WP 6: MODELLING STAKEHOLDER INTERPLAY AND POLICY SCENARIOS FOR BIOREFINERY AND BIODIESEL PRODUCTION.

D 6.7: Detailed specification of the theoretical social network model

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In this deliverable we first present a general description of the theoretical framework within which the model is developed. Subsequently, we present a detailed specification of the social network model paying due attention to specification of various actors, their social interaction rules and the niches formation process. The relevance of stakeholder interplay and various policy scenarios are then investigated. Finally, we make some suggestions for further developments of the prototype model presented.

1. Introduction

Innovation niches are small networks of dedicated actors interacting for the development and use of promising technologies by means of experimentation. The development of such niches is crucial in order to make possible socio-technical transition to occur. In fact, while variation in the technological scenario could open opportunities for a transition, if there are not sufficiently developed niches, then there is no clear substitute for the incumbent technology.

The niche formation can be modelled as the emergence of a stable network of agents. Following the discussion developed in deliverable 6.5, we shall define in
our theoretical model three key mechanisms for the emergence of niche-innovations:

1. **The expectation mechanism.** The convergences of actors’ expectations towards a common view is crucial for the emerging of an innovation-niche. One of the main barriers to the adoption of a new technology is that its advantages are not clearly understood by all possible adopters (Kemp et al., 1998). Indeed, actors take part in projects on the basis of their expectations (Van der Laak et al., 2007); diverging expectations can affect the way goals are defined and prioritised (Smith et al., 2005). This initial obstacle can be overcome only through the development of a robust and shared vision among the actors potentially involved. Such convergence provides the willingness to act, following Raven (2005), legitimates actors to invest time and effort in a new technology that does not yet have any market value (Raven, 2005). Thus, as noted by Smith et al. (2005: 1503), “the challenge […] is to analyse how contrasting visions and expectations enrol actors into coalitions of support, come to define their interests, and shape the way that they seek to respond to selection pressures”. This process occurs more easily when promises of the new technology are credible (supported by facts and tests), specific (referred to clearly identified problems), and coupled with shared problems not yet addressed by existing technology (Kemp et al., 2001).

2. **The power mechanism.** Networking actors need an adequate level of power to act. Considering the niche as a ‘small network of dedicated’ actors (Geels and Shot, 2007: 400), it is fundamental for its formation that powerful actors join the network. Their support is crucial to gather and mobilize the resources required to guide the technical change in a desirable way (Smith et al., 2005). Indeed, no single actor has sufficient resources on her/his own to coordinate the innovation process (Smith et al., 2005). As a result, niche members are dependent upon each other for crucial resources.

3. **The knowledge mechanism.** An adequate level of knowledge on the niche technology is required in order for the niche to emerge as a stable network of dedicated actors. This last method for niche creation concerns the formation of patterns of learning interactions occurring among agents in the niche. A large part of this process is deeply informal as tacit and uncodified knowledge can only be acquired and shared by means of intensive and direct interactions. Once a group of actors has established an innovation niche, they start producing and exchanging knowledge
relevant for the further development of the new technology. Hence, as an innovation niche emerges, the knowledge content relevant to the underlying technology grows, making the network itself more stable. This mechanism, therefore, is the final step of a process aiming at generating a stable and strong new technological niche able, eventually, to replace the incumbent technological regime.

2. The model specification

Agency in an innovation niche can be based on the concept of the firm as a typical type of stakeholder or actor, however with the caveat of different members holding often heterogeneous resources and conflicting preferences or expectations.

2.1 Firms and their social network

The social actor which represents the unit of analysis of this model is the firm, however, we shall define also institutional actors with different characteristics, to be specified later on. We assume a population of N firms allocated over a social network which is situated upon a grid of cells. Each firm is initially assigned a random position in the grid. Not all the cells of the grid are occupied by firms, and those occupied contain only one firm. Each firm can interact with any other firm in its visible range. The visible range includes all cells adjacent and within a distance \( v \). This arrangement is referred to as the Moore neighbourhood structure. Figure 1 shows a Moore neighbourhood with \( v = 3 \). That is, firm A (placed in the central cell) can interact with firm B because it is within three cells adjacent distance from B, where cells are permitted to be diagonally adjacent as well as horizontally and vertically adjacent. Whenever firms’ visibility is set equal to half of the size the (squared) grid, then each firm can see (and interact with) any other firm in the social network.

Figure 1: Moore neighbourhood with \( v = 3 \)
As time goes by, firms allocated in this social network have to decide which technology to use for production. The unit of time we define in our model is called the time step. As we will discuss later on, in this model the social network evolves over time as firms interact with each other. Each time step every agent (i.e. firms and institutional actors) will have the opportunity to interact with any other agent within its visible range. We shall now define in some details the key characteristics of each firm.

