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A STUDY ON GLOBAL COOPERATION STRATEGY IN OIL INDUSTRY BASED ON THE GAME THEORY

ESTUDO DA ESTRATÉGIA DE COOPERAÇÃO GLOBAL NA INDÚSTRIA DO PETRÓLEO COM BASE NA TEORIA DOS JOGOS

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Resumo

Veículos de passeio consomem mais de 21 milhões de barris de petróleo por dia. Apesar disso, estudos recentes projetam o eminente fim da era do petróleo. De modo concomitante, restrições ambientais apontam o bioetanol como um forte candidato a substituir a gasolina. Por outro lado, a expectativa de crescimento da frota de veículos leves no mundo e a capacidade limitada na produção de etanol sugerem que a substituição completa da gasolina como combustível não é factível no curto e no médio prazo. Entretanto, 30% de mistura de etanol na gasolina pode elevar o desempenho de motores de ciclo Otto, reduzindo a emissão de gases de efeito estufa e alterando a taxa de depleção das reservas mundiais de petróleo. Destarte, são analisados neste estudo, os benefícios do uso do etanol como complemento da gasolina e seus efeitos sobre as reservas mundiais de petróleo convencional. Conclui-se , com base na teoria dos jogos, que o processo de transição da era do petróleo para uma fonte de energia mais sustentável deveria privilegiar a estratégia de cooperação e compromisso, buscando resultados ótimos, tanto para a indústria do petróleo quanto para a indústria do etanol.

Palavras-chave: Teoria dos jogos, indústria do petróleo e de etanol, estratégia de cooperação.

Abstract

Light-duty vehicles consume over 21 million barrels of oil per day. Recent studies, however, have predicted the imminent oil age end. In addition, environmental restrictions point to ethanol as strong candidate to replace gasoline. On the other hand, the expected light-duty vehicles' worldwide growth and limited capacity for ethanol production suggest that total substitution of gasoline is not feasible in the short to medium-term. Nonetheless, 30% ethanol to gasoline blend could increase the performance of internal combustion engines, decrease the emission of greenhouse gases and alters the oil reserves depletion rate. In this study the benefits of using ethanol as a complement to base gasoline and its effects on the world's conventional oil reserves is analyzed. Finally, based on game theory, the transition process to a biomass age could focus on cooperation and compromise strategies in pursuing optimal results for both oil and ethanol industries.

Keywords: *Game theory, oil & ethanol industry, cooperation strategy*

1. INTRODUCTION

The huge global fuel market which supplies light-duty vehicles has been the subject of competition amongst major oil companies since the 1900s, but is now subject to significant challenges that require the adoption of long-term strategies. First, there is the threat of dwindling stocks, as predicted in peak oil reserve forecasts which have been the subject of academic research for decades.

Since the Hubbert curve calculations were confirmed for North-American oil onshore shale in the 1970s, other studies have predicted the end of the cheap oil age (CAMPBELL *et* LAHERRERE, 1998; DEFFEYES, 2003). Second, environmental restrictions, such as MTBE (Methyl Tertiary-Butyl Ether)

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substitution, and the need to mitigate greenhouse gas emissions highlight the importance of ethanol as main candidate to substitute one of the most important oil-products: gasoline (OPEC, 2009).

The fact remains, however, that the expected growth of the world's light-duty vehicle fleet over the next years, and the still limited capacity for producing cheap ethanol indicate that the whole scale substitution of gasoline is not feasible in the short and medium term. The Hubbert curve (HUBBERT, 1956) is nevertheless a useful tool to determine the impact on the fuel consumption market of the adoption of ethanol as complement rather than as a substitute of gasoline for cars, motorcycles and other light vehicles.

Technical studies indicate that the addition of 30% biofuel to gasoline increases the performance of Otto cycle engines and decreases greenhouse gas emissions, as well as reducing the pace of the depletion of oil reserves, thus extending the oil age (SZKLO *et* SCHAEFFER, 2006). This paper seeks to introduce the important use of ethanol as a complement to gasoline, emphasizing the effect of such substitution on the world's energy system and on the extension of the lifespan of oil reserves, as well as in mitigating the emission of greenhouse gases. Some qualitative and quantitative evidences regarding a possible extension of the oil age is presented.

