Supply chain development: insights from strategic niche management

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Abstract

Purpose – The purpose of this paper is to contribute to the study of supply chain design from the perspective of complex dynamic systems. Unlike extant studies that use formal simulation modelling and associated methodologies rooted in the physical sciences, it adopts a framework rooted in the social sciences, strategic niche management, which provides rich insights into the behavioural aspects of complex innovation dynamics of emerging supply chains.

Design/methodology/approach – The use of the framework is illustrated by means of a case study about the development of a new biofuels supply chain in East Africa.

Findings – Three key dynamic processes are found to be at the core of new supply chain development: networking, learning and the management of actor expectations. The case analysis suggests the need to actively manage these processes and suggests possible ways of doing so.

Research limitations/implications – Generalisability is limited since the research is based on one case study. Additional case studies using the same framework would help to validate and extend the results obtained.

Practical implications – Implications for strategic managerial decision making include the need to encourage stakeholder networking and shared learning, and managing their expectations.

Originality/value – The paper uses an innovative conceptual framework to examine new supply chain development, which yields new insights into how these processes can be actively managed and supported.

Keywords Supply chain management, Fuels, Energy sources, Tanzania, Strategic management

Paper type Case study

Introduction

Competitiveness and growth are increasingly seen to be driven by effective organization and co-ordination of entire supply chains, rather than by strategies and processes of individual firms (e.g. Vonderembse *et al.*, 2006; Bechtel and Jayaram, 1997; Tan, 2001; Cooper *et al.*, 1997; Martínez-Olvera and Shunk, 2006). Recent years have witnessed the emergence of a wealth of studies aiming to contribute to effective supply chain design, organization and management (see, for instance, Schary and Skjott-Larsen, 2001; Burt *et al.*, 2003; Simchi-Levi *et al.*, 2003).

Conventionally, writers in this line have been emphasizing supply chain design and management techniques in which the functioning of the supplier system can be predicted, controlled, and optimized. In a survey of models and methods of supply

The Learning Organization
Vol. 15 No. 4, 2008
pp. 336-353

0969-6474
DOI 10.1108/09696470810879583

chain design and analysis in 1998, 21 out of 24 major studies take a deterministic, stochastic approach or game-theoretic approach (Beamon, 1998). In these approaches, the major variables are either known and specified, or subject to a particular probability distribution. However, in today's dynamic and complex environment the practical value of these approaches is limited. Continuous change driven by, and involving the development of new products, processes and improved production organization is part and parcel of today's competitive reality (Choi *et al.*, 2001). Many processes, activities and relationships are not amenable to tight and detailed planning. In the words of Choi et al(2001):

> [. . .] what becomes important is keen observation of what emerges, and flexibility in making appropriate changes, while controlling the course of action toward the a priori determined goals (Choi *et al.*, 2001, p. 365).

It is also clear that, especially in its more radical forms, innovation is not merely a matter of developing new products or improved processes within the boundaries of one single firm, but involves reorganization and adjustment of entire chains. In some cases, completely new chains may even need to come into existence.

Within the supply chain management literature these changes are being reflected in an increasing emphasis on simulation modelling as a tool to deal with fundamental uncertainty and high complexity (Chang and Makatsoris, 2001; Kleijnen, 2005; Towill, 1991; Towill *et al.*, 1992; Wikner *et al.*, 1991). At the same time, researchers on new product development (NPD) are increasingly recognizing the need to understand NPD from a complex dynamic systems perspective, rejecting the notion of NDP as a linear, sequential and routine decision-making process (Leifer *et al.*, 2000; McDermott and O'Connor, 2002; Utterback, 1996). Examples are applications of chaos theory and the Complex Adaptive Systems (CAS) approach advocated by Buijs (2003), Chiva-Gomez (2004), Cunha and Comes (2003), and McCarthy *et al.* (2006). Choi *et al.* (2001) have also introduced CAS into the study of supply networks.

Thus, one can observe a certain convergence between supply chain management one the one hand, and NPD research on the other, around an emerging complex dynamic systems perspective. These recent approaches are thus much more powerful than the traditional mechanistic supply chain tools for handling organizational complexity in a context of continuous fast change. However, this emerging field still has some limitations. Its dominant methodological approach is rooted in physical sciences, namely cellular automata models and agent-based models (McCarthy *et al.*, 2006). The resulting computational methods are not ideally suited to capturing the rich and qualitative features of a social system. Hence, it has been argued that case study research in this field is required as a necessary complementary methodology. Case studies can provide in-depth insights into the behavioral aspects and the dynamics of the search, experimentation and learning processes that are essential features of dynamic supply chains (Brown and Eisenhardt, 1997; Eisenhardt and Bhatia, 2002).

This paper aims to contribute to filling this gap in the literature by studying new supply chain development processes from an evolutionary case-study vantage point. For this purpose we use strategic niche management (SNM), an analytical approach rooted in evolutionary innovation economics which has been used for studying radical product innovations, particularly in the context of discussions about long-term transitions to more sustainable development. SNM comes with a set of concepts with which one can systematically document the initial activities and processes that should lead to the eventual adoption and broad diffusion of new technologies in society, and with which can one take stock of important stimulating and constraining factors in that process (Hoogma *et al.*, 2002; Kemp *et al.*, 2001, 1998; Weber *et al.*, 1999; Elzen *et al.*, 2004; Raven, 2004, 2005).

