

Научная статья

ЭКОНОМИЧЕСКИЕ ПОСЛЕДСТВИЯ ДЕКАРБОНИЗАЦИИ ТРАНСПОРТА ДЛЯ СТРАН-ЭКСПОРТЕРОВ УГЛЕВОДОРОДОВ

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Аннотация. Актуальность исследования экономических последствий декарбонизации транспорта для стран-экспортеров углеводородов обусловлена масштабом потенциального воздействия на их макроэкономическую стабильность, фискальную устойчивость и траекторию долгосрочного развития. Внедрение технологий электрической мобильности, поддерживаемое ужесточением экологического регулирования и изменением потребительских предпочтений, способно существенно модифицировать прогнозы динамики мирового спроса на нефть. Это, в свою очередь, создает риски для государственных бюджетов, зависящих от нефтегазовых доходов, и формирует давление на платежные балансы, угрожая устойчивости национальных валют и величине золотовалютных резервов. Степень уязвимости отдельных стран неоднородна и определяется комплексом факторов, включая уровень диверсификации экономики, размеры фискальных буферов, структуру запасов и себестоимость добычи углеводородов. Целью данного исследования является выявление макроэкономических и фискальных рисков, возникающих для стран-экспортеров нефти и газа в контексте глобальной электрификации транспорта, и разработка на его основе рекомендаций по адаптации экономической политики. Основным выводом исследования является положение о том, что долгосрочные риски для стран-экспортеров углеводородов обусловлены не самим фактом энергоперехода, а степенью инерционности их экономических моделей и институтов. Стратегическая адаптация к новым реалиям мировой энергетики подразумевает переход от модели максимизации и перераспределения ренты к

концепции построения конкурентных преимуществ в постуглеродной экономике, что не представляется возможным без модернизации институциональной базы и фискальных правил.

Ключевые слова: последствия декарбонизации; транспорт; страны-экспортеры; углеводороды; рекомендации; конкурентные преимущества.

Original article

THE ECONOMIC CONSEQUENCES OF TRANSPORT DECARBONIZATION FOR HYDROCARBON-EXPORTING COUNTRIES

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Abstract. The relevance of studying the economic consequences of transport decarbonization for hydrocarbon-exporting countries is determined by the scale of the potential impact on their macroeconomic stability, fiscal sustainability, and long-term development trajectories. The introduction of electric mobility technologies, supported by stricter environmental regulations and changing consumer preferences, has the potential to significantly alter forecasts for global oil demand dynamics. This, in turn, creates risks for government budgets dependent on oil and gas revenues and puts pressure on balances of payments, threatening the stability of national currencies and the size of foreign exchange reserves. The degree of vulnerability of individual countries varies and is determined by a combination of factors, including the level of economic diversification, the size of fiscal buffers, the structure of reserves, and the cost of hydrocarbon production. The aim of this study is to identify the macroeconomic and fiscal risks arising for oil and gas exporting countries in the context of global transport electrification and, based on these findings, develop recommendations for adapting economic policy. The study's key conclusion is that long-term risks for hydrocarbon-exporting countries stem not from the energy transition itself, but from

the degree of inertia in their economic models and institutions. Strategic adaptation to the new realities of the global energy sector requires a shift from a model of rent maximization and redistribution to a concept of building competitive advantages in a post-carbon economy, which is impossible without modernizing the institutional framework and fiscal rules.

Keywords: consequences of decarbonization; transport; exporting countries; hydrocarbons; recommendations; competitive advantages.

Introduction. The global process of decarbonization, which is a fundamental element of international climate policy, entails a transformation in the structure of global energy consumption. One of the most significant areas of this transformation is the electrification of the transport sector, which is traditionally a key consumer of liquid hydrocarbon fuels. The accelerated transition to electric transport and the concomitant development of alternative forms of mobility form a long-term structural trend aimed at reducing the global economy's dependence on oil. It creates significant challenges for countries whose economic model has historically been based on the export of oil and natural gas. These countries face the need to adapt to a new energy paradigm characterized by a non-cyclical, structural decline in demand for their main export product.

The theoretical basis of the research is works in the field of world economy, resource economy, energy economy and macroeconomic modeling (in particular, sources [1-3]). The methodological framework includes methods of comparative and scenario analysis, statistical methods for evaluating dependencies, as well as elements of financial and fiscal modeling.

