Investigation and modelling framework of biofuels as a new socio-technical regime

Stamboulis Yeoryios[1] and Papachristos George[2]

[1] Laboratory of Infrastructure, Technological Policy and Development, Department of Planning and Regional Development , University of Thessaly, Pedion Areos, 33834, Volos, Greece; email: ystambou@uth.gr

[2] Dept. of Mechanical Engineering and Aeronautics, University of Patras, University campus, 26504, Rio, Patras, Greece

Abstract

The advance of a biofuels future involves a set of interconnected changes across the value system that amount to a techno-economic regime transition. Within such a process occur various situations of co-opetitive games which take place in a dynamic concurrent manner. Systems dynamic modelling is proposed as the core of a policy development methodology in order to facilitate the participatory investigation of policy alternatives.

Keywords: system dynamics, systems thinking, simulation, resource-based view, renewables, biofuels, socio-technical regime, innovation, diffusion, transition

1. Systemic Complexity of Socio-technical Regime Transition

Biofuels as a new technology are not just a substitute similar to the one they might potentially replace.

- Biofuels and renewable energy sources in general require different structures in production, distribution and consumption as well as in the financial relationships therein.
- There is different spatial arrangement in physical , technical and social levels
- New roles are emphasized, the importance of financial relationships changes, and new interactions and synergies appear
- In every sector, there are different requirements for human resources, know how, natural resource and capital

A socio-technical regime or system is a relatively stable configuration of institutions, technologies, rules, practices and networks of cooperation that determine the evolution and use of technology (Rip Kemp 1998). In its entirety a socio-technical regime includes production, diffusion and use of technology (Geels, 2004).

With regard to this definition, biofuels diffusion on a wide scale could be regarded as the successor of the fossil fuels regime. There are certain points that need attention in the transition from the one to the other. The problem of maintaining a coordinated and sustainable pace across the sectors is accentuated by the inherent complexity of the attempt which is not easily manageable. Interdependencies amongst sectors and actors in the production, distribution and consumption systems render coordinated action of the system sectors necessary. Otherwise delays or unanticipated rapid developments in the sectors might lead to a non sustainable situation and a failed transition.

What is described in the following sections is a framework of modelling and simulation that can facilitate this complexity, also operating as a tool for experimentation of scenarios and policies for the succession of the established fossil fuel regime in a virtual environment.

Scenario exploration is conducted by investigating the strategic interactions of the actors in the value system from primary production to final consumption and documenting how these can ultimately affect in positive or negative ways the new regime.

The proposed methodology provides the ‘space’ for investigating the effect various different parameters have on the framework of institutions and rules of the socio technical regime and their effectiveness as well as the policies for intervention and regulation. It outlines the conditions under which co-opetition games may evolve into either positive or negative outcomes.

2. Systemic innovation and co-opetition games

Regime transition involves the diffusion of complementary innovations and the commitment of relevant resources in a variety of activities across the value system. So, the diffusion of a renewable energy source such as biofuels has a system-wide nature. It demands changes across the spectrum.

The pace of diffusion of the new regime depends on the availability of the required resources. It depends on the willingness of actors to commit resources to the diffusion process. This willingness is conditioned by the expectations of return on their investment. This return, in turn, depends also on the coordinated actions of other actors in the value system, within and outside each sector. Hence, there emerge co-opetitive games amongst actors which co-operate for the diffusion of the new regime while at the same time they compete for the share of the total returns. These co-opetitive games occur intra-sectorally and along the value system.

The level of diffusion is directly analogous to the level of coordination of the committed resources.

The final result will portray synergies between resource commitments to activities across the value system.

Transition failure is highly probable, as breakdown may occur in any part of the system. A variety of factors could lead astray a transition process:

- A lack of coordination could lead to reduced investment return and market decline. For example investments in conversion units could surpass both/either investments in primary or tertiary sectors.
- Over-investment leads to cost increases (eg. land), reduced returns due to demand hysteresis, eventually discouraging other entrants and causing those already involved to withdraw.