2.2 Defining Firms’ mechanisms for niche creations
As discussed above, we consider three mechanisms for the emergence of niche-innovations which are discussed in some details in what follows.

Expectations mechanism
Each firm is initially assigned a level of expectation. It describes the preference of a firm towards the new technology. The higher it is, the more likely it is that the firm will join the new technology project. The value of expectation will vary from 0 (if the agent does not have preferences for the new technology) to 1 (if the agent has a complete preference for the new technology). The level of expectation characterizes various kinds of firms. The vast majority of firms has low but non-zero expectation (ranging between 0.1 and 0.3). This kind of firms belong to the group called ‘neutrals’. A small population of firms have high expectation towards the new technology (0.75). Such firms belong to the group called ‘supporters’ and, generally, represent a small proportion of the total population. Finally some firms have zero expectation. They prefer not using the technology, thus they are called ‘opponents’. Also this kind of firms represent, in general, a small percentage of the whole population.

An interesting feature of the model is that firms’ expectation can change according to the kind of interaction each firm undertakes. Specifically, every
time a firm interacts with an institutional actor called ‘spreader’ its expectation increases. The spreaders are special agents whose purpose is to spread the new technology. Their number can vary according to policy objectives. Any time a spreader interacts with a neutral or an opponent firm, it increases its expectation. When the firm’s expectation reaches the threshold of 0.75 (i.e. the firm becomes a supporter of the new technology), it becomes an ‘active’ agent, this means it is ready to link with other active agents. Specifically, every time two active agents meet, they establish a connection. Each active firm can establish a link with any other active firm, thus a network of relations among active firms can emerge. Such a network, which is the emerging innovation niche, can be seen as the socio-economic space where agents can jointly develop the new technology by means of sharing their knowledge and other strategic resources. As mentioned above, the network structure of an innovation niche evolves over time and this is the actual process which leads to the emergence and the development of such niche.

Power mechanism
‘Power’ describes the firms’ endowment of strategic resources. It ranges from 0 (no resources owned) to 1 (highest amount of resources owned). In general, the majority of firms are assigned a low level of power (lower than 0.3). Moreover, a small number of ‘powerful’ agents are initially assigned a power greater than 0.75. It is assumed that each time two active firms establish a link, the total amount of their respective resources flows through this link. Thus, each link has a feature called ‘energy’ which is the sum of the resources of the agents on either end of the link. The total sum of links’ energy represents in turn the overall network power. The overall network power affects the stability of the emerging network. Specifically, each new established link is unstable and will decay if the total amount of power present in the network is below a specific threshold. On the other hand, when the network power overcomes such a threshold its links become stable and endure for the next time step. Once a stable network is established, the knowledge about the new technology starts to grow in the network.

Knowledge mechanism
Each firm is initially assigned a level of knowledge with respect to the new technology. In general, the initial level is low (ranging between 0.1 and 0.3), but this value increases steadily as the agent remains within the niche and interacts

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5 Intuitively, a strategic resource is a resource which can be used in order to develop and promote a new technology. For instance, an R&D laboratory is a resource which could serve the purpose of developing a new technology. A wide-ranging proxy of such resources could be firms’ turnover as, in general, larger firms would also be the most powerful.
successfully (becoming active in building a link with a second agent as described above). Moreover, a small portion of ‘wise’ firms will initially have a high level of knowledge (on the new technology). Such a knowledge mechanism represents the idea of developing expertise; a link will provide an opportunity to perfect the technology through the application of the knowledge. In this model, a firm will only apply the knowledge in partnership with another.

2.3 Defining various types of firms and institutional actors

In the discussion above, several kinds of agents have emerged. Their features are summarized below for a complete picture.
Specifically, 6 types of agents are defined, combining the different characteristics discussed so far, in various ways. These are:
1. Neutrals (firms). This kind of agents are characterized by low expectations towards the new technology. They represent the majority of the population. Other specific features of these agents are that their power and their knowledge are also low;
2. Opponents (firms). Their proportion in the whole population is generally small. These agents are adverse to the new technology. Their expectation is 0. Their power and knowledge can vary.
3. Supporters (firms). Their proportion in the whole population is generally small. They have high expectations (at least 0.75) and so they can be considered active agents ready to interact with others in order to develop the new technological platform. Their power and knowledge can vary.
4. Powerful (firms ). Their proportion in the whole population is generally small. These type of agents are characterized by a high level of power (at least 0.75). The inclusion of such agents in the niche is crucial in order to make the overall network model stable. Their expectation and knowledge can vary.
5. Wises (firms). This is a small group of agents endowed with a high level of knowledge on the new technology. While their level of knowledge is high, their power and expectation can vary. Such agents play a vital role once the innovation niche has emerged as a stable network, as they contribute to the overall enhancement of the system knowledge.
6. Spreaders (institutional actors). This kind of agents do not have expectation, or power. They have a complete knowledge on the new technology (i.e. knowledge equal to 1) and play the special role of spreading the new technology into the system. They do so by interacting with firms and trying to increase their expectation. The amount of spreaders in the system is a key policy variable which varies in accordance with the objective function of the policy maker.
3. **Experimental options and settings**

