012). The oil refining sector operates within a volatile macroeconomic landscape, where variations in crude oil prices, demand fluctuations, imports of refined products, and GDP growth rate influence refinery operations. Macroeconomic factors influence the pricing, supply, and demand for refined products both domestically and internationally, and they take a crucial role in determining investment incentives for refinery enhancements.

Empirical research affirms the role of macroeconomic factors that significantly affect capacity utilization in refining sectors. Goldar and Renganathan (2008) link the market demand and import penetration, which significantly affect capacity utilization in refining sectors. Ezie (2023) investigated the impact of specific macroeconomic factors on oil refining production. The study highlights how crude oil prices and fluctuations in exchange rates influence refinery margins. Therefore, a thorough understanding of these components is necessary to develop efficient policies, form informed strategic decisions, and plan investments within the energy sector.

4.2 Theoretical Approaches

4.2.1 Production Function Theory

The production function theory, derived from neoclassical economics, posits that production output is a function of inputs such as labor, capital, and raw materials, alongside a specific technology (Samuelson & Nordhaus, 2009; Varian, 1992).

$$Q = f(K, L, M)$$

Production function theory describes how input prices and technical efficiency determine output levels. The decision for a refinery to operate at or below capacity primarily depends on labor efficiency, capital availability, and crude oil costs. The theory posits that firms aim to operate at a point where marginal cost is equal to marginal revenue. Macroeconomic factors such as depreciating currencies or increasing oil prices can increase input costs. For oil refineries, high crude prices or capital constraints may lead companies to operate below full capacity to mitigate losses. Several empirical studies concerning industrial production and energy-intensive sectors have employed this method (Kerstens & Managi, 2012b; Rentschler, 2013), providing a theoretical basis for this research. For instance, Rentschler (2013) used it to examine how capital constraints and energy prices affect capacity and productivity decisions in developing countries. These findings support the theoretical underpinnings of this study on capacity utilization in oil refineries.

4.2.2 Keynesian Aggregate Demand Theory

The aggregate demand theory, originating in the 1930s with John Maynard Keynes, suggests that fluctuations in aggregate demand primarily influence short-term economic production and employment levels. In contrast to classical economic models that emphasize supply-side factors and assume markets inherently move towards full employment, the Keynesian framework acknowledges that insufficient demand can keep output levels below potential (Keynes, 1936; Mankiw, 2015). Analyzing industrial sectors, such as oil refining, that experience cyclical fluctuations in economic activity, relies on this theoretical framework.

The oil refining sector, viewed through a Keynesian lens, posits that macroeconomic conditions influence refinery production and capacity utilization. Increased income levels, heightened manufacturing activity, and enhanced mobility during robust economic growth contribute to a rise in demand for refined petroleum products. The increased demand compels refineries to optimize throughput, pushing capacity utilization to its technological limits. Conversely, reductions in industrial activity, transportation demand, and consumer spending contributed to

decreased demand for petroleum products during periods of economic downturn or stagnation. Refineries are compelled to reduce output, leading to suboptimal utilization of existing capacity (Hamilton, 2009b). Similarly, in Pakistan, excessive imports of refined products undermined domestic production and significantly affected the capacity utilization of oil refineries (Kiani, 2025).

Keynesian theory remains particularly pertinent, where industrial sectors are highly susceptible to fluctuations in aggregate demand. Essential demand-side factors encompass GDP growth, which indicates industrial and transportation demand; currency exchange rates, which affect import prices and competitive positioning; and refined product imports, which may undermine domestic refining activities. Robust GDP growth typically results in a corresponding increase in energy consumption, prompting refineries to operate at higher capacities. Similarly, favorable exchange rates reduce input costs and enhance refinery profitability, encouraging increased utilization.

4.3 Conceptual Framework

This study examines the determinants of capacity utilization in Pakistan's oil refining industry through a dual-theoretical framework that integrates Production Function Theory and Keynesian Aggregate Demand Theory. Production Function Theory, grounded in neoclassical microeconomics, posits that output is determined by factor inputs such as capital, labor, and raw materials, contingent upon technological efficiency (Varian, 1992). It explains the influence of input factors (such as crude oil prices, technology, etc.). However, this model alone cannot explain fluctuations driven by macroeconomic conditions, such as GDP growth, exchange rate fluctuations, and import penetration, which affect both the demand for refined products and the cost of inputs, ultimately influencing the operational scale of refineries.

Aggregate demand theory focuses on broader macroeconomic influences such as crude oil prices, demand for refined petroleum products, exchange rate, and GDP growth rate. Keynesian economics posits that an increase in aggregate demand during periods of economic expansion leads to heightened energy consumption, thereby encouraging greater capacity utilization. Additionally, excessive dependence on imports may diminish domestic production; however, a declining exchange rate raises the expenses associated with imported fuels, suggesting a potential benefit in promoting domestic production.

The conceptual framework models capacity usage as a function of production-side factors, such as crude oil prices, and macroeconomic variables, including import of refined products, exchange rate, and GDP growth rate.

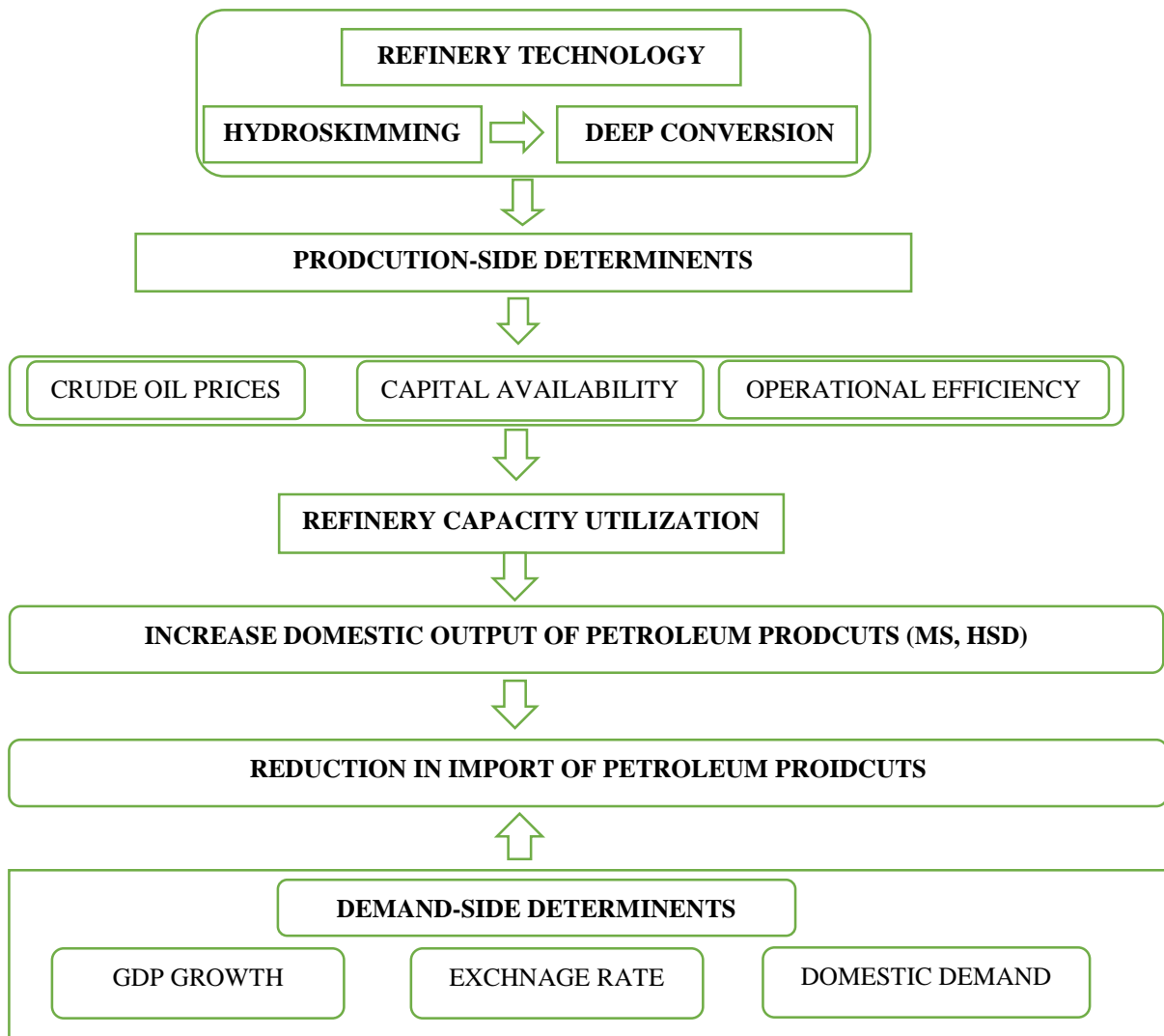


Figure 4.1. Conceptual framework

Figure 4.1 outlines a conceptual framework that visually links the study's key constructs. The framework integrates the production-side determinants derived from Production Function Theory with macroeconomic demand-side factors grounded in Keynesian Aggregate Demand Theory, including refinery technology (hydro-skimming versus deep-conversion) in shaping operational efficiency. These collectively determine refinery capacity utilization, which, in turn, influences domestic output of refined petroleum products and the level of refined product imports.

4.4 Data and Variables Description

This section describes the variables for the quantitative analysis, which are essential in understanding the refinery capacity utilization and its influencing factors.

4.4.1 Dependent Variables (Capacity Utilization)

Capacity utilization is an essential factor that characterizes business activity in any economy and is a significant concern in economic analysis. It is usually applied in empirical studies to explain productivity measurement, inventory, and investment behavior, and is sometimes used as an indicator of aggregate demand (Schultze, 1963). Various definitions of capacity utilization exist, such as economic and engineering. It is an essential concept in industrial economics that measures how much a firm or plant uses its productive capacity.

$$\text{Capacity Utilization (CU)} = \frac{\text{Actual output}}{\text{Potential output}} \times 100$$

Thus, plant capacity is considered the maximum output that can be attained using the given technology and the fixed input when the variable input vector may assume any non-negative value. Therefore, capacity utilization equals the ratio of observed output to Plant capacity (Coelli et al., 2002). Capacity utilization is the ratio of actual output produced to potential capacity output, achievable using the quasi-fixed input. Utilization also reflects the ability to generate output within a given time period (Afroz & Roy, 1976). In economic terms, capacity utilization is the ratio of actual output to the optimum output level before the average cost of production rises. Capacity utilization is a percentage of total potential output (Berndt & Morrison, 1981).