2. METHODS AND TOOLS

2.1 Method description

The deductive-hypothetic method was used to design this study. The following hypothesis was formulated:

- h0: The oil industry blocks the introduction of ethanol into the oil system in order to secure long-term economic gain;
- h1: The global ethanol industry achieves 100% rate of substitution (of E100- pure ethanol), for gasoline;
- h2: A gradual 30% ethanol-gasoline blend enables a transition in line with the world's agro-industrial yield. In this hypothesis, few modifications to vehicles are needed. Geopolitical crises are decentralized, CO_2 emissions are mitigated and oil reserves are extended beyond the forty year period in which they are currently predicted to run out.

Having tested the above hypothesis, we will analyze each scenario in the light of the application of the game theory using as a basis a cooperative game applied to the transition from fossil fuel to its biomass successor, the aim being positive results for both energy sectors.

2.2 The application of game theory to the hypothesis

The game theory was drawn up by Morgansten and Neuwman in 1947 as a tool for analyzing the strategic interaction between players (organizations, entities or characters). It is used nowadays for the study of strategic interactions amongst agents in extremely competitive markets, applying a payoff matrix and decision trees approach. John Nash contributed to the game theory by demonstrating balanced situations where competitors make reasoned choices based on information about their opponents and the actions they perform (VARIAN, 2006).

The game can be cooperative, when participants negotiate contracts (GINTIS, 2000). This enables a balance between coordinated strategies. Alternatively the game may be non- cooperative, when agreements are not possible (PINDICK *et* RUBINFELD, 2006). Applying the game theory we can observe the interaction between the oil and ethanol industries, thus simulating gain and loss scenarios for each player in the fuel market. In this study, the actions and strategies undertaken by each industry are qualitatively analyzed, particularly in regard to the oil industry, which is the incumbent industry.

The hypothesis (h0), in this case, considers that the oil industry will succeed in blocking the introduction of large volumes of ethanol worldwide. In the long-term, the fewer the number of competitors, the better it is for the oligopoly's game. However in terms of oil reserves, the exhaustion of oil upstream and sunk - atmosphere downstream, may lead the oil and ethanol industries, as well as the planet, to environmental and energy collapse.

On the other hand, under the h1 hypothesis – the E100 – introduction of ethanol onto the market as a short-term substitute for gasoline, could be as noxious as the E0 leading for example to collapse in food production as more and more agricultural land is used for the cultivation of sugar cane. The frog and scorpion analogy (VARIAN, 2006) presents the manner in which the game theory interprets the sequential movements of a compromise game where the best tactical option is cooperation between the two players.

Varian's analogy describes a frog's options when a scorpion asks it for a ride on its back across a river. The frog has two alternatives: to accept or refuse to give the scorpion a ride. If the frog accepts, it faces two new possibilities: the scorpion may sting it and both will likely succumb and drawn; on the other hand, if there is no sting, both will cross the river in a win-win result. If the frog rejects the proposal, neither party will achieve any gain. By accepting the proposal the frog will hold a credit against the scorpion and may be entitled to seek the scorpion's protection.

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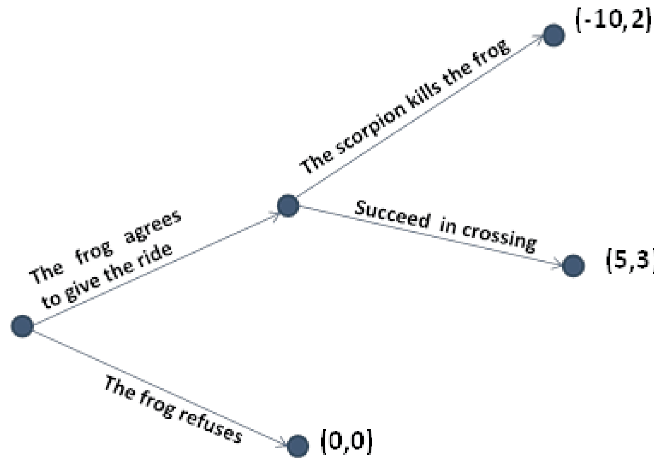