The study contributes to understanding the mechanisms of transmission of global structural shifts in the energy sector to national economies that depend on the export of non-renewable resources, and offers analytical tools for assessing and managing the corresponding risks.

Literature review. Analyzing the prospects for hydrocarbon demand in the

context of the energy transition requires going beyond extrapolation of historical trends. The key factor of uncertainty is the speed and depth of decarbonization of the transport sector, which traditionally accounts for about 55-60% of global oil consumption [4], [5]. The scientific novelty of the analysis lies in the integration of technological, regulatory and behavioral variables into a multi-factor scenario model, where transport electrification is considered as an element of transformation of energy systems, interconnected with the development of renewable energy and sustainable development policies.

Methodologically, scenario modeling is based on identifying three key drivers:

- technological center: the speed of reducing the cost of batteries, the development of charging infrastructure, progress in hydrogen technologies and improving the efficiency of internal combustion engines;
- regulatory: the severity of bans on the sale of cars with internal combustion engines, a system of carbon taxes and quotas, subsidies for the purchase of electric vehicles (EV);
- market: dynamics of oil and electricity prices, consumer preferences.

Three scenarios are generated based on the combination of these drivers (Table 1).

Table 1-Characteristics of basic scenarios of oil demand dynamics in the transport sector

Scenario parameter	Conservative	Basic	Radical
Technological background	Slow decline in EV costs, limited mileage growth on a single charge	Rapid degradation of battery costs, accelerated development of fast charging	Technological breakthrough in energy storage, full integration of EV in smart networks (V2G),

	Progress in hybrid forms of technology	EV and hydrogen competition in cargo	hydrogen dominance in heavy transport
transportation Regulatory approach background	Maintaining moderate subsidies, postponing the internal combustion engine ban	Implementing the announced bans by 2035-2040, introducing a carbon tax in key economies	Global agreement to Phase out internal combustion engines by 2030-2035, high carbon tax (over \$ 100 / ton _{of CO2})
Expected EV share in new sales by 2035, %	35	65	95
Peak oil demand (transport)	After 2035	In the period 2028-2032.	Completed or completed in the mid-2020s.
Decline in oil demand by 2050 relative to 2020, %	15	40	69

Source: compiled by the authors on the basis of [6-8].

The impact on natural gas demand is more indirect and ambiguous. In the short and medium term, gas can act as a transition fuel for electric power generation, feeding the growing EV fleet, especially in regions that are moving away from coal. However, in the long run, under a radical scenario, the replacement of gas in the electric power industry by wind, solar and storage, as well as the potential development of "green" hydrogen as an alternative to gas in industry, create risks of stagnation, and then a decline in demand. Thus, the correlation between transport electrification and gas

demand has an inverted U-shape, since the initial increase is replaced by a decline as the energy system itself decarbonizes.

The vulnerability of the economies of hydrocarbon exporting countries to demand reduction is determined by the degree of dependence of key macroeconomic aggregates on oil and gas revenues. This dependence creates two main channels of vulnerability: fiscal (through the state budget) and foreign trade (in the context of the balance of payments) [9-11].

A decrease in prices or export volumes leads to a significant budget deficit, which requires either accumulated reserves, an increase in public debt, or painful spending cuts to finance. The key indicator is the fiscal break-even price – the price of oil required for a balanced state budget.

According to the IMF, for 2023, the fiscal break-even price for Saudi Arabia was about \$ 80 per barrel of Brent, for Russia - \$ 60, for Kuwait - \$ 50, for Norway - below \$ 40 (due to the diversification of the tax base). Even if the Baseline Scenario assumes long-term price pressures, countries with a high indicator are in a zone of constant resource scarcity. For example, the budget of Saudi Arabia during the period of low prices in 2015-2016 and 2020 showed a deficit exceeding 10% of GDP, which led to active borrowing in international markets and reduced spending.

A reduction in export earnings worsens the trade balance, and with it the current account of the balance of payments. To maintain the stability of the national currency and finance imports, the use of funds from sovereign funds or foreign exchange reserves is required. The indicator here is the external break-even price in order to ensure a zero current account balance.

In 2014-2015, the fall in oil prices contributed to a significant deterioration in Russia's current account: a surplus of 3% of GDP in 2013 was replaced by a deficit of 5% of GDP in 2015. This caused significant pressure on the Russian ruble, devaluation, and a reduction of about \$ 200 billion in international reserves to smooth out the adjustment. Similarly, Nigeria, which depends almost entirely on oil and gas exports, has experienced a shortage of foreign currency, a devaluation of the naira, and a

recession.