4.4.2 Independent Variables

a) Crude oil prices

Crude oil prices are input costs that, in theory, should significantly affect refinery capacity utilization through a complex interplay between market dynamics and operational considerations (Shokouhi et al., 2024). As feedstock constitutes a substantial portion of the refinery's operating expenses, refinery margins are decreased when crude oil prices increase without a corresponding increase in refined product pricing (Shokouhi et al., 2024). Assuming that the demand for refined products is sufficiently strong and that market conditions allow refineries to take advantage of the reduced input costs, a decrease in the price of crude oil, on the other hand, inspires a greater throughput. This would result in an increase in profitability

and a higher capacity utilization rate. Similarly, Ruble (2019) highlighted that fluctuations in crude oil prices affect the refinery margins, leading to lower utilization.

b) Import of refined products

Goldar & Renganathan (2008) studied the impact of import penetration on the domestic industry and found a significant impact on capacity utilization. From this study, we concluded that the import of refined products significantly impacts capacity utilization, representing an external market factor that compels refineries to adjust their operations dynamically to correspond with prevailing market conditions.

c) GDP Growth Rate

Energy consumption is driven by economic growth, which in turn influences refinery utilization directly. As the economy expands, demand for petroleum products increases, which stimulates higher output from refinery production due to more utilization. Empirical studies such as Ezie (2023); De Lima and Schaeffer (2011) confirm a positive correlation between GDP growth and capacity utilization of refineries.

d) Exchange rate

The exchange rate plays a significant role in determining capacity utilization, especially since refineries rely on imported crude oil and equipment. Thus, fluctuations in the exchange rate impact on the cost of crude oil and equipment imports. Similarly, a depreciating local currency increases the production cost, resulting in the refinery operating at a lower capacity (Agarwal, 1997; Ezie, 2023a).

e) Crude oil supply

Crude oil is a fundamental prerequisite that serves as an essential input, determining the extent to which installed capacity can be utilized, and is considered an important factor in determining the capacity utilization level. There are more than 150 types of crude oil, which are differentiated based on sulfur content (sweet vs. sour) and API gravity (light, medium, heavy), which affects their suitability for specific refinery configurations. Moreover, the crude oil supply chain disruption, limited supply, port handling infrastructure, and the technical configuration of domestic refineries (e.g., hydro-skimming and deep conversion) affect the refinery operation. The profitability of a refinery operation primarily depends on two key elements: a stable supply of crude oil and technical ability (Chen, 2003b). Crude oil is difficult

to store and is typically processed in fixed ratios with capital and labor. However, the adoption of advanced technical capabilities, such as refinery complexity, enables refineries to extract a higher yield of light-fuel products from lower-quality and lower-cost crude oil. This process significantly increases the profit margins on refined products.

Table 4.1: Determinants of Capacity Utilization

Variables	Unit	Formulae	References	Data Source
Dependent Variable				
Capacity utilization	Percentage %	$\frac{Actual\ throughput}{Nameplate\ capacity} \times 100$	(Desrochers, 2013) (Atris, 2020)	Pakistan Energy Yearbook
Independent Variables				
Import refined products	Percentage %	$IRP = \frac{Import\ Products}{Total\ demand} \times 100$	(Goldar & Renganathan, 2008)	Pakistan Energy Yearbook
GDP growth rate	Percentage %	$GDP_g = \frac{GDP - GDP_{t-1}}{GDP_{t-1}} \times 100$	(Ezie, 2023a)	World Development Indicator (WDI)
Crude oil Prices	USD per barrel	Average annual Crude oil prices	(De Lima & Schaeffer, 2011)	West Texas Intermediate crude (WTI)
Exchange rate	Percentage %	$NEX = \frac{N \times P_T}{P_N}$	(Agarwal, 1997)	World Development Indicator (WDI)
Crude oil supply	MMT/Year or Barrels/Year	Annual import of crude oil	(Zurlo, 2016)	Pakistan Energy Yearbook

CHAPTER 5

DATA AND METHODOLOGY

This chapter presents the methodological framework employed to address the research objectives. The study aims to investigate the macroeconomic factors that influence the capacity utilization of oil refineries, compute the economic implications of increased utilization through a scenario-based analytical framework, and explore the issues that contribute to underutilization and impede technological upgrades through qualitative analysis. A mixed-methods approach is adopted, which includes econometric modelling, scenario analysis, and qualitative analysis. This triangulated technique ensures that the research assesses both the empirical and policy-level factors that shape the operational landscape of the oil refining sector.

5.1 Econometric Methodology

This section outlines the methodological framework adopted to empirically examine the impact of macroeconomic determinants and the capacity utilization of oil refineries in Pakistan. We use unbalanced panel data from 1996 to 2023, given the time series and cross sectional units of the data covering six oil refineries over 28 years, the study adopts the Panel Autoregressive Distribution Lag (Panel ARDL) model using the Pooled Mean Group (PMG) estimator, as proposed by (Pesaran et al., 1999) to show the dynamic relationship between macroeconomic determinants and the impact of the capacity utilization rate of oil refineries. The panel ARDL is suitable for three reasons. Firstly, the data sets include a moderate number of cross sections ($N = 6$) and a relatively long time dimension ($T = 28$). Secondly, this model is applicable when the variables are in mixed order $I(0)$ or $I(1)$ (Pesaran et al., 1999b). Thirdly, our objective is to show the impact of macroeconomic determinants on capacity utilization in both the short and long run.

The empirical analysis is based on models involving sets of explanatory variables. The following empirical models estimate factors affecting capacity utilization. We have used the following equation as a basic model to capture the impact of factors influencing the capacity utilization rate.

$$\ln CU_{it} = \beta_0 + \beta_1 \ln CP_{it} + \beta_2 \ln IRP_{it} + \beta_3 \ln GDPGR_{it} + \beta_4 \ln REXR_{it} + \beta_5 \ln CS_{it} + \varepsilon_{it} \dots \dots \dots (5.1)$$

Where,

- $LnCU_{it}$: Log of Capacity utilization rate i at time t
- $LnCP_{it}$: Log of Crude oil prices i at time t
- $LnIRP_{it}$: Log of Import of refined products i at time t
- $GDPGR_{it}$: GDP growth rate i at time t
- $LnREXR_{it}$: Log of Real Exchange rate i at time t
- $LnCS_{it}$: Log of Crude oil supply i at time t
- ε_{it} : error term

Based on the work of (Pesaran & Shin, 1996), the ARDL(p,q) model is defined by the following equation.

$$lnCU_{it} = \sum_{j=1}^p \alpha_{ij} lnCU_{i,t-j} + \sum_{j=0}^q \delta'_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (5.2)$$

Where,

$lnCU_{it}$ is the dependent variable, X_{it} Indicates a Vector of explanatory variables includes LnCU, LnCP, LnIRP, GDPGR, LnREXR, and LnCS. α_i is the coefficient of the lagged dependent variable, β'_{ij} are the coefficients of the vector and U_i indicates a specific fixed effect, ε_{it} : error term

To incorporate the adjustment coefficient, the long-run dynamics equation 5.2 is reparametrized into an Error Correction Model (ECM) as follows.

$$\Delta lnCU_{it} = \phi_i (lnCU_{i,t-1} - \beta'_i X_{i,t}) + \sum_{j=1}^{p-1} \alpha_{ij} \Delta lnCU_{i,t-j} + \sum_{k=0}^{q-1} \delta_{ij} \Delta X_{i,t-j} + \mu_i + \dots + \varepsilon_{it} \dots \quad (5.3)$$

Where ϕ_i is the speed of adjustment coefficient (Error correction) of the long run dynamics (expected to be negative and significant). β'_i A vector of long-run equilibrium coefficients between $lnCU_{it}$ (Dependent variable) and X_{it} (Explanatory variables), α_{ik} and δ_{ij} indicates the Short-run dynamic coefficients linking capacity utilization with its past values and the variable of interest X_{it} . A long-run relationship between capacity utilization and macroeconomic determinants exists if the ϕ_i is negative and statistically significant, then cointegration exists between $lnCU_{it}$ and X_{it} . To estimate three estimation (5.3), three techniques are used: Pooled Mean Group (PMG) developed by Pesaran et al. (1999), Mean Group (MG) developed by (Pesaran & Smith, 1995), and Dynamic Fixed Estimator (DFE).

This study employs the Pooled Mean Group (PMG) estimator in the Panel ARDL framework, as developed by Pesaran et al. (1999), to estimate the short-run and long-run relationship between macroeconomic determinants and capacity utilization. The PMG estimator is well-suited for dynamic heterogeneous panels where the number of cross-sectional units (N) is less than the number of time periods (T). In the short run, the dynamics are different between units, such as error variances, intercepts, and adjustment speeds, but keep the long-run slope coefficients the same across units.

Alternatively, the Mean Group (MG) and Dynamic Fixed Effects (DFE) estimators are two other methods for estimating panel ARDL models. Pesaran and Smith (1995) developed the MG estimator, which calculates the mean of the coefficients from the distinct regressions of each cross-sectional unit, allowing for total heterogeneity in both short-term and long-term factors. This method is flexible; nonetheless, it requires an extensive time series to be effective. The DFE estimator, instead, posits that all units possess identical slope coefficients and error variances. This indicates that all units possess identical adjustment speeds and short-run dynamics, while also allowing for unit-specific intercepts.

5.2 Scenario-Based Analytical Framework

This section uses scenarios to evaluate the economic benefits of enhancing refinery capacity utilization and shifting from hydro-skimming to deep conversion technology in Pakistan's oil refining sector. The main objective is to quantify potential foreign exchange savings from reduced imports of refined petroleum products and improved domestic refinery utilization.