Figure 1. The decision tree: the frog and scorpion metaphor in a compromise game

Similarly, it is possible to simulate a strategic interaction between the oil and ethanol industries. The oil industry may opt to carry the scorpion, represented by the ethanol industry (i.e. to accept and cooperate with the introduction of ethanol onto the fuel market). If the oil-industry resists or refuses to cooperate with the ethanol scorpion the widespread introduction of ethanol onto the global market is hampered and both industries and the society will lose out on the gains of this partnership.

If there is cooperation in terms e.g. of a 30% ethanol-gasoline blend, then both will win, with positive marginal results to society as a whole. If the ethanol scorpion kills the oil industry frog, ethanol will compete with the gasoline completely – 100% (E100), but, at least in the short-to-medium term, the results for both industries will be disastrous as shown at Figure 2.

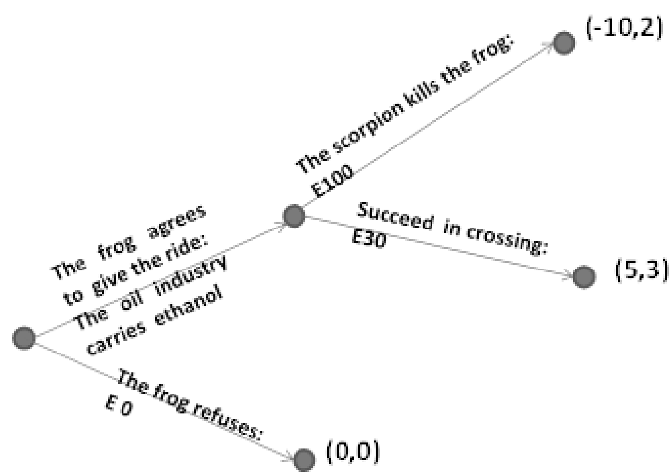

Figure 2. The compromise game: oil x ethanol

The figures are solely illustrative of the compromise game. They did not represent a real quantitative assessment of the losses and benefits incurred by the two industries analyzed in this paper. In terms of the first alternative As first alternative, the matrix sets out the status of cooperation between the oil industry and ethanol, limiting the mixture of 30% ethanol to and gasoline in the worldwide fuel market for light vehicles (E30).

In the second alternative, the oil industry resists the entry of ethanol onto the market reducing the blend to zero or near-zero (E0). The third and least likely alternative, used mainly for illustration purposes, ethanol substitutes gasoline at a rate of 100% da (E100). We analyzed hypotheses, h0 and h1 through a sequential movement test, by simulating a compromise game between ethanol and gasoline (figure 3).

Despite the apparent short-term gain for the oil industry, in banishing ethanol, in the medium-to-long-term, the 'conventional' oil industry would suffer losses and reduction of hegemony. Cheap oil reserves would decline and high prices would force the entrance of backstop technologies, particularly orimulsions and tar sands (and even perhaps shale oil). This would pressure the demand for natural

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resources (natural gas and water) in the long-term and result in increasing greenhouse gas emissions, aggravating an already delicate situation. In the long-term it would lead to upstream collapse, reduction of reserves (the Hubbert curve contraction) and to energy supply system chaos.

In hypothesis h1, E100 seems to solve this environmental challenge. Nevertheless, as of today, only Brazil has a liquid biofuel industry that is economically and environmentally viable. In other countries, the amount of land required from traditional agriculture for biomass resources could force a continuum of high commodities prices, collapsing this segment. Furthermore, the sudden rise of the initial demand for fossil fuels would amplify costs and provoke a possible Hubbert curve contraction.