- Constraints in critical resources (land, human resources, equipment etc.), set limits to the development of the sectors or the industry in general.
- Asymmetrical pricing in wholesale and retail prices and returns could lead to significant fluctuation or crises.

An effective policy analysis would highlight the factors that could potentially impede development or those that are leverage points for the total system.

3. Systems dynamics modelling of biofuels diffusion as regime transition

Below we present a systems dynamics model – as well as the corresponding causal loop diagrams – that serves for an exploratory analysis of the described diffusion process via simulation. The model is divided in three sectors (Figures 1-3) for the purpose of ontological realism and user friendliness: the primary sector is dealing with the introduction of new "energy crops"; the secondary sector deals with the investment in the processing of these crops for the production of biofuels; finally, the third sector deals with the dynamics of diffusion in retailing and end users. The model has been developed in the Powersim system dynamics simulation environment (Figure 4).

Important, but realistic, simplifying assumptions have been made. Most significant are two:

- the source of biomass for biofuels is limited to dedicated "energy" crops;
- biofuels consumption is limited to individual consumers (for transport of other purposes); industrial users are not dealt with here in any specific way.

Key resources are identified:

- in the primary sector the land committed to biomass production;
- in the secondary sector the investment in production (processing) capacity; and
- in the market sector the availability of retailing sites and the attraction of end users.

In all cases the expected benefit is the critical factor affecting investment decisions. Benefit is determined primarily by intermediate and end prices and level of scaling. It is important to notice that prices may affect decisions in counteracting ways. Thus, while increases in biomass and biofuels wholesale price may favour the producers of the corresponding goods and induce them to invest in further production resources, at the same time they reduce the prospect of benefit for the next actor in the value system, thus putting them of committing resources downstream. Time delays are also critical in this process.

In the process of policy development two sets of issues demand particular attention in terms of methodology. First, the question of performance and success criteria and the variables that signify them is directly related to the dynamic hypothesis under investigation and the scope of the investigation; the first (dynamic hypothesis) is raising the question of modelling realism and the extend that the modelling exercise is relevant to the problem it aims to address; the second (scope) involves boundary determination and the selection of the parameters and factors investigated.

The second set of issues is related to the involvement of the actors in the modelling and policy formation exercise. Participatory modelling and assumption formation could involve two generic steps: arriving at a common understanding of the system by causal loop diagrams and investigating alternative policies by using system dynamics models, in search of the most robust policy.

4. Conclusion

A biofuels future would involve spectrum wide interrelated changes in a coordinated and interacting systemic structure, involving a variety of actors across the economy. It is possible to form a scientific, practical framework for policy making addressing problems characterized by systemic complexity. This would involve systems thinking and systems dynamic modelling at the heart of a participatory decision making process. Such a framework would facilitate robust and concrete scenario analysis and enables policy making with higher success potential. It would highlight points of leverage and risks of transition breakdown.

References

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi level perspective and a case study. *Research Policy*, 31(8/9): 1257-1274.

Kemp, R., Schot J., Hoogma R. (1998). Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technology Analysis and Strategic Management*, 10(3): 175 – 195.

Rogers, Everett M. (1962) "Diffusion of Innovations" New York: The free Press

Smith, A., Stirling A., Berkhout F. (2005). The governance of socio-technical transitions. *Research Policy*, 34: 1491 – 1510.