The methodological approach includes developing hypothetical scenarios, which is a widely applicable method for assessing the impact of technological shifts to simulate enhanced operational performance within the current refinery infrastructure. The scenario-based analysis is appropriate for studies in the energy sector, where infrastructural change, investment decisions, policy change, and technological advancement have long-term and dependent consequences (Fortes et al., 2015; Van Vuuren et al., 2014). In oil refining, decisions to enhance capacity utilization or to upgrade technology significantly impact operational economic performance and national energy security. Numerous studies have employed scenario-based approaches to examine refinery expansion and energy transitions in both global and regional contexts. Fortes et al. (2008) employed scenario modelling to examine the expansion of refineries worldwide in response to varying demand scenarios. This method allows for the estimation of economic impacts resulting from improved refinery performance.

It involves creating realistic future scenarios and calculating the potential economic benefits of decreasing the import of refined petroleum products. This is achieved through increased domestic refining activity and technological upgrades in oil refineries.

This analysis aims to assess two interconnected strategic interventions.

- Increase refinery capacity utilization from the current average of 53 percent to 80 percent.
- Transforming all existing refineries from hydro skimming to deep conversion technology, as it enhances the yield of high-value products such as motor spirit (MS) and high-speed diesel (HSD) while reducing the output of residual fuel oil.⁶

The study simulates plausible future scenarios of the refining sector under various combinations of these two characteristics. Each scenario assesses the associated economic outcomes, particularly reducing import dependency, foreign exchange savings, and enhanced product yield. This study utilizes scenario analysis to evaluate the above two aspects:

- **Baseline Scenario:** It reflects a current average capacity utilization rate of 53% approx.
- **Scenario A:** The first scenario will assume constant capacity and an increase in utilization rate up to 6 % per year.
- **Scenario B:** The second scenario assumes an increase in nameplate capacity of 5 % and a utilization rate of 6% per year, respectively.

These two scenarios will be utilized in hydroskimming and deep conversion technology. In order to facilitate the scenario-based evaluation of enhanced capacity utilization and technological improvements in Pakistan's oil refining sector, a collection of well-informed assumptions is established. These assumptions reflect the operational improvements through focused upgrades and maintenance by ongoing planned projects. The 5% capacity enhancement is based on the current capacity expansion plan of domestic refineries, while the 5-7% annual increase in utilization is achievable in developing refining markets through maintenance and technological upgrades.

⁶ All refineries are operating on hydroskimming technology except PARCO which are based on Mild Conversion for the simplicity of the analysis we assume that all refineries are operating on hydroskimming.

Table 5.1: Assumptions for Scenario-Based Analysis

Variables	Assumption
Crude oil prices	Increase in the cost of crude oil up to 10%
Refined products prices	Increase in the cost of refined products up to 10%
Domestic demand	Increase in domestic demand up to 5%
Capacity utilization increases	6% per year

According to the energy technology system analysis programme (ETSAP) asserts that hydro-skimming and deep conversion refinery techniques provide significant differences in product outputs, which directly influence the economic efficiency of petroleum refining. Hydro-skimming refineries have a limited capacity to transform greater proportions of crude oil into high-value products, typically yielding around 28% motor spirit and 30% high-speed diesel.

Table 5.2: Assumptions-Level of Complexity and Yield Pattern

Technology	Product Yield (Motor Spirit/Gasoline)	Product Yield (High Speed Diesel)	Residual fuel Oil
Hydro skimming	28%	30%	More than 30%
Deep Conversion	42%	47%	Less than 10%

Source: ETSAP, 2014

In comparison, deep conversion is a special class of conversion refineries. They include not only hydrocracking and/or catalytic cracking to convert gas oil fractions but also coking. The coking units crack the heaviest and least valuable crude oil fractions (residual oil) by converting them to lighter streams that produce more valuable light products, approximately 42% motor spirit and 47% diesel, using sophisticated upgrading equipment such as hydrocrackers and catalytic crackers (ETSAP, 2014). Deep conversion units are more suitable for meeting market demand trends that favor light and medium distillates. By incorporating these yield variances into scenario analysis, it is possible to more accurately calculate the potential benefits of technical upgrading in Pakistan's oil refining industry.

5.3 Qualitative Analysis

The qualitative research component of the study is designed to explore the issues of underutilized capacity and barriers that impede the modernization of oil refineries. Given the complexities associated with the oil refining sector, quantitative methods may not adequately capture these challenges. Therefore, this part of the research employs a case study approach suitable for an in-depth understanding of complex phenomena.

5.3.1 Sampling Technique and Data Collection

The purposive sampling method was utilized to identify key informants with relevant experience in the oil refining industry, such as policymakers, industry specialists, and energy economists. This technique ensures that only participants with a comprehensive understanding of the refining sector are selected, thereby enhancing the quality and relevance of the information collected. The participants are expanded through professional networks; snowball sampling, in which initial participants suggest more knowledgeable individuals in their professional networks. Furthermore, the sample size was determined on the principle of data saturation, allowing data collection to continue until no new themes were identified during the interviews.

The primary data are collected through Key Informant Interviews (KIIs) with key stakeholders in a semi-structured format. Semi-structured interviews allow researchers to add to a pre-established list of questions with further questions to probe the phenomenon and facilitate participants to describe in more detail their experiences and insights. A total of 9 interviews were conducted, and the last number was decided on the point of data saturation. Out of 9 interviews, 7 were conducted in person, and 2 were online. In addition, document analysis is performed to review the current brownfield refinery policy (2023) with a particular emphasis on the clauses relating to refinery upgrades. This combination of interviews, policy analysis, and existing literature is discussed with a thorough understanding of both institutional and regulatory constraints to refinery modernization.

5.3.2 Qualitative Data Analysis

After collecting data, we will use thematic analysis to systematically identify, analyze, and interpret patterns in the data. Thematic analysis is a method of analyzing and interpreting data to identify themes and patterns within qualitative data. Braun and Clarke (2006) define thematic analysis as a method applicable at various stages of analyzing and reporting data after coding, allowing the capture of the patterns in the qualitative data.

Thematic analysis is a qualitative technique used to identify, organize, and interpret the pattern of meaning (themes) observed in the dataset. The Thematic Analysis involves various steps for analyzing data collected through interviews. According to Bryman and Burgess (1994), the following are steps for the thematic analysis approach. (1) Familiarization with data (2) Identification of themes (3) Generating initial themes (4) Reviewing themes (5) Defining and naming themes (6) Using themes to interpret the results. It is a technique that enables the identification of patterns, whereby one gets familiar with the data, develops codes, looks for themes, refines and defines themes, and, in the end, produces narratives that respond to the research question.

Limitations and Ethical Considerations

The qualitative section of this study involved in-depth interviews with key stakeholders, including industry experts, providing an insight into operational and policy dynamics. Nonetheless, a number of methodological and ethical limitations should be acknowledged. First, the findings are based on a purposive sample selected for expertise and relevance; therefore, the results should not be generalized beyond the studied participants (Orb et al., 2001). Second, as is characteristic of qualitative interviewing, participants' responses are framed by individual experience, perception, and professional background (Hammarberg et al., 2016). Third, data reflect the situation at the time of collection; hence, policy changes and emerging market conditions may affect the applicability of these insights over time. Despite these limitations, the qualitative approach provides valuable depth and contextual insights that complement quantitative analysis.

Given that human participants were involved, the research adhered to stringent ethical standards in line with existing guidelines for qualitative research. The participants were fully informed about the purpose of the study, the use of data, and their right to withdraw from the study at any stage without any consequences, as principles for ensuring informed consent and voluntary participation, as suggested in the literature (Hammarberg et al., 2016; Orb et al., 2001). Likewise, in line with the economic literature (Wiles et al., 2008), confidentiality and anonymity were ensured by storing data in a secure location and deleting information that could lead to disclosure. Specific measures were taken to ensure that sensitive information during interviews was protected from harm or undue influence. All contributions were accurately represented in the analyses, ensuring the trustworthiness, integrity, and credibility of the qualitative findings.

CHAPTER 6

RESULTS AND DISCUSSION

This chapter presents the main results of quantitative and qualitative analysis, addressing the core objectives of the study. The quantitative analysis investigates the macroeconomic determinants of capacity utilization in Pakistan's oil refineries using the panel ARDL approach. The findings reveal the short-run and long-run elasticities of the panel ARDL, supported by necessary pre-estimation tests, including unit root and model selection criteria. In line with the second research objective, a scenario-based analysis is conducted to assess the potential economic impact of enhancing capacity, utilization level, and upgrading technology from hydroskimming to deep conversion configuration, which aims to reduce imports of finished products. Finally, the chapter addresses the third research objective by interpreting and explaining the findings of the qualitative analysis, which was conducted through thematic analysis as part of the study to explore the issues behind underutilization and delayed modernization in the Pakistani refining sector.

6.1 Empirical Analysis of Macroeconomic Determinants

6.1.1 Panel Unit Root Test

Prior to conducting the panel estimation, a unit test was performed for all selected variables to ensure that there was no tendency towards spurious regression when using panel data. To test the unit root of panel data sets, we used a variety of tests, taking into consideration sample size and the asymptotic properties of the panel root tests: the Levin-Lin-Chu test (Levin et al., 2002), the Im-Pesaran-Shin test (Im et al., 2003), and the Fisher-ADF test (Choi, 2001), which have the null hypothesis that all the panels have a unit root. The results of the unit root tests are presented in Table 6.1 below, at both levels and first differences.

The finding shows a mixed order of stationarity. Some of the variables, such as LnIRP and GDPGR, are stationary at level $I(0)$, while the remaining variables, such as LnCU, LnCP, LnREXR, and LnCS, are stationary at the first order difference $I(1)$. The results of the stationarity tests reveal a mixed order of integration, $I(0)$ and $I(1)$, which confirms the use of

the panel Autoregressive Distributed Lag (ARDL) model. However, none of the variables are integrated of order two I (2), a requirement for estimating the panel ARDL model.

Where LnCU, LnCP, LnIRP, GDPGR, LREXR, and LnCS, represent Log of capacity utilization, Log of crude oil prices, GDP growth rate, Log of real exchange rate, Log of supply of crude oil, respectively.