Worldwide, the gradual ethanol introduction hypothesis (E30) facilitates the entrance of this new fuel into the global economy, without its clashing directly with t the barriers created by the oil industry. In addition, as mentioned before, E30 blends result in less gasoline consumption (and CO_2 emissions), the possibility of producing all ethanol from inputs (basically, sugar cane)that do not pressure land use leading to competition with food production, and the alternative of adopting lean-combustion high efficiency Otto cycle engines (SZKLO *et al.*, 2007).

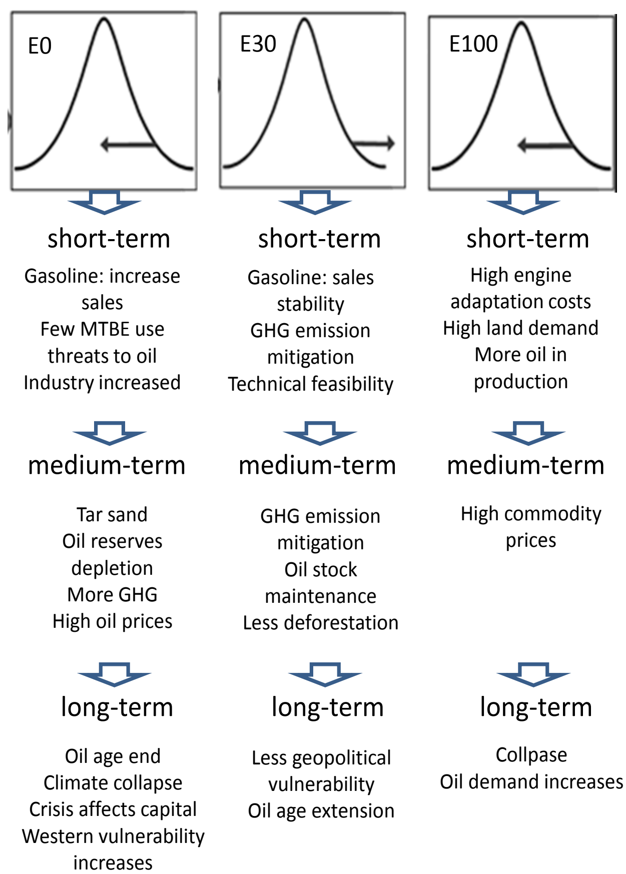

Figure 3. Sequential Movement in the Ethanol x Gasoline compromise game

In this hypothesis the Hubbert curve would be extended, prolonging the oil age. Moreover, crude oil, which would be diverted from gasoline production, could be increasingly used to produce petrochemicals, lube oils, and other products that stock carbon rather than emit it. Additionally, the sunken (atmosphere) would be less saturated. Meanwhile, the vulnerability and risk generated by geopolitical issues would be reduced.

3. DISCUSSION OF RESULTS

The analysis made by Table 1 deploys the simulated effects of E30 on the global oil market. The first column (after time series projections) sets out the demand for gasoline demand. OPEC (2009) expects that the demand for gasoline will increase to 25 million barrels per day by 2030. But OPEC also projects a reduction of the share of gasoline (in oil production). In other words, bio-fuels are already considered as a potential competitor to gasoline.

Significant growth in the market share of bio-fuels up to 2030 is predicted. The bio-fuel market share is forecast to jump from 7.5% to 20.4%. Although oil saved by the introduction of ethanol does not markedly impact on oil reserves, over a period of 21 years the total amount of

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oil saved is considerable. Over 34 billion of barrels could be saved. This is the equivalent of o double the estimated amount of Brazil's pre salt reserves. The greatest E30 gains are observed in terms of environmental issues. At the end of 21 years it is possible to have avoided the emission of 10 thousand Gtons of GHG. It should be borne in mind however that in order to produce this quantity of ethanol, over 62,180 thousand hectares of agricultural land will be used.