The structural nature of the future shock, unlike the cyclical decline of 2014 or 2020, means that prices should not be expected to recover to their previous values. This requires a review of the fundamentals of the budget rule and long-term macroeconomic policy [12-14].

Organization and methodology of the study. Comparative analysis of diversification strategies and assessment of the fiscal sustainability of hydrocarbon exporting countries in the context of the long-term decarbonization trend is the main focus of research.

Three representative models were chosen as the object of research: Saudi Arabia (a single-industry economy with high incomes and an active state transformation policy), the United Arab Emirates (a federal economy with significant diversification already achieved within certain territories) and Norway (a developed diversified economy with an institutionalized rent management model). This choice allows you to cover the range of possible approaches from the initiation of diversification to its mature forms.

The methodological framework includes a comparative historical and economic analysis of strategic documents and the results of the implementation of diversification programs. The second part of the study is based on quantitative modeling methods. To assess fiscal stress, a simplified model has been developed that takes into account the dependence of budget revenues on oil and gas rents under various price scenarios. The model uses the following key parameters: the share of oil and gas revenues in total budget revenues (α), the fiscal break-even price (P_{fisc}), the sensitivity of non-oil revenues to economic growth rates (β), and the volume of financial buffers (sovereign funds) to GDP.

Modeling is carried out for three groups of countries (high, medium and low vulnerability) in the context of two energy transition scenarios: basic (medium speed) and radical (high speed). The price corridor for Brent crude oil is set as a long-term trend for the period up to 2040: \$ 50-65 per barrel in the baseline scenario and \$ 35-50

in the radical scenario. The result of the simulation is an estimate of the period (in years) during which the country will be able to compensate for the projected structural budget deficit from accumulated financial reserves without making a significant fiscal adjustment.

Results of the study and their discussion. The strategies of the three countries studied show fundamental differences in goals, tools, and stages, as shown in Table 2.

Table 2-Comparative characteristics of economic diversification strategies

Criterion	Saudi Arabia (Vision 2030)	United Arab Emirates (strategies for selected Territories)	Norway
Main goal	Reducing the budget's dependence on oil	Securing the status of a global hub for trade, logistics, finance, tourism and high technologies	Preserving and increasing wealth for future generations after the depletion of natural resources
	Creating new economic sectors and jobs		
Key tools	Investment through mutual funds in new sectors (NEOM, green hydrogen, tourism)	Creation of infrastructure and free economic zones	Transparent accumulation of income in the Global Pension Fund (GPFG)
	Partial privatization	Attraction of foreign capital and specialists	Strict budget rule
	Regulatory reforms	Investment in innovation (Masdar)	Investing in human capital and R
& D The role of a sovereign	wealth fund The Mutual Fund is a tool for active internal	Investment organizations of Abu Dhabi (ADIA,	Global Pension Fund (GPFG) - a stabilization and

	transformation (an active investor in the country)	Mubadala) - a tool for diversifying assets and generating financial income abroad	savings tool, investments exclusively outside of Norway
The budget rule	was introduced relatively recently, aimed at limiting the budget deficit, but so far it is difficult to comply with it. Due to the high costs of diversification	, there is actually a strict rule in Abu Dhabi, linking the growth of expenditures with non-resource revenues	: only the fund's profitability is spent in the budget (up to 3% of its value per year), which completely decouples expenditures from current oil prices
. The level of institutional quality	of Reforms is carried out "from above"	. Very high level for the region	the region. high level
	There are bureaucratic and corruption risks	Effective bureaucracy	Full transparency
		Rule of law for business	Strong democratic institutions

Source: developed by the authors.

The strategy of Saudi Arabia is an active industrial and social transformation, financed from the current rent. The concept of the UAE, especially Dubai – is to focus on the service economy and the status of a global hub. The Norwegian model reflects the institutional separation of rental income and the current budget with the priority of capital preservation [15].

The results of fiscal stress modeling for representatives of the three vulnerability groups are presented in Table 3. The initial parameters are averaged over groups of countries.