Table 6.1: Panel Unit Root Test Results

Variables	Level & 1st Diff.	Intercept/trend	LLC	IPS	ADF	Inference
LnCU	Level	Intercept	0.99	0.70	0.34	I(1)
		Intercept & trend	0.95	0.85	0.83	
	1 st Diff.	Intercept	0.00***	0.00***	0.00***	
		Intercept & trend	0.00***	0.00***	0.00***	
LnCP	Level	Intercept	0.14	0.15	0.22	I(1)
		Intercept & trend	0.02**	0.12	0.23	
	1 st Diff.	Intercept	0.00***	0.00***	0.00***	
		Intercept & trend	0.00***	0.00***	0.00***	
LnIRP	Level	Intercept	0.02**	0.018**	0.03**	I(0)
		Intercept & trend	0.06	0.16	0.28	
	1 st Diff.	Intercept	0.00***	0.00***	0.00***	
		Intercept & trend	0.00***	0.00***	0.00***	
LnREXR	Level	Intercept	0.18	0.14	0.29	I(1)
		Intercept & trend	0.51	0.55	0.71	
	1 st Diff.	Intercept	0.00***	0.00***	0.00***	
		Intercept & trend	0.00***	0.00***	0.00***	
GDPGR	Level	Intercept	0.00***	0.00***	0.00***	I(0)
		Intercept & trend	0.00***	0.00***	0.00***	
LnCS	Level	Intercept	0.24	0.44	0.50	I(1)
		Intercept & trend	0.224	0.37	0.56	
	1 st Diff.	Intercept	0.00***	0.00***	0.00***	
		Intercept & trend	0.00***	0.00***	0.00***	

Note 1: **, *** indicate, 5%, 1%

6.1.2 Long Run Analysis

To determine the relationship between refinery capacity utilization and macroeconomic variables, a panel ARDL model is employed. In the ARDL framework, selecting the appropriate lag length is a crucial step. The Akaike Information Criterion (AIC) is utilized for this purpose to determine the optimal lag length. Based on the Akaike Information Criterion (AIC), the optimal lag length selection indicated that a maximum of two lags should be included in the ARDL model. The results of the long-run Panel ARDL model are presented in Table 5.2.

Table 6.2:Results of Long-Run Elasticities of Panel ARDL

Selected Model: ARDL (1, 2, 2, 2, 2, 2)			
Variables	Coefficient	t-Statistic	P-Value
LnCP	-0.081	-4.35	0.000
LnIRP	0.593	13.27	0.000
GDPGR	0.109	11.70	0.000
LnREXR	-1.181	-7.90	0.000
LnCS	0.057	0.87	0.383

The findings indicate a negative and statistically significant relationship between crude oil prices and capacity utilization, suggesting that an increase in crude oil prices contributes to a decrease in capacity utilization. This inverse relationship coincides with economic expectations, as an increase in crude oil prices (input costs) can reduce refining margins and discourage refinery utilization. Economically, this result can be attributed to cost-push inflation. When crude is the primary input for refineries, it becomes expensive, raising operational costs and increasing uncertainty in supply chain planning and financial forecasting. These findings are consistent with the study by Chesnes (2015), which examined the impact of higher crude oil prices on refinery capacity utilization, considering volatility in the energy markets. Even minor disruptions in crude prices can significantly impact refinery capacity, which in turn has a large effect on downstream petroleum prices. Such results highlight the broader economic vulnerability of oil-importing countries due to the extraordinary dependence of other industries on petroleum products. Similarly, Yasmeen et al. (2019) emphasize that the oil price volatility negatively affects industrial operations due to increased input costs.

The coefficient of import of refined products (LnIRP) is positive and has a statistically significant relationship with capacity utilization. This result reveals a demand-driven

relationship; a surge in imports reflects increasing domestic consumption, which in turn encourages the utilization of refinery capacity to meet growing domestic demand. In contrast, the increase in imports can crowd out domestic production; this positive relationship highlights a more complex dynamic in the Pakistani oil refining sector. Given the persistent imbalance between domestic production and consumption, imports serve as a supplement rather than a substitute to meet domestic demand⁷. According to the Pakistan Energy Yearbook, 2022-23, local refineries currently meet only 30 percent of motor spirit and 70 percent of diesel demand, leaving the remaining supply-demand gap to be filled by imports. Imports demonstrates the need to expand refining capability to satisfy rising domestic demand. This indicates that imports exert upward pressure on local refining activities by demonstrating consistent growth in domestic consumption.

Furthermore, the positive relation between GDP growth rate (GDPGR) and capacity utilization is consistent with demand theory, as national income grows, energy consumption rises. This result is supported by the findings of Khan et al. (2020), who confirmed that economic growth drives industry energy demand, thereby fostering higher utilization of a refinery. As the economy grows, it stimulates energy demand for petroleum products across the manufacturing, transportation, and power sectors; these factors collectively encourage higher utilization of refining capacity.

The real exchange rate (LnREXR) exhibits a statistically significant negative long-term relationship with capacity utilization. These results align with a prior study by Ahmad et al. (2023) that emphasizes the adverse effects of exchange rate volatility on manufacturing output in Pakistan. The study suggests that currency depreciation raises the cost of crude imports, discourages procurement and refinery operations. As a result, it reduces financial viability, which in turn scales back operations to mitigate financial losses.

Lastly, the crude oil supply (LnCS) is positive but statistically insignificant in its relationship with capacity utilization, suggesting that variations in crude availability have a weak long-term effect on refinery utilization. The local crude production covers only 18-20% of the refineries' needs. Moreover, considering the technical limitations in refinery configuration and crude characteristics (e.g., sulfur content or API gravity), it is not possible to process all crude types.

⁷ As per the discussion during the interview with the Oil Industry expert

6.1.3 Short-run Analysis

The short-run results from the Panel ARDL error correction regression, presented in Table 5.3, indicate that the current change in imports of refined products, $\Delta(\text{LnIRP})$, is negatively and significantly related to the import of petroleum products and the capacity utilization in the short run. This suggests that an increase in refined products immediately puts downward pressure on the refinery capacity utilization, reflecting a short-run substitution effect. This is consistent with the empirical findings of Adewuyi. (2016) who examine a similar inverse relationship in Nigeria's downstream industry, high imports decline domestic refining throughput, as local markets were unable to compete with cheaper imports. The short-run substitution effect of imports appears to contradict the long-run demand hypothesis. However, it does not persist in the long run, which means that it is only a short-term phenomenon. Alternatively, the lagged imports change ($\Delta(\text{LnIRP}(-1))$ is not significant, showing that the effects of changes in import volume are current and don't persist in subsequent periods. Nonetheless, the inclusion of lag terms makes the model complete and captures short-run inertia possibilities. Although their impacts are not significant (Pesaran et al., 1999b).

Table 6.3: Results of Short-Run Elasticities of Panel ARDL

Variables	Coefficient	t-Statistic	P-Value
$\Delta(\text{LnPC})$	0.49	1.32	0.19
$\Delta(\text{LnPC}(-1))$	-0.09	-0.69	0.48
$\Delta(\text{LnIRP})$	-0.11	-2.30	0.02**
$\Delta(\text{LnIRP}(-1))$	-0.93	-0.95	0.34
$\Delta(\text{GDPGR})$	-0.06	-1.58	0.11
$\Delta(\text{GDPGR}(-1))$	-0.07	-1.37	0.17
$\Delta(\text{LREXR})$	0.98	2.92	0.00***
$\Delta(\text{LnREXR}(-1))$	2.84	0.92	0.35
$\Delta(\text{LnCS})$	-0.24	-0.69	0.48
$\Delta(\text{LnCS}(-1))$	1.52	1.05	0.29
$\Delta\text{COINEQ01}$	-0.72	-2.36	0.02**

Furthermore, the current exchange rate $\Delta(\text{LnREXR})$ has a positive and statistically significant effect on capacity utilization, indicating that currency depreciation affects capacity utilization in the short term. The findings imply that the short-term substitution impact, depreciation of

the exchange rate, raises the cost of importing refined products, incentivizing domestic refineries to operate at high utilization. These findings align with the empirical study by Shah et al. (2022), which explained that when the local currency depreciates, it makes imports more expensive and increases local competitiveness. Similarly, one argument is that currency depreciation decreases imports of refined products and boosts domestic refinery throughput. In the short term, refineries adjust quickly to exchange rate driven by immediate import cost changes, while in the long term, structural adjustment and market adjustment moderate this responsiveness. On the other hand, the lagged change in exchange rate, $\Delta(\text{LnREXR} (-1))$, is insignificant, indicating that refineries respond to current changes in exchange rate rather than those from previous periods.

Furthermore, neither the current nor the lagged GDP growth rate ($\Delta(\text{GDPGR})$ and $\Delta(\text{GDPGR} (-1))$) is statistically insignificant. This suggests that economic activity, as measured by GDP growth, does not have a substantial impact on refinery capacity utilization in the short-run. Economic growth is likely to impact refinery operations in the medium to long-run, as high demand induces capacity expansion and investment. According to Blanchard and Gali. (2007) found that short-term fluctuations in GDP are ineffective in influencing production plans in capital-intensive industries. This finding aligns with the refining sector, in which operations are rigid and respond mainly to structural, rather than cyclical, shifts in the economy.

In the short-run estimation, crude oil prices in the current period ($\Delta(\text{LnCS})$) and the lagged period ($\Delta(\text{LnCS} (-1))$) are statistically insignificant. This indicates that short-run fluctuations in international crude oil prices do not have an immediate impact on the capacity utilization of oil refineries in Pakistan. The results reflect the contractual and structural decisions based on long-term expectations, the medium-to-long-term crude oil supply agreements. These contracts are designed to prevent short-term price volatility in the international market. As a result, refineries are less likely to respond to crude price shocks. Moreover, as Tang et al. (2010) describe, the economic impact of oil price shocks is frequently nonlinear and delayed, with firms demonstrating inertia in responding to input costs. The insignificance of crude oil prices supports the notion that refinery capacity utilization is influenced by structural factors such as regulatory policies, infrastructural constraints, and the investment cycle.

The error correction term ($\text{CointEq} (-1)$) is -0.72 and significant ($p\text{-value} = 0.02$). This confirms the existence of a stable long-run relationship among the variables. The coefficient value of -0.72 indicates that approximately 70% of any short-run deviation from the long-run equilibrium

can be corrected within one period, confirming a strong speed of adjustment towards equilibrium aftershocks.