The model will be set up as described in section 2. The modeller will be presented with the ability to control the following settings:

- **Number of firms/institutional actors** – the total population consists of some of each of the six agent types described in section 2.3. The subpopulations will each be individually sized. Note that it is also possible to specify zero agents in a subpopulation. Each number is fixed for the duration of the simulation.
- **Visibility** – the visible range of agents will be set by the modeller at initialisation of each simulation run. Note that it can vary across agent types (e.g. powerful agents can have a wider visible range than other agents). The visibility is fixed for the duration of the simulation.
- **Effectiveness of spreaders action** – the action of the spreader can affect differently agents’ expectations. The modeller will be able to set the strengths of the spreaders action, varying the parameter by which a neutral or an opponent firm’s expectation is increased each time a spreader interacts with it.

Several agent-based modelling platforms provide built-in libraries or functions for the straightforward set-up of visual elements for observing real-time model dynamics. We will use these platform features to provide plots of all the relevant variables and display of the social space for our grid-based model. A further feature is the ability to record experimental runs to files for later analysis. Experiments which shall be carried out with a prototype model will aim to explore the different potential policy scenarios identified by the case study in order to support the investigation.

For example, the efficacy of a policy action aiming at promoting the diffusion of a new technology could be tested, by varying the number or the effectiveness of spreaders. Further, these two actions could be compared underlying pro and cons of each type of policy intervention. Along with this policy scenario, the role of wise firms could also be investigated and their impact over a newly established innovation niche tested.

The results of each of these experiments will be compared by running batches of simulations. In each batch, one, or a strictly limited number of parameters, will be varied systematically over a given range. This allows us to isolate each variable and analyse it more comprehensively.
At each point in the model parameter space, several simulations will be executed in order to obtain a sample of the model dynamics. We shall report averages of these samples as well as variation within and among them.

4. Conclusions and further developments

The niche formation process described in this deliverable defines a progression of goals that need to be met for actors to become part of a successful innovation niche.

- Initially, actors need to develop a high level of expectation in the technology in order for them to become active agents - this is the first condition for actually creating a link.
- Second, agents need to access sufficient power – the partnership as well as the network itself can contribute power – to be able to stabilise a link.
- Third, agents need to build up their level of knowledge which requires repeated interaction taking place across a relatively stable network.

Increased knowledge on a particular technology is one component of the transition pathway by which a niche can eventually mature and potentially become a dominant technology. This involves superceeding the incumbent technological regime which is a much more complicated process which we are not attempting to model here.

We hope to show that the approach employed in the theoretical social network model of niche formation does offer some promise for clarifying parts of the theory and testing some of its hypotheses.

The prototype model presented in this deliverable could be further developed along several directions. One promising line of research would be looking at the possibility of multiple niche creation. Using a tag mechanism would allow us to define several competing new technologies.

A tag is an identifier which can be applied to a group or niche, and can be observed by all agents in the society: individual members of the group inherit the tag of the group to which they belong. The mechanism was first studied in a game-theoretic context to show that cooperation could arise within groups (Holland, 1993; Riolo, 1997; Riolo et al. 2001). The tag in general has some bearing on with whom the bearer interacts (e.g. interactions may be bounded to same-group members) and/or on which strategies are employed for social
interaction. The model has also been described as an example of a group selection “design pattern' which balances the often contradictory forces between individual goals and collective goals” (Hales et al. 2007). Generally speaking, non-cooperative agents tend to ‘invade’ successful groups (because non-cooperation is slightly more advantageous to the individual) at the expense of the collective enterprise.

Although technological regimes are not characterised by this dynamic (decay due to free-rider behaviour): as discussed in the previous deliverable (6.5), changes in the landscape at the macro-level as well as the existence of alternative technologies (niches) with the necessary stability are thought to contribute to transition events, the mechanism may merit further exploration.

Interestingly, the mechanism can be an approach suitable for studying the emergence of evolutionary niches facing natural selection pressures. Our aim is to apply these ideas to technological niche formation and transition processes in the case where a niche represents a particular type of group, identified by its resources, rules, and expertise for application of potential new technology.

References


