José Vitor Bomtempo

INNOVATION STRATEGIES IN BIOFUELS: INDUSTRY DYNAMICS AND THE BRAZILIAN CASE

Escola de Química UFRJ/ Instituto de Economia UFRJ, Rio de Janeiro - Brasil,
e-mail: Vitor@eq.ufrj.br

A great number of technological alternatives have been proposed as possible options to the fuel mix, particularly in the transport case. This paper limits its scope to the biofuel field and tries to explore the many dimensions of the innovation strategies in biofuels. The paper takes an evolutionary perspective and examines the selection environment construction, the possible technological trajectories and the innovation strategies in biofuels.
Assuming that biofuels will surely play a central role in the fuel mix, we can identify at this stage of development a huge number of technological alternatives seen as viable to produce biofuels. It is possible to consider as well multiple strategic alternatives and even multiple business models. In this scenario, long term planning is a quite hazardous exercise. Following what we have learned from innovation studies, the current available possibilities in biofuels tend to be submitted to a selection process and to converge to a small number of alternatives. Some degree of convergence or standardization is influenced by factors as: complementary assets, governmental regulations, firm strategic movements and user producer interactions (Utterback, 1994). So, it is quite difficult to control, to impose or to anticipate the final choices. In that situation, agents should consider this process in their planning otherwise their future positions in the industry could be at risk. We could wonder if firms and other actors concerned by biofuels have been taking this perspective in their planning.

The first section of paper examines the notion of natural trajectory and its role in the definition of technological trajectories. The evolutionary theory of technical change places substantial emphasis on the learning process to explain technological progress (for example: Nelson and Winter, 1982; Dosi, 1982). The innovation process is seen as a result of knowledge accumulation under specific evolutionary patterns. Knowledge that generates technological innovation is assumed to be local, tacit to some extent, and path dependent. The evolutionary theory claims that we can explain the rhythm and direction of technical change, analyzing the history of the learning process. We can even identify the determinants of technical change if we recognize the technical, scientific and economic factors that drive the learning process. This approach has identified clear trends for the technological progress in different industries that can be grasped as “natural trajectories” (Nelson and Winter, 1977). Nelson and Winter further argued that a trajectory is usually “specific to a particular technology or broadly defined ‘technological regime” (Ibid. 1977: 57). The regime concept refers to the cognitive foundation underlying engineering “beliefs about what is feasible or at least worth attempting” (Ibid. 1977: 57).
Regimes or paradigms (as proposed by Dosi,1982) differ in their underlying scientific and technological principles. At the pre-paradigmatic stage of development, different sets of principles compete. Once principles become increasingly codified, the choice behavior is increasingly guided by perceived differences in the relative potential development of different technologies. At this point, standardization becomes more likely. In many cases, the phase of standardization is marked by what has been called a “dominant design” (Abernathy and Utterback 1978; Utterback, 1994), a successful product model based on a particular set of technological principles. As far as the process industries are concerned, the exploitation of economies of scale has historically been the main direction for technological

development. Will biofuel industry follow the natural trajectories? Or, considering that innovation represents ruptures with the established technological practices, challenging the natural trajectory could be a winner strategy in the biofuel industry?
The second part of the paper presents the biofuel industry as a field of multiple technological, strategic and business model alternatives that actors have to face in their strategic planning. Even if, this paper deals with the biofuel industry in a global perspective, the study emphasizes the Brazilian case. Brazil could be a good case to illustrate the biofuel evolution. It is possible to put in perspective the ethanol evolution in the last 30 years to become a kind of model of competitive biofuel production and the Brazilian biodiesel initiative. A crucial point in the industry is to consider first and second generation biofuels. First generation biofuels include sugar cane ethanol and vegetal oil biodiesel, for example. These are mature routes, particularly in the sugar cane ethanol. Second generation biofuels come from low value biomass. So they don't compete with food crops. But there are many technological challenges to overcome. The second generation is still in a development stage. Nevertheless, according to some studies, it seems that, if biofuels is due at a significant role in the energy mix, second generation biofuels will probably overtake first generation products. Are first generation biofuels no more than a transition stage?
Even if we stay in the first generation field, multiple technological and market alternatives can be identified, as the nascent Brazilian biodiesel industry testifies. Many oil plants are cited as possible raw materials: from technological intensive crops as soya beans to very alternative plants as Jatropha curcas (physic nut). Many questions are still open in the technological design of the industrial plants: continuous or batch plants? Methanol or ethanol based? Dedicated to one kind of raw material or flexible plants easily adapted to different kind of oils? Are scales following the "natural trajectory" of the process industry? Or, will small flexible plants, more adapted to regional conditions, be competitive? Will small and medium firms remain the traditional players in the biodiesel industry? Or, will the industry be as concentrated as similar sectors? Finally, what are the business models that probably will emerge in the biodiesel industry?
In such complex scenario, firms and other actors are increasingly taking decisions and making strategic movements that contribute to the industry evolution and consolidation.

The third section examines the firm strategies, oil and gas companies in particular, in the biofuel industry. It is possible to identify at least three typical actions: to invest in the conventional technologies as a first generation biofuel producer (Repsol, Petrobras, Marathon, NNPC and Chevron); to invest in the first generation biofuels but with some renovated technology (Neste, Petrobras, UOP) and finally to focus in the development of the second generation biofuel, investing in a R&D program to overcome the technological challenges of the new biofuel technologies (Shell, BP/Du Pont).

Finally, the fourth section of the paper addresses some concluding remarks. Multiple alternatives now available will probably converge to a more restrict number of options. Strategic planning in the biofuel industry should try to consider this trend. Nevertheless, as some crucial questions are still open, uncertainty remains high. Biofuels are a promising industry but innovation process is still unclear and difficult to actors' innovation strategies.

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