6.2 Scenario-Based Results and Their Implications

This section presents the results and discussions of four future scenario-based analyses aimed at computing the economic benefits in terms of reduced imports, as well as the strategic benefits of technological upgrades and capacity enhancements. These scenarios were developed to examine the implications of varying refinery capacity throughput, utilization rates, and technological upgrades on domestic production, import reduction, and economic efficiency. The central focus is to compare hydro-skimming versus deep conversion technologies in the context of enhancing the performance and economic contribution of Pakistan's refining sector.

6.2.1 Overview of the Scenarios

Four scenarios were constructed to analyze their respective economic implications systematically. To address the price volatility, the five-year average annual change in international crude oil and refined products (MS and HSD) was calculated using historical data. Based on the calculation, we assume a 10% increase in both crude oil and refined products prices. In 2023, the average crude oil import was 7.81 MMT, and finished products were 11.0 MMT. The cost per MMT is derived from real data for crude oil and finished product imports. The cost of crude oil surged from the base year (2023) of 522/MMT to 1,017 US million/MMT in year 7, whereas the average cost of petroleum products increased from \$729 million to \$1420 million. Furthermore, the demand for petroleum products is assumed to increase by 5 per cent per year⁸.

Scenario 1 (S1): Hydro-skimming Technology (Assume constant nameplate capacity with a 6% annual increase in utilization. This scenario projects performance enhancement without technological upgrades).

Scenario 2 (S2): Hydro-skimming Technology (Assume 5% annual increase in nameplate capacity with a 6% annual increase in utilization rate). This scenario maintains the same technological level (Hydro-skimming).

⁸ Keeping in view we assume that economy will grow at a rate of 5 percent

Scenario 3 (S3): Deep conversion Technology (Assume constant nameplate capacity with a 6% annual increase in utilization. This scenario project performance enhancement with technological upgrades under a deep conversion setup.

Scenario 4 (S4): Deep Conversion Technology (Assume 5% annual increase in nameplate capacity with a 6% annual increase in utilization rate). This scenario maintains the same (deep conversion) technological level.

These four distinct scenarios are discussed below.

Scenario 1 (S1): Hydroskimming Technology: Constant capacity with an increase in utilization rate (6%/Year)

If we keep the refineries' capacity constant at 20.8 million metric tons (MMT), with a 6 percent annual increase in utilization rate. This scenario is based on a hydroskimming configuration, characterized by limited conversion capabilities and low product flexibility. According to ETSAP (2014), yield assumptions specific to hydro-skimming units are fixed at 28% for motor spirit (MS) and 30% for high-speed diesel (HSD).

Table 6.4: Constant Nameplate Capacity with Increase in Utilization Rate (6% per annum)

Year	Base	Y-1	Y-2	Y-3	Y-4	Y-5	Y-6	Y-7
Nameplate Capacity (MMT) @5% (1)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Production (MMT) (2) = (1)*(3)	11.55	12.25	12.98	13.76	14.59	15.46	16.39	17.37
Utilization Rate 6% (3)	0.53	0.56	0.60	0.63	0.67	0.71	0.75	0.80
MS Yield (MMT) (4)=(2)*0.28%	3.12	3.43	3.63	3.85	4.08	4.33	4.59	4.86
HSD Yield (MMT) (5)=(2)*30%	3.47	3.67	3.89	4.13	4.38	4.64	4.92	5.21
Light Oil Product (MMT) (6)=(4)+(5)	6.59	7.10	7.53	7.98	8.46	8.97	9.51	10.08
MS Demand (MMT) @5% (7)	7.98	8.38	8.80	9.24	9.70	10.18	10.69	11.23
HSD Demand (MMT) @5% (8)	7.41	7.78	8.17	8.58	9.01	9.46	9.93	10.43
Industry Demand (MMT) (9)=(7)+(8)	15.39	16.16	16.97	17.81	18.70	19.64	20.62	21.65
MS Import (MMT) (10)=(7)-(4)	4.86	4.95	5.16	5.38	5.61	5.85	6.10	6.36
HSD Import (MMT) (11)=(8)-(5)	3.94	4.11	4.28	4.45	4.63	4.82	5.01	5.22
Import Requirement (MMT) (12)=(9)-(6)	8.80	9.05	9.44	9.83	10.24	10.67	11.12	11.58
Crude Cost (\$/MMT) @10% (13)	522	574	632	695	764	841	925	1017
Cost of Domestic Production (\$M) (14)=(6)*(13)	3438	4079	4756	5545	6466	7539	8791	10250
Imported MS Cost (\$/MMT) @10% (15)	737	811	892	981	1079	1187	1306	1436
Imported HSD Cost (\$/MMT) @10% (16)	720	792	871	958	1054	1160	1276	1403
Average (MS, HSD) Unit Cost \$M (17)	729	801	881	970	1067	1173	1291	1420
Total Import Value (\$ M) (18)=(17)×(12)	6412	7255	8317	9534	10926	12520	14345	16434
Net Savings \$ Million (19)=(14)-(18)	-2975	-3177	-3562	-3988	-4460	-4981	-5555	-6184

(Author's calculation)

As the utilization rate improves from 53 percent in the base year to 80 percent by Year 7. The total production of petroleum products increases from 11.55 MMT to 17.37 MMT. However, despite this increased throughput, the domestic production of light oil products (MS and HSD) only grew from 6.69 MMT in the base year to 10.08 MMT in Year 7. This projected growth is insufficient to keep pace with the growing industry demand, which is expected to increase at a rate of 5 percent per annum, reaching 21.65 MMT in the same period. As a result, the import requirement for these two products increases from 8.80 MMT to 11.58 MMT. This widening import gap highlights the technological limitations of hydroskimming units in processing heavier fractions of crude into higher-value products. A study by Siddiki and Kabir (2019) also highlights that hydroskimming refineries are inefficient and incompatible with modern fuel markets, which are expected to increase in developing economies.

Even at higher utilization, these (production) results are insufficient to meet industry demand, resulting in a continued reliance on costly imports of finished products. Consequently, the cumulative net savings remain negative throughout the scenario time frame, deteriorating from a –USD 2.97 billion deficit in the base year to a –USD 6.18 billion deficit by Year 7, as shown above in Table 6.4.

Scenario 2 (S2): Hydroskimming Technology: Incremental Expansion of Nameplate Capacity (5%) and Utilization rate (6%)

In this scenario, if the refineries increase their capacity and utilization rate, it will help determine whether simultaneous improvement can overcome the limitations of hydro-skimming technology. Over the projection period, the nameplate capacity increases from 21.8 MMT to 30.67 MMT, and the utilization rate reaches 80 percent by Year 7. The total production of petroleum products increases from 11.55 MMT to 24.45 MMT. As a result, the domestic production of light oil products (MS and HSD) increased from 6.59 MMT to 14.18 MMT, significantly reducing the import requirement to 7.47 MMT, compared to 11.58 MMT in Scenario S1 by Year 7. This indicates significant progressive gains due to capacity expansion, which slightly meets domestic demand and reduces the import burden at a slowing rate throughout the projected time frame.

The result shows that the net savings shift from negative to positive, reaching USD 9 million in Year 5 and increasing to USD 3.81 billion by Year 7 (see Table 6.5). However, the results provide substantial import substitution and economic gains in terms of foreign exchange savings. Yet, similar to Scenario 1, the technological rigidity of hydro-skimming is constrained

by its low product yield efficiency and high production of residual oils such as furnace oil, which restricts the refining operations from fully aligning with domestic demand patterns.

Table 6.5: Incremental Expansion of Nameplate Capacity (5% Per Annum) and Increase in Utilization Rate (6% Per Annum)

Year	Base	Y-1	Y-2	Y-3	Y-4	Y-5	Y-6	Y-7
Nameplate Capacity (MMT) @5% (1)	21.80	22.89	24.03	25.24	26.50	27.82	29.21	30.67
Production (MMT) (2) = (1)*(3)	11.55	12.86	14.31	15.93	17.73	19.73	21.96	24.45
Utilization Rate 6% (3)	0.53	0.56	0.60	0.63	0.67	0.71	0.75	0.80
MS Yield (MMT) (4)=(2)*0.28%	3.12	3.60	4.01	4.46	4.96	5.53	6.15	6.84
HSD Yield (MMT) (5)=(2)*30%	3.47	3.86	4.29	4.78	5.32	5.92	6.59	7.33
Light Oil Product (MMT) (6)=(4)+(5)	6.59	7.46	8.30	9.24	10.28	11.45	12.74	14.18
MS Demand (MMT) @5% (7)	7.98	8.38	8.80	9.24	9.70	10.18	10.69	11.23
HSD Demand (MMT) @5% (8)	7.41	7.78	8.17	8.58	9.01	9.46	9.93	10.43
Industry Demand (MMT) (9)=(7)+(8)	15.39	16.16	16.97	17.81	18.70	19.64	20.62	21.65
MS Import (MMT) (10)=(7)-(4)	4.86	4.78	4.79	4.77	4.73	4.66	4.54	4.38
HSD Import (MMT) (11)=(8)-(5)	3.94	3.92	3.88	3.80	3.69	3.54	3.34	3.09
Import Requirement (MMT) (12)=(9)-(6)	8.80	8.70	8.66	8.57	8.42	8.19	7.88	7.47
Crude Cost (\$/MMT) @10% (13)	522	574	632	695	764	841	925	1017
Cost of Domestic Production (\$M) (14)=(6)*(13)	3438	4283	5243	6419	7859	9622	11780	14423
Imported MS Cost (\$/MMT) @10% (15)	737	811	892	981	1079	1187	1306	1436
Imported HSD Cost (\$/MMT) @10% (16)	720	792	871	958	1054	1160	1276	1403
Average (MS, HSD) Unit Cost \$M (17)	729	801	881	970	1067	1173	1291	1420
Total Import Value (\$ M) (18)=(17)×(12)	6412	6971	7637	8314	8982	9614	10173	10611
Net Savings \$ Million (19)=(14)-(18)	-2975	-2688	-2394	-1894	-1122	9	1607	3812

(Author's calculation)

Scenario 3 (S3): Deep Conversion Technology; Constant capacity with an increase in utilization rate(6%/Year)

Scenario S3 projects the transition from hydro-skimming to deep conversion technology, maintaining a constant capacity of 21.8 MMT with a 6 percent annual increase in utilization rate. Unlike hydro-skimming, the deep conversion technology enables higher yields of light oil products such as MS and HSD, while minimizing residual fuel oil due to advanced refining

configurations such as hydrocracking, fluid catalytic cracking, and delayed coking. These types of configurations crack the heavy fraction of crude oil into high-value products.

