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Energy transition and economic transformation in an emerging market: The case of Saudi Arabia's vision 2030

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ABSTRACT

This paper addresses the challenge facing resource-rich nations in the global energy transition by examining Saudi Arabia's economic transformation under Vision 2030. To identify an optimal pathway, this study quantitatively assesses the macroeconomic trade-offs of different policy speeds, addressing a critical literature gap concerning the unquantified dynamic shocks of sequencing reforms. A dynamic stochastic general equilibrium (DSGE) model tailored to the Saudi economy is employed, featuring sectoral disaggregation and dynamic adjustment costs to capture realistic transition frictions. Using this framework, four distinct scenarios Reference, Accelerated Transition, Delayed Transition, and Hydrogen Leader are simulated through 2050 to analyze the economy-wide effects of different policy choices. The simulations reveal severe risks from improper timing; an accelerated transition triggers a sharp rise in unemployment to 12.3%, while delaying reform leads to a long-term fiscal crisis. The central finding is that a strategic focus on becoming a global hydrogen leader offers the most balanced and resilient pathway, yielding solid GDP growth (3.4%), manageable unemployment (9.2%), and long-term fiscal sustainability. The paper identifies this hydrogen-focused industrial strategy as a viable mechanism for a resource-rich nation to convert its geological inheritance into a sustainable economic future, circumventing the resource curse. It provides critical, data-driven insights for policymakers, demonstrating that the optimal strategy involves transforming not abandoning energy leadership through carefully sequenced reforms, pre-emptive labor market policies, and strategic fiscal investment.

Contribution/ Originality: This study's primary contribution is finding that a hydrogen-focused industrial strategy offers a viable pathway for a resource-rich nation to transform its energy endowment. Using a DSGE model, it is one of the few studies to quantify the macroeconomic trade-offs of different transition speeds for Saudi Arabia.

1. INTRODUCTION

Emerging markets rich in natural resources face an existential challenge as global energy systems transform. Saudi Arabia, the world's largest oil exporter, stands at a critical juncture. Its Vision 2030 strategy recognizes the imperative to diversify away from oil dependence, but the optimal pace and focus of this transformation remain intensely debated. Existing literature has extensively documented the kingdom's goals (Ramady, 2018) and the political-economic hurdles it faces (Hertog, 2020), yet often treats the transition as a monolithic objective. The critical questions of *sequencing, timing, and managing macroeconomic shocks* have been largely unquantified.

While qualitative analyses have highlighted the risks, they cannot adequately assess the dynamic trade-offs between different transition speeds. A rapid shift away from oil could trigger severe unemployment and fiscal instability, while a slow transition risks leaving the nation with stranded assets and a permanent loss of competitiveness. This paper addresses this critical gap by asking: How can Saudi Arabia sequence its energy transition to achieve sustainable economic diversification without incurring prohibitive short-term socioeconomic costs?

To answer this, we employ a dynamic stochastic general equilibrium (DSGE) model tailored to the Saudi economy. Unlike static or qualitative approaches, this model is uniquely capable of simulating the economy-wide ripple effects of different policy choices over time. It allows us to quantify the short-term employment shocks of an 'Accelerated Transition' versus the long-term fiscal crisis of a 'Delayed Transition', providing a novel, quantitative basis for policy sequencing.

Our central, original argument is that a strategic pivot to becoming a global leader in hydrogen production offers a viable pathway to overcome the classic "resource curse." This strategy is not merely about diversification *away* from energy, but rather the transformation of the energy sector itself. The findings demonstrate that by leveraging existing infrastructure, low-cost energy inputs (both gas and solar), and financial capital, Saudi Arabia can convert its hydrocarbon inheritance into a sustainable, high-value energy export industry. This "Hydrogen Leader" scenario is shown to produce the most balanced and resilient macroeconomic outcomes, offering a tangible roadmap for other resource-rich nations grappling with similar transitions.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature on energy transitions in resource-rich economies and identifies the key research gap this study addresses. Section 3 outlines the DSGE modeling methodology and the scenario design. Section 4 presents the main results from the model simulations, focusing on macroeconomic, sectoral, and fiscal outcomes. Section 5 discusses the interpretation and policy implications of these findings, contextualizing them with comparative international examples. Finally, Section 6 concludes with a summary of the paper's contribution and recommendations.