Table 1. Ethanol 30 Possible Effects on Global Market

Years	Gasoline Mb/d	Share of Oil	Share etanol/ gas	E30 (30% biofuel)	EUR* reference case	EUR (E30)	Oil b/d saved by E30 (millions)	GEE (million tons) saved emissions	Land use (thousand hectare) + - 7000 l/ha
2009	21,2	25%	8%	6,4	-30,8	22	4,8	650.157	52.729
2015	22,4	25%	11%	6,7	-230,1	222	4,3	2.950.291	55.714
2020	23,4	24%	13%	7,0	-405,7	391	3,9	2.677.116	58.201
2025	24,2	24%	17%	7,3	-589,8	569	3,3	2.226.377	60.191
2030	25,0	24%	20%	7,5	-782,4	757	2,4	1.639.051	62.180
					Total (09/30)		34.055	10.142.993	

Sources: Based on EIA (2011), Horta (2008), OPEC (2009), Deffeyes (2005), FAO (2011).

Notes:
EUR in billion barrels = 2,000; 1 gl =0.02381 barrel ; 1 gasoline gl = 8.91kg CO_2
Ethanol productivity = 7,000 liters/ ha; Mb/d = Millions barrels per day
Biofuels are considered as Ethanol plus biodiesel in these numbers.

It can be reasonably assumed that the participation of the ethanol industry in the fuel market, in conjunction with cooperation between the two industries (ethanol and oil) will lead to balanced oil prices on the international market. .An oil price expansion could be catastrophic to the oil industry. In such circumstances there would be increased pressure to look to alternative energy sources (backstop technologies).

A total substitution of gasoline by ethanol market is unfeasible and would, in any event produce a food crisis and supply problems. Even though the use of automobiles as an urban modal provokes many social and environmental external costs, this fuel market is in constant expansion, so that it is essential that it be supplied and supported in the most economically and environmentally sound manner. In sum, it is possible to avoid the emission of about 10,000 tons of GHG up until 2030 merely by increasing the participation of ethanol in the fuel market. This action could also diminish the tension between oil industry and global society.

Furthermore, a saving of approximately 34 billion barrels of oil could be achieved by 2030. This could extend the oil age, establish a balance in oil prices and reduce the level of the threat of technological alternatives substituting the oil industry. In addition, the vulnerability of oil-dependent non-producers could be substantially reduced. This could in turn diffuse some of the political and economic tension related to Middle Eastern oil supplies.

4. CONCLUSIONS

This article aimed to explore and consider the benefits of cooperation between the ethanol and oil industries, in particular, in order to extend oil age. We found that the use of 30% ethanol-gasoline blend was a factor in the distention of the Hubbert curve. Moreover, we sought to explore some of the reasons that justify the adoption of liquid bio-fuels worldwide not as substitute, but rather as complementary products associated to gasoline.

Strategic cooperation between the ethanol and oil industries presents benefits to society, because the geo-political and economic risks are lowered; it benefits the ethanol industry because it allows for a broader time range for adaptation towards improved ethanol production worldwide; and finally, it benefits the oil industry because it expands its influence in time, hindering the emergence of back stop technologies. In addition, the risk of more stringent petrol fuel specifications is decreased, as ethanol can also be an alternative means of improving gasoline specification (e.g., related to sulphur content) without increasing CO_2 emissions in oil refineries.

In sum, the complete substitution of gasoline by ethanol in the short-term is only remotely feasible in some regions or countries, such as Brazil. For most other countries, however, a time-delay for adaptation is necessary; and the

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transition process, with the ethanol-gasoline blend (E30), is an attractive option. In the medium-term, advanced bio-fuels might alter the 'game' studied. These biofuels, which include the BTLs and the ethanol from hydrolysis, will increase the producers' capacity to offer ethanol to the market. In the medium-term, a suitable more globalized ethanol market might also lead the game towards a more wide spread use of biofuels.

In other words, the energy system needs to adapt to this change: the so-called phase-in to break the established lock-in, delaying the changes in the dominant structure. It is crucial that there be further research into enhancing and determining the optimal proportion of ethanol proportion to be blended to gasoline.

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