Table 6.6: Deep Conversion Technology; Constant Nameplate Capacity with Increase in Utilization Rate (6% per annum)

Year	Base	Y-1	Y-2	Y-3	Y-4	Y-5	Y-6	Y-7
Nameplate Capacity (MMT) @5% (1)	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
Production (MMT) (2) = (1)*(3)	11.55	12.25	12.98	13.76	14.59	15.46	16.39	17.37
Utilization Rate 6% (3)	0.53	0.56	0.60	0.63	0.67	0.71	0.75	0.80
MS Yield (MMT) (4)=(2)*0.42%	4.85	5.14	5.45	5.78	6.13	6.49	6.88	7.30
HSD Yield (MMT) (5)=(2)*47%	5.43	5.76	6.10	6.47	6.86	7.27	7.70	8.17
Light Oil Products (MMT) (6)=(4)+(5)	10.3	10.9	11.6	12.2	13.0	13.8	14.6	15.5
MS Demand (MMT) @5% (7)	8.0	8.4	8.8	9.2	9.7	10.2	10.7	11.2
HSD Demand (MMT) @5% (8)	7.4	7.8	8.2	8.6	9.0	9.5	9.9	10.4
Domestic Demand (MMT) (9)=(7)+(8)	15.4	16.2	17.0	17.8	18.7	19.6	20.6	21.7
MS Import (MMT) (10)=(7)-(4)	3.13	3.23	3.34	3.46	3.57	3.69	3.81	3.93
HSD Import (MMT) (11)=(8)-(5)	1.98	2.02	2.07	2.11	2.15	2.19	2.23	2.26
Import Requirement (MMT) (12)=(9)-(6)	5.1	5.3	5.4	5.6	5.7	5.9	6.0	6.2
Crude Cost (\$/MMT) @10% (13)	522	574	632	695	764	841	925	1017
Cost of Domestic Production (\$M) (14)=(6)*(13)	5368	6259	7298	8509	9922	11569	13489	15728
Imported MS Cost (\$/MMT) @10% (15)	737	811	892	981	1079	1187	1306	1436
Imported HSD Cost (\$/MMT) @10% (16)	720	792	871	958	1054	1160	1276	1403
Average (MS, HSD) Unit Cost \$M (17)	729	801	881	970	1067	1173	1291	1420
Total Import Value (\$ M) (18)=(17)×(12)	3719	4213	4770	5397	6103	6897	7788	8788
Net Savings \$ Million (19)=(14)-(18)	1649	2046	2528	3112	3819	4672	5701	6940

(Author's calculation)

The total production of petroleum products increases from 11.55 MMT to 17.37 MMT, matching scenario S1. According to ETSAP (2014), deep conversion typically yields 47 percent MS and 48 percent HSD. Applying these assumptions increases light oil production from 10.3 MMT to 15.5 MMT, representing a 50 per cent increase over the projection period. However, despite the increase in production, the total import requirement is slightly growing from 5.1 MMT to 6.2 MMT. On the other hand, the industry demand for light oil products is expected to reach a level of 21.7 MMT by Year 7, compared to 15.4 MMT in Year 1. These

results align with the demand forecasting in the Pakistan Energy Outlook Report 2021-2030 (GoP, 2021).

Nonetheless, the operational and economic performance significantly improves with the transition to deep conversion, as net savings from import substitution increased steadily from USD 1.68 billion in Year 1 to USD 6.94 billion by Year 7, due to an increase in domestic production of high-value fuels and import reduction (see Table 5.3). This scenario highlights that even without capacity expansion, the installation of deep conversion technology offers a significant economic advantage. By minimizing the production of residual fuel oil and maximizing high-value products, it can make the process can be made more sustainable and cost-effective, even in volatile crude oil markets. Furthermore, Speight (2013) confirms that modern deep conversion can improve the production of high-value products and meet market demand, reduce the production of low-value residual fuel oil, and enhance overall refinery efficiency and profitability.

Scenario 4 (S4): Deep Conversion Technology: Incremental Expansion of Nameplate Capacity and Utilization Rate (6%/Year)

The scenario assumes a simultaneous 5 percent increase in capacity and a 6 percent increase in the utilization rate annually. At the baseline, refinery stands at 21.8 MMT, increasing to 30.67 MMT by Year 7, while the utilization rate improves from 53 percent to 80 percent. As a result, total production grows from 11.55 MMT in the base year to 24.45 MMT by Year 7. The production of light oil products reached 21.76 MMT by Year 7, marginally exceeding the projected domestic demand. This indicates a transition from being a net importer to a net exporter. Consequently, the import requirement significantly decreases. MS imports decreased from 3.13 MMT to 0.96 MMT, and HSD imports decreased from 1.98 MMT to -1.06 MMT, indicating a potential surplus by Year 7. Despite an annual increase of 10 per cent in the prices of crude oil and petroleum products. The overall import requirements have decreased from 5.10 MMT to -0.10 MMT, suggesting a complete reversal from importer to exporter status by the end of the projected period. This output growth is sufficient to satisfy the projected demand for light oil products and can bring considerable economic benefits in terms of a reduction in imports bill.

These results underscore the long-term cost efficiency of upgrading refineries to deep conversion technology, which provides higher product yields and adaptability compared to

outdated hydroskimming technology. Initially, the net savings from import substitution are USD 2.79 billion per year and will rise to USD 22.26 billion by the end of the projected period.

Table 06.7: Deep Conversion Technology; Incremental Expansion of Nameplate Capacity (5% Per Annum) and increase in Utilization Rate (6% Per Annum)

Years	Base	Y-1	Y-2	Y-3	Y-4	Y-5	Y-6	Y-7
Nameplate Capacity (MMT) @5% (1)	21.8	22.9	24.0	25.2	26.5	27.8	29.2	30.7
Production (MMT) (2) = (1)*(3)	11.55	12.86	14.31	15.93	17.73	19.73	21.96	24.45
Utilization Rate 6% (3)	0.53	0.56	0.60	0.63	0.67	0.71	0.75	0.80
MS Yield (MMT) (4)=(2)*0.42%	4.85	5.40	6.01	6.69	7.45	8.29	9.22	10.27
HSD Yield (MMT) (5)=(2)*47%	5.43	6.04	6.73	7.49	8.33	9.27	10.32	11.49
Light Oil Products (MMT) (6)=(4)+(5)	10.28	11.45	12.74	14.18	15.78	17.56	19.55	21.76
MS Demand (MMT) @5% (7)	7.98	8.38	8.80	9.24	9.70	10.18	10.69	11.23
HSD Demand (MMT) @5% (8)	7.41	7.78	8.17	8.58	9.01	9.46	9.93	10.43
Industry Demand (MMT) (9)=(7)+(8)	15.39	16.16	16.97	17.81	18.70	19.64	20.62	21.65
MS Import (MMT) (10)=(7)-(4)	3.13	2.98	2.78	2.54	2.25	1.89	1.47	0.96
HSD Import (MMT) (11)=(8)-(5)	1.98	1.74	1.44	1.09	0.67	0.18	-0.39	-1.06
Import Requirement (MMT) (12)=(9)-(6)	5.10	4.71	4.23	3.64	2.92	2.08	1.07	-0.10
Crude Cost (\$/MMT) @10% (13)	522	574	632	695	764	841	925	1017
Cost of Domestic Production (\$M) (14)=(6)*(13)	5368	6572	8046	9850	12060	14765	18077	22131
Imported MS Cost (\$/MMT) @10% (15)	737	811	892	981	1079	1187	1306	1436
Imported HSD Cost (\$/MMT) @10% (16)	720	792	832	873	917	963	1011	1061
Average (MS, HSD) Unit Cost \$M (17)	729	801	862	927	998	1075	1158	1249
Total Import Value (\$ M) (18)=(17)×(12)	3719	3776	3642	3371	2918	2232	1244	-130
Net Savings \$ Million (19)=(14)-(18)	1649	2795	4403	6480	9142	12533	16833	22261

(Author's calculation)

Scenarios - Net Result

Considering the four projected scenarios, it is evident that improving the utilization rate alone is insufficient to achieve sustainable economic gain unless it is paired with technological upgradation and capacity expansion. The findings align with refining economic theory, that

crude oil processed is critical for refinery profitability.⁹ (IEA Refining Margin Methodology, 2024). Under the hydroskimming-based scenario (S1 and S2), even with increasing utilization, the refineries continue to produce a relatively small share of light products (MS and HSD) and a large share of low-value residuals. As a result, the hydroskimming configuration maintains net savings throughout the scenario period, the deficit growing from approximately a –USD 2.97 billion to a –USD 6.18 billion in S1 and a – USD 2.9 billion to USD 3.8 billion in S2, respectively. Economically, this outcome reflects product-slate mismatch because most of Pakistan’s refineries are based on the outdated hydroskimming process, which limits their ability to convert heavier fractions into more valuable products, and this leaves the import substitution gap largely unfilled, as illustrated in Scenarios S1 and S2 above.

In contrast, when refineries operate under deep conversion technology, with capacity constant, the domestic supply-demand gap narrows significantly and improves economic outcomes. In the most favorable scenario, S4, where both capacity and utilization increase along with a technological shift to deep conversion technology. Pakistan can transition from a net importer to an exporter of HSD by Year 7, and foreign exchange savings may reach \$22 billion. This outcome reflects evidence that refineries investing in complexity achieve higher margin spreads and cost savings. On the other hand, hydro-skimming-based scenarios, even with higher utilization, offer limited economic advantages due to the low production of light products (MS and HSD) and the high residual fuels, especially furnace oil. However, the industry demand for light oil is growing with the increase in global oil prices, and there is an urgent need to upgrade existing refineries and expand refining capacity, or to install new refineries.