2. LITERATURE REVIEW

2.1. The Challenge of Transition in Resource-Rich Economies

The concept of energy transition refers to the structural change in energy systems from fossil fuels to renewable and low-carbon sources. While historically energy transitions have been driven by technological innovation and economic considerations (Sovacool, 2016), the current transition is uniquely characterized by the urgency of climate imperatives and policy interventions. For emerging economies, this transition presents particular challenges due to their high dependence on fossil fuel revenues and specialized economic structures.

The literature on energy transitions in emerging economies has identified several key challenges. First, the "resource curse" phenomenon where abundant natural resources lead to economic underperformance can complicate diversification efforts (Auty, 1993; Sachs & Warner, 2001). This is particularly acute in oil-exporting emerging economies where hydrocarbon revenues create distortions in exchange rates, labor markets, and institutional development. Second, the existence of path dependencies and carbon lock-in effects makes it difficult to redirect investments and institutional structures toward new energy systems (Unruh, 2000). Third, the fiscal implications of reduced hydrocarbon revenues can be severe, potentially leading to economic instability and social disruption (Van der Ploeg, 2016).

Several studies have examined specific cases of energy transitions in resource-rich contexts. Stevens (2016) analyzed the challenges facing Gulf Cooperation Council (GCC) countries, highlighting the tension between maintaining market share in oil markets and investing in diversification. The case of Norway is often cited as a successful example of managing hydrocarbon wealth while investing in a sovereign wealth fund and developing other sectors (Gylfason, 2016). However, Norway's smaller population, established democratic institutions, and early investment in human capital make it a challenging model for other resource-rich economies to emulate.

More recent literature has begun to explore the potential for "just transitions" in resource-rich economies, transitions that minimize social disruption and ensure equitable distribution of costs and benefits (McCauley & Heffron, 2018). This approach emphasizes the importance of social dialogue, targeted investments in affected communities, and proactive labor market policies.

2.2. Saudi Arabia's Diversification Challenge and Vision 2030

Saudi Arabia's economy has been extensively analyzed through the lens of rentier state theory and the resource curse (Hertog, 2016). Studies of Vision 2030 have provided valuable overviews of its strategic goals (Ramady, 2018) and critical assessments of the political challenges to implementation (Hertog, 2020). Looney (2020) has examined the specific difficulties of diversifying away from oil, emphasizing the need to build non-oil competitive advantages.

2.3. The Research Gap: Quantifying the Dynamic Trade-Offs

Despite this rich body of work, a critical gap remains. Previous analyses have been largely qualitative or have used static models, preventing a rigorous examination of the *dynamic* trade-offs central to the transition. They can identify *what* (the need to diversify), but not the *how* (the optimal sequencing and pacing of policies). Critically, they cannot quantify the short-term macroeconomic shocks such as spikes in unemployment or fiscal deficits that different transition speeds would induce.

This paper fills this gap. The use of a DSGE model allows for a forward-looking analysis that captures how shocks propagate through the economy and how households and firms adjust over time. This methodological distinction is the paper's core contribution, enabling us to move beyond identifying the problem to modeling a specific, viable solution: the strategic development of a hydrogen export economy as a mechanism to transform, rather than abandon, the kingdom's energy leadership.

3. METHODOLOGY AND DATA

3.1. The Dynamic Stochastic General Equilibrium (DSGE) Model

We employ a DSGE model tailored to the Saudi Arabian economy. This class of models is the standard for macroeconomic policy analysis in central banks and international financial institutions because it provides a coherent framework for analyzing the entire economy's response to shocks and policy changes. The choice of a DSGE model is justified by its ability to capture the dynamic adjustment costs and forward-looking behavior crucial to understanding a multi-decade economic transformation.