Sterman, John D. (2000) "Business Ddynamics: Systems Thinking and Modeling for a Complex World" New York: Irwin McGraw-Hill

Warren, Kim (2002) "Competitive Strategy Dynamics", John Wiley & Sons

Figure 1: Biomass production (primary sector)

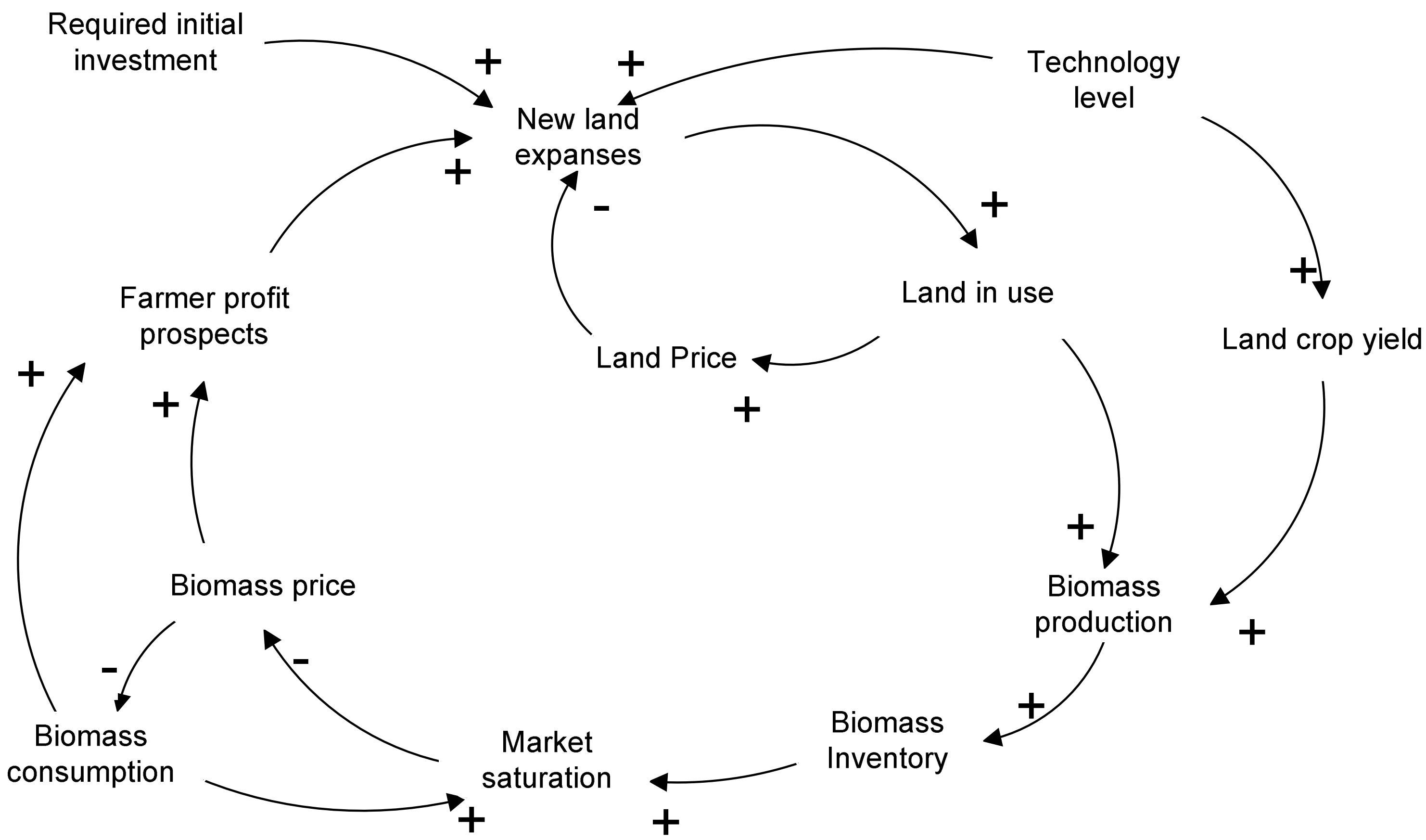

Figure 2: Biofuel production (secondary sector)