6.3 Thematic Analysis

This section presents and interprets the findings of the qualitative analysis based on key informant interviews conducted with representatives from various government agencies and stakeholders in the private sector, using thematic analysis, on the issues of underutilization and modernization of refineries in Pakistan. The government agencies included the Ministry of Energy, Petroleum Division (MoEPD), the Oil and Gas Regulatory Authority (OGRA), and the Pakistan Oil Refinery (POL). While the private stakeholders included Attock Refinery Limited (ARL) and Cynergio. Two of the interviews, one with PRL and the other with the

⁹ [IEARefineryMarginMethodologyAugust2024.pdf](#)

representative of Cynergio, were conducted online. The respondent(s) details are provided in Table 6.8.

Table 6.8: Description of Respondents

Organization	Number of Respondents	Profile of Respondents
Ministry of Energy, Petroleum Division (MoEPD)	03	Senior Officials (MoEPD)
Oil and Gas Regulatory Authority (OGRA)	03	Senior Officials (OGRA)
Pakistan Refinery Limited (PRL)	01	Senior Staff Member
Cynergio Refinery	01	Technical Expert
Attock Refinery Limited (ARL)	01	Operational Manager

Following the interviews and data collection, a thematic analysis is conducted using the six-step technique outlined by Braun & Clarke (2006).

- (1) Familiarization with data; all interviews were transcribed and read multiple times.
- (2) Identification of themes; all the themes were grouped into preliminary categories such as financial and investment challenges, regulatory barriers, technological limitations, market-driven challenges, and institutional issues.
- (3) Generating initial themes; a total of 46 initial codes were generated. These include aging infrastructure, operational inefficiencies, furnace oil burden, financial constraints, policy delays, and challenges in technological upgradation.
- (4) Reviewing themes; the themes were refined, and each theme was checked to ensure that it reflected patterns evident in the data.
- (5) Defining and naming themes; after conducting the prior steps, the seven (7) following themes are finalized: Environmental Compliance and Fuel Standards, Decline in Furnace Oil Demand, Operational Inefficiencies, Outdated Refinery Technology, Fiscal Policy and Investment Constraints, Deemed Duty Protection, and Coordination and Collaboration.
- (6) Producing a Narrative; all the themes were transformed into analytical findings, supported by document evidence and respondent quotes.

This section discusses the themes of underutilized refining capacity and the factors that impede upgradation. The themes discussed are as follows.

6.3.1 Concerns Regarding Capacity Underutilization

6.3.1.1 Environmental Compliance and Fuel Standards

This theme highlights the challenges faced by Pakistani refineries in meeting international environmental fuel standards, such as Euro V and Euro VI specifications. Environmental compliance is increasingly significant in the refining industry due to global initiatives aimed at reducing carbon emissions and other harmful pollutants. The existing hydroskimming refineries produce high-sulfur fuels due to outdated equipment and insufficient availability of desulfurization units, which emit sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter into the atmosphere. These pollutants significantly contribute to urban smog, acid rain, and respiratory disorders (CAFE, 2019).

“When the fuels burn, they emit Sulphur dioxide (SO₂) and Sulphur trioxide (SO₃), they are part of smog... one of the primary aims is to protect the environment.”

The refining industry in Pakistan has been relatively sluggish in implementing environmental changes. This primarily results from inadequate enforcement of regulations, as well as financial and technological limitations. Respondents indicated that most of the refineries in the country continue to produce high-sulfur petroleum products, particularly furnace oil, which contains sulfur levels significantly exceeding the Euro V limit of 10 parts per million (ppm). Faria et al. (2024) also indicate that the application of hydrocracking and hydrotreating techniques in advanced refineries worldwide has significantly reduced the sulfur content in products. Failure to adhere to global environmental standards impacts commerce, undermines the nation’s climate commitments under the Paris Agreement, and affects overall environmental governance.

The United Nations Environment Programme (UNEP, 2024) demonstrates that non-compliance with clean fuel requirements diminishes public trust in environmental regulations and complicates governmental efforts to address climate-related issues. Environmental compliance encompasses adherence to regulations and is crucial for public health, combating climate change, enhancing commercial competitiveness, and ensuring future energy availability.

6.3.1.2 Decline in Furnace Oil Demand

The underutilization of refining capacity is a crucial issue attributed to outdated technology and declining demand for petroleum products, particularly the decline in furnace oil (FO) demand. Historically, FO was used to generate electricity in thermal power plants. However, a strategic shift towards cleaner energy sources, such as Liquefied Natural Gas (LNG), has reduced the demand in the power sector. From 2016 to 2021, the furnace oil (FO) consumption plummeted from 9.6 MT to 3 MT. Given the refinery configuration, they produce a significant portion of FO, accounting for up to 30 percent to 40 percent of the total output. Consequently, Pakistan started exporting furnace oil at a low price, which is also known as a negative margin product. Its decline compelled oil refineries to scale back their operations and manage excess inventory. Furthermore, the imposition of the petroleum levy and climate support levy on furnace oil threatens industrial activity and financial stability.

“Export of FO is the last resort for the refineries to safeguard their refinery margins from high-speed diesel and motor spirit production until their upgrade projects materialize.”

6.3.1.3 Operational Inefficiencies

The oil refining sector is largely outdated and inadequate to meet the evolving quality of the modern petroleum market. Most operational refineries are hydro-skimming units, representing the most basic refining technology. These units have limitations in processing heavy crude oil fractions into lighter, high-value petroleum products, such as gasoline, diesel, and jet fuel. Consequently, the prevailing technological configurations result in an excess production of residual products, such as furnace oil, which faces a decrease in domestic demand and has limited export prospects (TDAP, 2022; PACRA, 2023).

Hydro-skimming refineries produce a low product slate of high-value light product yields compared to advanced deep-conversion refineries. For instance, the motor spirit production-to-consumption ratio remains low, with domestic refineries meeting only 30 percent of the country’s demand, necessitating the importation of refined petroleum worth billions of dollars annually (OCAC, 2022). This technology limitation reduces energy independence and exposes the country to the uncertainty of global oil prices and exchange rate fluctuations, thereby worsening macroeconomic vulnerabilities. In addition to producing low yields, the refineries lack the infrastructure to meet environmental and fuel quality standards. Local refineries have

yet to upgrade their facilities to meet these standards due to the substantial investment requirements (SAARC Energy Center, 2021).

Operational inefficiencies persist as a significant obstacle to achieving optimal performance. Without significant investments in modernization, the sector will continue to lag behind global standards, keeping its reliance on expensive fuel imports and contributing to overall energy insecurity.

6.3.1.4 Outdated Refinery Technology

One of the most critical issues confronting Pakistan's existing refinery infrastructure is its obsolescence. The majority of oil refineries are outdated and inefficient in processing heavier crude oils or meeting contemporary gasoline standards, particularly those employing hydroskimming technology. Hydroskimming refineries are designed with limited capabilities, primarily functioning to separate crude oil into basic fractions, without the ability to convert residuals into higher-value products (Speight, 2006).

A significant issue raised was the excessive production of furnace oil by these refineries, which is not marketable. The power generation sector is increasingly reducing its reliance on furnace oil, shifting towards imported LNG and renewable energy sources. Hydroskimming units are unable to perform deep conversion processes such as catalytic cracking or hydrocracking, which are essential for maximizing diesel and motor spirit yields. These products exhibit significant demand and premium prices in both local and international markets. The stagnation in technological advancement adversely affects profits, capacity utilization, and compliance with environmental regulations. Refineries are unable to utilize their full capacity due to high production of furnace oil, which does not align with domestic demand Patterns. This results in suboptimal performance, described by one respondent as *“forced underutilization driven by product mismatch.”*

Many Respondents indicate that the discrepancy between the outputs of existing refineries and market demand renders these assets economically inefficient. Pakistani refineries will remain uncompetitive in a region where neighboring countries are rapidly enhancing their infrastructure unless significant investments are made to upgrade processes, including fluid catalytic cracking (FCC) units, hydrocracking units, and residue fluid catalytic cracking (RFCC) units. Modernization is essential not only for enhancing yields and profits but also for

ensuring that refinery outputs align with national energy objectives and strategies aimed at reducing imports.

“The refineries will operate at their maximum or optimal capacity once they have been upgraded..... The high production of furnace oil is the root cause of their limited throughput.”

6.3.2 Barriers to Refinery Upgradations

6.3.2.1 Fiscal Policy and Investment Constraints

The government's sudden policy changes delay the economic feasibility of refinery upgrading projects under the Brownfield Refinery Policy. Respondents consistently emphasized that the sudden policy shifts, particularly the imposition of an 18% General Sales Tax (GST) on equipment and machinery upgrades, affect the internal rate of return (IRR), which extends the payback periods of planned enhancement projects.

In addition, the Finance Act, 2024, changed the status of zero-rating of petroleum products to sales tax exemption, heavily impacting the upgradation projects because the refineries are unable to claim input tax they pay on the stage of imports or intermediate goods. The imposition of GST has led to protracted payback durations for refinery projects. Some exceed 20 years, rendering them economically unviable within conventional investment horizons. A refinery executive stated, *“Our internal rate of return halved overnight following the alteration in tax policy. No investor will endure a 20-30 year wait to recoup their capital.”*

The broader macroeconomic landscape, encompassing inflation, currency devaluation, and escalating interest rates, has exacerbated financial vulnerabilities. Local financiers are reluctant to finance long-term, capital-intensive industrial projects without governmental guarantees or robust tax frameworks. The findings from this theme underscore the necessity of a coherent and proactive fiscal approach to effectively make improvements in the refinery sector. The Brownfield Refinery Policy is unlikely to achieve its investment mobilization objectives without sustained tax concessions, financial incentives, and safeguards against policy changes throughout the project’s execution.

“If the government delays the refinery upgrade process by even one year, the country will effectively lose between \$1.5 and \$2 billion annually due to prolonged dependence on imported refined products and inefficiencies in domestic output.”

6.3.2.2 Deemed Duty Protection

In 1997, the government introduced the petroleum policy (amended in 2002) to provide tariff protection to refineries. The policy replaced the minimum 10 percent guaranteed rate of return as a deemed duty (10% on high-speed diesel, 6% on light diesel, kerosene, and JP-4). However, the tariff protection was reduced to 7.5 percent on high-speed diesel in 2008, which discouraged investment in upgradation/new refineries. A Brownfield Policy introduced in 2021 (amended in 2024) mandated the refineries to upgrade their facilities to produce Euro V specifications within 6 years. To support this initiative, a minimum customs duty (deemed duty) of 10% on Motor Spirit and HSD imported into the country has been allowed. The deemed duty will be deposited into an escrow account maintained by OGRA with the respective refinery for meeting 25% of the upgradation cost.