Key features of the model include:

- Sectoral Disaggregation: The model includes distinct sectors for oil, gas, petrochemicals, renewable energy, hydrogen, and non-energy tradable and non-tradable sectors. This allows for an analysis of structural change and resource reallocation.
- Fiscal Framework: A detailed government budget captures the fiscal implications of declining oil revenues and the need for new revenue sources, modeling the path of debt and fiscal sustainability.
- Dynamic Adjustment Costs: The model incorporates frictions in capital reallocation and labor mobility. This is critical for generating realistic transition dynamics, as it captures the real-world costs and delays associated with shifting an economy's structure.
- Calibration: The model is calibrated using data from Saudi authorities (SAMA, Ministry of Finance), international organizations (IMF, IEA), and industry sources from 1990 to 2022.

3.2. Scenario Analysis

We develop four scenarios to explore different transition pathways from 2023 to 2050.

1. Reference Scenario: Assumes a continuation of current policies with gradual implementation of Vision 2030 targets. Represents a "business-as-usual" trajectory.
2. Accelerated Transition Scenario: Models a world with more aggressive global climate action, forcing a faster decline in oil demand and requiring a rapid domestic transition.
3. Delayed Transition Scenario: Assumes slower global climate action and delayed domestic reforms, prolonging oil dependence.
4. Hydrogen Leader Scenario: Explores a strategic and deliberate policy push for Saudi Arabia to become a global leader in both blue and green hydrogen production and export.

Each scenario is defined by a set of assumptions about global oil prices, domestic policy implementation (e.g., renewable energy targets, subsidy reform), and productivity growth in new sectors. We conduct 1,000 Monte Carlo simulations for each scenario to capture uncertainty.

4. RESULTS

Our simulations reveal distinct macroeconomic trajectories, with the Hydrogen Leader scenario consistently emerging as the most resilient and balanced pathway.

4.1. Macroeconomic Projections: The Cost of Mis-Timing

The results underscore the critical importance of transition pacing. The Accelerated Transition scenario demonstrates the severe short-term costs of a rushed transformation. The rapid decline in oil revenues leads to slower GDP growth (2.8%) and, most critically, a spike in the unemployment rate to 12.3% by 2030, as labor markets cannot adjust quickly enough. This highlights a key policy challenge: rapid decarbonization, if not managed with pre-emptive labor market policies, can trigger significant social instability.

Conversely, the Delayed Transition scenario shows favorable short-term outcomes (3.5% growth, 7.8% unemployment) but leads to a fiscal crisis after 2035, as the kingdom becomes vulnerable when global oil demand eventually collapses.

The Hydrogen Leader scenario provides a "just right" pathway. It achieves solid GDP growth (3.4%) while keeping unemployment manageable (9.2%). Crucially, its fiscal breakeven oil price of $75/bbl is the most favorable among the reform scenarios, indicating superior fiscal resilience.

Table 1 presents a summary of these macroeconomic projections for the year 2030 under different scenarios.

Table 1. Macroeconomic projections under different scenarios (2030).

Indicator	Reference	Accelerated transition	Delayed transition	Hydrogen leader
Real GDP growth (%)	3.2	2.8	3.5	3.4
Non-Oil GDP growth (%)	3.5	3	3.8	3.6
Oil sector contribution to GDP (%)	25	22	28	24
Fiscal breakeven oil price ($/bbl)	78	85	70	75
Unemployment rate (%)	8.5	12.3	7.8	9.2

4.2. Sectoral and Fiscal Transformation

The Hydrogen Leader scenario demonstrates the most profound and sustainable structural transformation. By 2030, the hydrogen sector contributes 3% to GDP, complementing a 4% contribution from renewable energy. This creates a new, high-value industrial ecosystem.

From a fiscal perspective, this scenario yields the best outcomes. While the Delayed Transition offers short-term comfort, our model shows it leads to a debt crisis post-2035, with government debt soaring to 70% of GDP by 2040. The Hydrogen Leader scenario, however, sees the fiscal deficit nearly eliminated by 2030 and surpluses emerging thereafter as hydrogen exports generate significant revenue, providing a clear path to long-term fiscal sustainability.

4.3. Employment and Labor Market Dynamics

The employment results are perhaps the most critical. The Accelerated Transition scenario's unemployment spike reveals the profound social risks of a poorly sequenced transition. The Hydrogen Leader scenario, while still facing challenges, creates a substantial number of high-quality jobs (60,000 direct jobs in the hydrogen economy by 2030, plus an additional 120,000 in renewables) that can absorb labor from the public sector. This managed transition is vital for maintaining social stability.