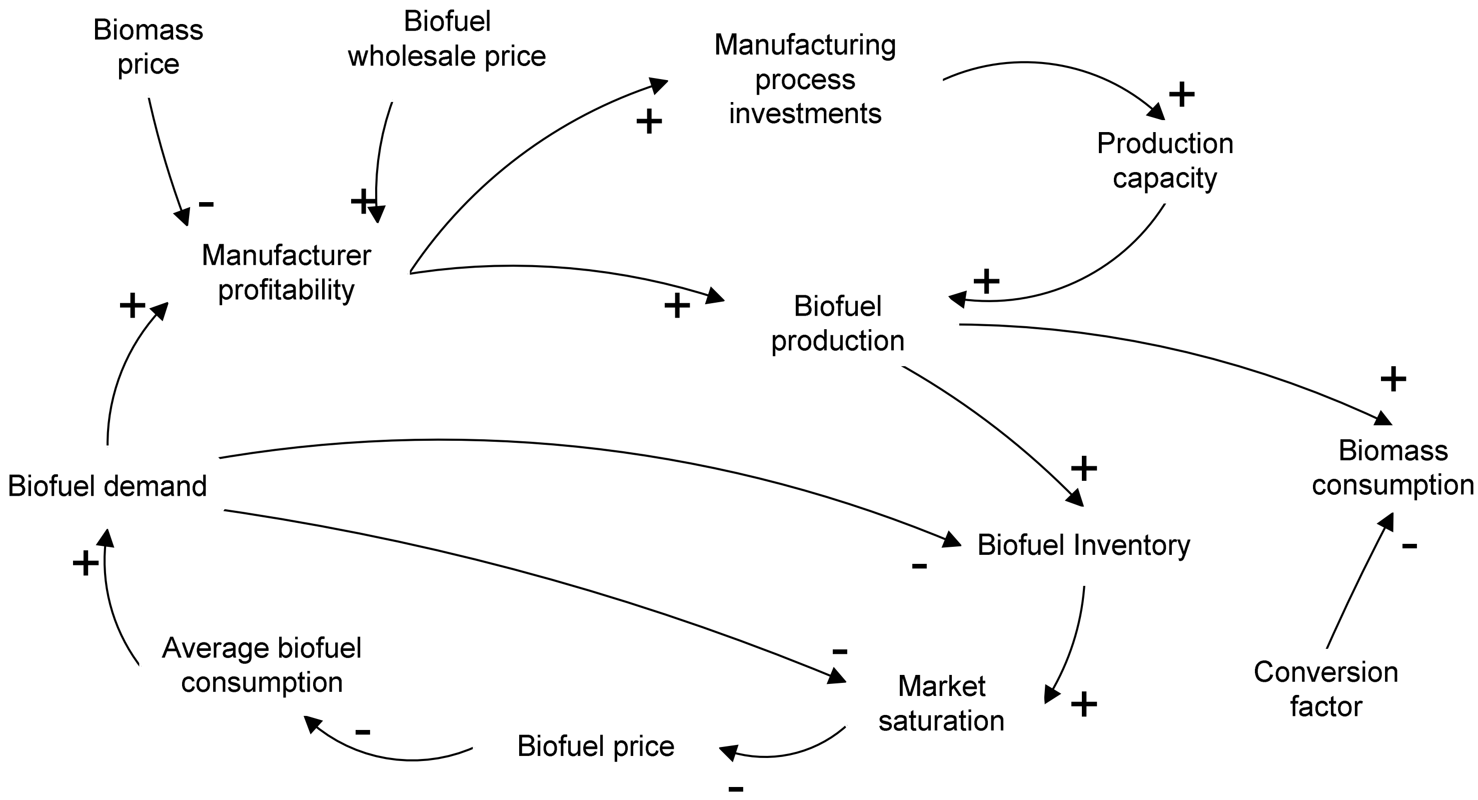

Figure 3: Biofuel distribution (tertiary sector)