Table 3-Modeling the period of budget sustainability at the expense of financial reserves

Country group	Baseline parameters for modeling	Baseline scenario	Radical scenario
High vulnerability (Nigeria, Angola)	$\alpha = 70\%$	0.5-1.5 years	Less than 6 months
	$P_{fisc} = \$ 75$	Persistent deficit with immediate acute crisis	Fiscal crisis occurs almost immediately
	Financial buffers to GDP - 5%		
Average vulnerability (Saudi Arabia, Oman)	$\alpha = 65\%$	4-7 years	2-4 years
	$P_{fisc} = \$ 70$	There is a time window for policy adjustments, but the pressure on reserves is high	, the window for maneuver is sharply narrowing, rapid adjustment of spending is required
	Volume of financial buffers to GDP-80%		
Relative stability (Norway, Kuwait, UAE)	$\alpha = 25\%$ (for Norway), $\alpha = 60\%$ (for Kuwait)	Less than 15 years (for Norway), less than 20 years (for Kuwait)	8-12 years old (for Norway), less than 15 years old (for Kuwait)
	$P_{fisc} = \$ 40$ (for Norway), $P_{fisc} = \$ 50$ (for Kuwait),	There are no risks to medium-term stability	Stability remains, but long-term trends require attention
	Volume of financial buffers to GDP-250% (for Norway); 400% (for Kuwait)		

Source: developed by the authors.

Nigeria and Angola do not have enough time. Even in a moderate scenario, their

reserves are depleted over a period of 1-2 years, reflecting the need for emergency external assistance, sharp spending cuts, devaluation, and socio-political destabilization. Countries with medium vulnerability (Saudi Arabia, Oman), despite significant financial buffers, are at risk. Their sustainability period (4-7 years in the baseline scenario) coincides with the period of implementation of their diversification programs (for example, Vision 2030 in Saudi Arabia). There is a dilemma between financing transformation and maintaining budget stability. Sufficiently high investment costs in the face of falling incomes can accelerate the depletion of reserves. At the same time, Norway, Kuwait, and the United Arab Emirates are relatively protected for the long term. For Norway, the main risk is a long – term decline in the yield of its fund due to structural changes in the global economy. For the countries of the Persian Gulf (Qatar, Kuwait), the key task is to gradually adapt spending obligations to the new rate of income.

Based on the analysis, recommendations are formulated, differentiated by country groups:

1. For highly vulnerable countries: review energy subsidies, optimize capital expenditures, improve the efficiency of taxation of the non-oil sector; fight corruption, improve the business climate; actively work with the IMF and the World Bank on support programs, including possibly financing the green transition.

2. For countries of medium vulnerability (with diversification programs): tightening the budget rule to protect financial buffers, focusing on developing sectors that are competitive in the post-carbon world (digital services, logistics, niche high-tech manufacturing, green hydrogen), partially switching to a model of financial savings and diversifying assets abroad to reduce risks.

3. For countries of relative sustainability: maintaining and developing transparency, the rule of law, and the quality of public administration as key assets in the uncertain future; channeling part of the funds ' resources into infrastructure, education, science, and technology that ensure long-term competitiveness in the context of the fourth industrial revolution; using financial and political weight to

participate in the development of international carbon regulation standards. This will help protect interests and find new niches in the low-carbon economy.

Conclusions. The global energy transition, whose fundamental element is the electrification of transport, creates a structural shock for oil markets. Modeling of demand dynamics shows a high probability of reaching the peak of resource consumption in the transport sector in the period up to 2035, followed by a steady decline. The impact on the gas market is more complex, inverted U-shaped, determined by its role as a transition fuel in the electric power industry.

A comparative analysis of diversification strategies has revealed that their effectiveness is more correlated with the quality of the institutional environment than with the amount of financial resources allocated. The Norwegian model, based on a clear institutional separation of rental income and the current budget through a sovereign fund mechanism and a strict budget rule, has proven to be as resilient as possible to external price shocks. Active government transformation programs like Saudi Arabia's Vision 2030 face a dilemma between the need for high investment spending on diversification and the need for fiscal consolidation in the face of declining oil revenues. The success of such programs depends on the ability to implement parallel institutional reforms.

The obtained results of fiscal stress modeling confirm the need to improve the macroeconomic policy framework of hydrocarbon exporting countries. The management policy focused on smoothing cyclical fluctuations in commodity prices becomes ineffective in the context of their long-term decline. A key imperative is the transition to a permanent fiscal consolidation regime and the creation of new sources of revenue that are not related to hydrocarbons. This requires the transformation of the role of sovereign funds from stabilization funds to instruments of strategic accumulation and financing of structural transformation.

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