One of the respondents stated that deemed duty refers to the customs duty included in the ex-refinery price of petroleum products produced by domestic refineries, based on the import parity pricing formulae designed to align the prices of domestically refined and imported fuel. Under the Brownfield Refinery Policy 2023, the deemed duty mechanism has been allowed to protect domestic refineries from import competition and utilize the funds for upgradation projects. The anticipated duty fund has been deposited into a designated “Escort Account,” maintained by OGRA.

“Deemed duty is added into our prices not as an additional charge, but as an incentive aligned with import parity.”

6.3.2.3 Performance-based Disbursement

Respondents indicated that the deemed duty mechanism initially makes upgrades economically feasible. However, the disbursement of these collected funds is increasingly tied to milestones set by OGRA. Performance-based funding may theoretically promote operational enhancements; however, in practice, it often results in delays and uncertainty. Although the funding has been approved in the budget, refineries are not allowed to use it for upgrading their facilities. The allocation procedure has been hindered by bureaucratic red tape and subsequent post-budget revisions, which have impeded investment flows. These findings align with the assertions of public finance, who argue that excessively stringent performance requirements may diminish policy effectiveness during economic instability (Manta, 2020).

6.3.2.4 Financial Mechanism and Structure Barriers

Financial mechanisms and structural barriers make it difficult to invest in large-scale refinery upgrades; the structural and institutional flaws persist despite a 25:75 equity-to-debt ratio. The absence of a developed infrastructure finance market and macroeconomic impediments impede the acquisition of funding for long-term, capital-intensive projects.

The 25:75 equity-to-debt model posits that 25% of the capital required for refinery upgradation will be sourced from equity, possibly derived via duty allocations, while the remaining 75% will be obtained through loans or debt from financial institutions. However, in reality, banks and other financial institutions hesitate to take risks due to political and economic uncertainty.

“Securing equity domestically is challenging, and commercial banks are reluctant to provide long-term loans without government guarantees or a stable fiscal policy.”

This mirrors the broader issues associated with financing in Pakistan, as the majority of commercial banks provide loans only for short durations and lack the liquidity or inclination to participate in long-term, capital-intensive initiatives. The volatility of energy prices and tax regulations has exacerbated credit risk, making it unfeasible for several refineries to modernize their facilities under current conditions.

6.3.2.5 Coordination and Collaboration

The absence of integrated decision-making frameworks and systematic communication channels hinders the development of modernization strategies for refineries, optimization of supply chains, and long-term energy planning. Respondent specifically mentioned that the government agencies are working in silos; they do not prioritize the national interest. Good governance is often viewed as requiring strong coordination and collaboration among agencies, particularly in complex domains such as petroleum refining. In Pakistan, overlapping mandates, fragmented institutional structures, and inconsistent communication protocols among agencies such as OGRA, the Ministry of Energy (Petroleum Division), and the Federal Board of Revenue (FBR) have resulted in diminished procedural efficiency and policy effectiveness.

“OGRA, the MoEPD, and FBR move on divergent objectives, without any coordination on the overall picture.”

There is currently no formal mechanism for regular collaboration among ministries, regulatory agencies, and provincial departments. Countries that exhibit effective downstream governance typically establish multi-stakeholder working groups or inter-agency task forces to ensure alignment of strategies, mandates, and the resolution of implementation issues.

*“We lack regular meetings, universally accessible data systems, and real-time coordination.”
Typically, action is initiated only in response to the emergence of a problem.”*

Thematic analysis explores that the main issues in capacity underutilization is inability to meet Euro V/VI fuel standards, outdated hydroskimming technology, excess production of residual oil, and operational inefficiencies. It also identifies the factors that hinder upgradation projects, that includes fiscal policy instability, such as changes to the status of GST on products, imposition of taxes on upgraded equipment, ineffective disbursement of deemed duty funds, and poor coordination between government agencies, which undermine the financial viability of long term financing for refineries to modernize.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

This study concludes that the capacity utilization (CU) of Pakistan's oil refining sector is shaped by a multifaceted dynamic of macroeconomic conditions, technological constraints, and institutional inefficiencies. The empirical results reveal that CU is significantly constrained by volatile crude oil prices and exchange rate depreciation, while GDP growth rate and import of refined products exert a positive influence, indicating the sector's sensitivity to both global market fluctuations and domestic demand growth. Scenario-based results further demonstrate that reliance on outdated hydroskimming technology provides negligible economic gains, even when substantial improvements in capacity and utilization are unable to close the persistent domestic supply-demand gap. In contrast, the transition towards deep conversion technology coupled with incremental capacity expansion could drastically enhance the production of high-value fuels, narrow the supply-demand gap, and generate potential foreign exchange savings of approximately USD 22 billion. Hence, the transition to advanced deep conversion technology provides an opportunity for Pakistan's petroleum industry to shift from a net importer to a marginal exporter status.

Furthermore, qualitative findings also reveal that persistent underutilization arises from structural issues, including outdated technology, environmental non-compliance, and high residual oil output by domestic refineries, indicating the product mismatch. Meanwhile, inefficient incentive mechanisms, institutional fragmentation, limited financing options, and a lack of fiscal continuity hinder technological modernization and long-term investment. This study's findings underscore that Pakistan's downstream refining sector requires structural transformation through institutional coordination and a coherent national refining strategy. This is crucial for attracting investment, enabling refineries to upgrade, reducing import dependency, and fostering sustainable growth in Pakistan's oil refining sector.

Recommendations

- The country must should formulate a stabilization strategy to mitigate the crude oil prices volatility for crude prices volatiliy, and the exchange rate overvaluation should be avoided.
- Capacity expansion and upgradation plans should be aligned with projected GDP growth and the national energy demand forecast, ensuring consistency with the domestic fuel demand pattern.

To ensure a sustainable transition and an economically feasible modernization process, the following key policy recommendations are proposed to support the technological upgradation of oil refineries, promote self-sufficiency, and achieve long-term energy security.

- The government of Pakistan (GoP), through the Ministry of Energy (Petroleum Division), should provide policy incentives to facilitate phased upgradation projects.
- To withdraw the GST exemption on petroleum products and ensure that sales tax input tax adjustments are made for refineries to restore the financial viability of upgradation projects. This will foster investor confidence for long-term planning, aligning with the objectives of the Pakistan Brownfield Refinery Policy 2023.

Limitations of the study

- Scenario analysis inherently depends on the quality of the underlying assumptions (as outlined in Tables 5.1 and 5.2). While actual nameplate capacity and utilization rates are considered as baselines, they do not consider the types of crude oil and actual product slate produced by the refineries.
- The analysis focuses solely on two major products (MS and HSD) in the oil refining sector, due to their significant share in imports and domestic demand.
- The study does not examine long-term fiscal implications (e.g., tax revenues) or dynamic market feedback (e.g., price elasticity, demand responses), which could be explored in future research that employs CGE models or system dynamics techniques.
- This study is limited to the oil refining sector. It does not consider other sectors of the economy (e.g., transport and petrochemicals).

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Appendix

Appendix A

Formulas used in the scenarios are given in the Table below.

Variables	Formulas
Assumptions Under Hydro skimming	
MS Yield (MMT) (4)=(2)*0.28%	The production slate of MS is fixed at 28%
HSD Yield (MMT) (5)=(2)*30%	The production slate, of HSD is fixed at 30% of HSD
Assumptions Under Deep Conversion	
MS Yield (MMT) (4)=(2)*0.42%	The production slate of MS is fixed at 42%
HSD Yield (MMT) (5)=(2)*47%	The n production slate, of HSD is fixed at 47% of HSD
Production (MMT) (2) = (1)*(3)	Nameplate Capacity (MMT) × Utilization Rate
Utilization Rate 6% (3)	Six percent increase in annual utilization rate
Light Product Yield (MMT) (6)=(4)+(5)	Motor Spirit Yield (MMT) + High Speed Diesel Yield (MMT)
MS Demand (MMT) @5% (7)	Motor Spirit (MS) demand increase by 5 percent per year
HSD Demand (MMT) @5% (8)	High Speed Diesel (HSD) demand increase by 5 percent per year
Industry Demand (MMT) (9)=(7)+(8)	MS Demand (MMT) + HSD Demand (MMT)
MS Import (MMT) (10)=(7)-(4)	MS Demand (MMT) MS Yield (MMT)
HSD Import (MMT) (11)=(8)-(5)	HSD Import (MMT) HSD Yield (MMT)
Import Requirement (MMT) (12)=(9)-(6)	Industry Demand (MMT) Light Product Yield (MMT)
Crude Cost (\$/MMT) @10% (13)	Cost of crude oil increase by 10 percent per year
Cost of Domestic Production (\$M) (14)=(6)*(13)	Domestic Production (MMT) × Crude Price (\$/MMT)
Imported MS Cost (\$/MMT) @10% (15)	Cost of Motor Spirit (MS) increase by 10 percent per year
Imported HSD Cost (\$/MMT) @10% (16)	Cost of High Speed Diesel (HSD) by 10 percent per year
Average (MS, HSD) Unit Cost \$M (17)	Avg (MS Cost (\$/MMT), HSD Cost (\$/MMT))
Total Import Value (\$ M) (18)=(17)×(12)	Average (MS, HSD) Unit \$M × Import Requirement (MMT)
Net Savings \$ Million (19)=(14)-(18)	Cost of Domestic Production (\$M) Total Import Value (\$M)

Appendix B
Interview Questionnaire Guide

1. What are the main issues contributing to the underutilization of oil refineries?
2. What is your understanding about the new brownfield refinery policy, and how do you interpret its goals and provisions?
3. What are the key opportunities associated with the Brownfield Refinery Policy?
5. What are the main reasons for delays in modernization/upgradation projects?
6. To what extent do investment constraints, financial limitations, and tariff protection such as deemed duty affect refineries' upgradation and expansion decisions?
7. What types of financial mechanisms (e.g., government funding, public-private partnerships, tax incentives) could make refinery upgrades more economically feasible?
8. What policy reforms or market interventions could help to improve refinery utilization and competitiveness, reduce import reliance, and secure long-term energy security?