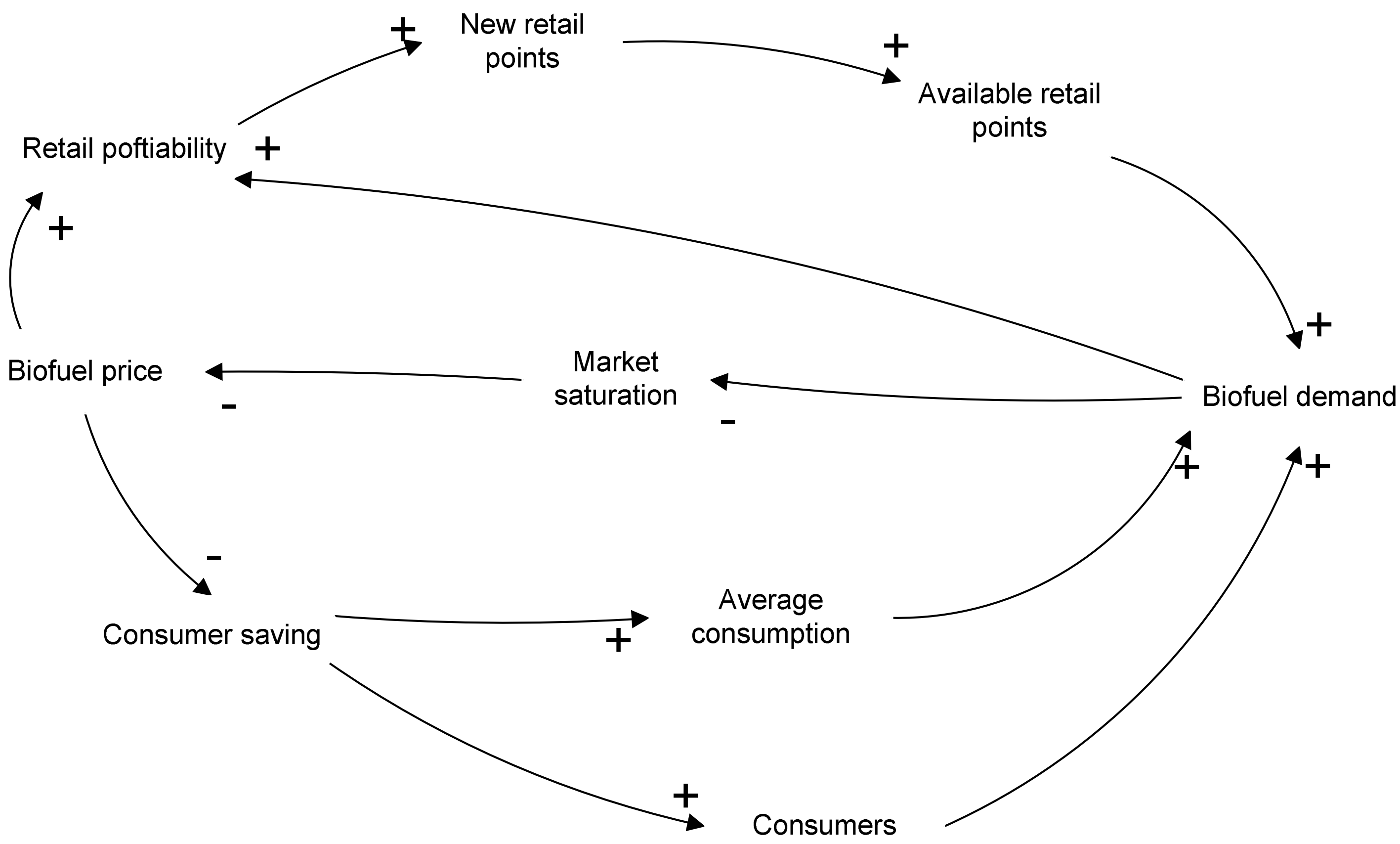

Figure 4: Systems Dynamic Model of Biofuels Diffusion