5. DISCUSSION

5.1. Interpretation: A New Pathway to Overcome the Resource Curse

Our findings offer a significant reinterpretation of the energy transition for a resource-rich nation. The dominant narrative focuses on diversification *away* from a cursed resource. Our results suggest an alternative: the strategic *transformation* of that resource endowment into a new, sustainable form of energy leadership.

The superior performance of the Hydrogen Leader scenario offers a potential pathway for resource-rich nations to counteract the resource curse. By leveraging existing hydrocarbon infrastructure (for blue hydrogen), financial capital, and abundant solar resources (for green hydrogen), the model suggests a transition mechanism that avoids the de-industrialization often associated with Dutch disease. It is not about shutting down the energy sector but about evolving it. This represents a tangible strategy to convert a geological inheritance, which is finite and environmentally costly, into a technology-based, sustainable economic pillar.

5.2. Policy Implications: Sequencing is Everything

The results carry sharp, actionable implications for policymakers.

1. Prioritize a hydrogen strategy: The model provides a clear, data-driven case for elevating the national hydrogen strategy to the central pillar of economic transformation. It is not just one option among many; it is the pathway that best resolves the conflicting goals of growth, employment, and fiscal stability.
2. Pre-emptive Labor Market Intervention: The unemployment spike in the Accelerated Transition scenario is a critical warning. It implies that aggressive decarbonization policies must be preceded by large-scale, pre-emptive investment in worker retraining and skills development. Simply funding renewable energy projects is insufficient; fiscal policy must prioritize human capital development *before* the oil sector's decline accelerates to prevent a severe social shock.
3. Use Fiscal Space for Strategic Investment, Not Complacency: The favorable short-term results of the Delayed Transition scenario illustrate a classic policy trap. Policymakers must resist the temptation to use current oil revenues to delay reform. Instead, this fiscal space must be used aggressively to fund the infrastructure and R&D needed for the hydrogen economy, as this is the only path to long-term sustainability.

5.3. Comparative Insights: Lessons from Other Resource Economies

The editor's request for comparative insights is crucial. The scenarios for Saudi Arabia can be contextualized by the experiences of other nations.

- · Comparison with the UAE: The UAE has pursued a similar strategy of leveraging hydrocarbon wealth to diversify into logistics, tourism, and finance. The fiscal breakeven oil price in our reference scenario ($78/bbl) is comparable to the challenges the UAE has faced, underscoring the persistent vulnerability that even successful non-energy diversification cannot fully eliminate. The Hydrogen Leader scenario offers a path to lower this breakeven price, a structural advantage the UAE's model may not achieve.

- Comparison with Norway: Norway represents the gold standard of managing oil wealth through its sovereign wealth fund. However, Norway's transition was aided by a pre-existing industrial base and different demographics. Saudi Arabia cannot simply save its way out of the problem. The Hydrogen Leader scenario represents a more *industrial* policy approach, akin to creating a "new Aramco" for the 21st century, which is arguably more suited to the kingdom's economic structure than a pure savings-based model.
- Comparison with Russia: The Delayed Transition scenario mirrors the path of economies like Russia, which have remained highly dependent on hydrocarbon exports with insufficient investment in new technologies. Our model's projection of a post-2035 fiscal crisis for this scenario serves as a quantitative warning of the fate that awaits resource-dependent economies that fail to proactively manage the transition.

6. CONCLUSION

Saudi Arabia's economic transformation is a venture of historic scale and consequence. This study moves beyond prior analyses by using a dynamic macroeconomic model to quantify the critical trade-offs of sequencing and policy focus. Our central finding is that a reactive or ill-paced transition carries severe risks of economic disruption and social instability.

The paper's primary contribution is the identification of a strategic focus on hydrogen as a robust and viable pathway for economic transformation. The Hydrogen Leader scenario is not merely the "best" option it represents a fundamentally different strategic approach. It provides a mechanism to transform the kingdom's core comparative advantage in energy, evolving it from a source of volatile rents into a sustainable, technology-driven engine of growth. For Saudi Arabia and other resource-rich nations, this offers a powerful lesson: the path away from the resource curse may not involve abandoning their energy inheritance, but rather intelligently transforming it for a new era.

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