SNM posits that successful radical innovations emanate from socio-technical experiments in which various stakeholders collaborate and exchange information, knowledge and experience, thus embarking on an interactive learning process that will facilitate the incubation of a new technology. This occurs in a protected space called a "niche", a specific application domain for the new technology. Experiments create "proto-markets", in which connections with market parties are made even when the technology is still in a laboratory phase. When incubation goes well, an actual market niche will develop, in which the innovation can sustain itself commercially (Hoogma *et al.*, 2002, p. 30). These experiments take place in the context of a broader complex system, a "socio-technological regime". This comprises:

> [...] the whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures (Hoogma *et al.*, 2002, p. 19).

In turn, the regime is embedded in a wider contextual "landscape", which consists of societal factors that can change only slowly over time, such as demographics, political culture, lifestyles and the economic system (Raven, 2005, pp. 31-32).

When viewed from a supply chain perspective, SNM experiments actually involve the establishment of a new chain of coordinated actors who together will bring a new product to market. Therefore, we propose that it is possible to derive insights from SNM studies about the supply chain development process. In particular, SNM authors have emphasized three key processes in successful technological development:

(1) the formation of a wide and interconnected actor network;
(2) extensive experimentation and broad learning; and
(3) expectations that become more specific and better aligned among the actors.

In the paper we conceptualize new supply chain development with reference to the three key processes in successful technological development. We then proceed to illustrate how these processes contribute to successful supply chain establishment with case study evidence from biofuel production in Africa. We choose to focus on biodiesel production because it constitutes an important new sector. Supply chain research in emerging industries is said to be vital for informing national and international policy and strategic decision in industry (Shah, 2005). The biodiesel case is based on own fieldwork supplemented by secondary material.

The case study method allows us to explore the value of an existing evolutionary theory when applied to a new field of practice, namely supply chain development. The main purpose of the paper is thus to generate ideas in an exploratory fashion, which could later be subjected to further validation. The appropriateness of the case study method for this type of study has been discussed in Voss *et al.* (2002).

This paper sheds light on how actual learning takes place during the period in which a new supply chain is being formed. Our results indicate that the supply chain in the case study did not result from purposeful attempts at optimal ("blueprint") design, but rather emerged and evolved in iterative fashion in the course of a complex interplay of various actors, whose activities are shaped by a dynamic and uncertain environment. At this stage, trial and error, search, learning and networking are the central activities of the concerned parties. In particular, it becomes clear that the only way to generate innovations that are accepted and adopted by the market is to emphasize all three key processes, i.e. network formation, experimentation and learning, and alignment of expectations. In particular one should call attention to the learning process, which can be considered as the driving force of the other two processes. Extensive experimentation and broad learning will be most effective when several different groups of actors are involved in the development of a new product and when their expectations of the new product become aligned over time. Based on these insights, we derive tentative suggestions for further research and propose focal points in supply chain-development strategies for companies which will, in turn, generate successful innovations.

In the next section the SNM approach is elaborated, and its relevance for supply chain design is made clear. Then follows the research methodology, and the application of the theory to our empirical case. The final section concludes.

Strategic niche management

For the successful development of radical innovations, SNM advocates the purposive creation of socio-technical experiments that are in one way or another shielded from commercial market conditions. Protection is a broad concept. It can take the form of protective government policies, private firms committing substantial R&D budgets to the development of innovations, or prospective adopters' willingness to participate in trials voluntarily. Protection can give rise to a sheltered space (niche), in which various individuals and groups can become engaged as participants in the innovation process. In this way they have opportunities to interact and learn about the innovation, and about their own preferences and attitudes in relation to the innovation.

In addition to experimentation and learning, SNM authors have pointed up the importance of network formation and convergence, and alignment of actors' expectations. Together, these three processes are seen to interrelate closely, and be mutually reinforcing (Raven, 2005, p. 43). Niche creation is widely seen to require a broad and diverse co-operating actor network. According to Hoogma (2000, p. 84), it will be conducive to success when actors' motivations to participate are not centred on short-term financial gains. Furthermore, the composition of the network is important (Kemp *et al.*, 1998, p. 191). Following Von Hippel (1986), SNM authors advocate that the role of users should be far greater than sources of market information (Weber *et al.*, 1999, p. 68; Hoogma and Schot, 2001).

The third niche process, convergence and alignment of expectations, refers to the importance of developing a common core view about where the participating actors are going with each other and with the technology. Actors' strategies, expectations, beliefs, practices, outlooks, perceptions and views must go in the same direction and become more specific and consistent (Hoogma, 2000, pp. 85-86).

From the perspective of the objective of this paper, the three niche processes can be visualized as being intimately intertwined with new supply chain formation. An important element of the learning and experimentation process consists of bringing together unconnected parties in a new supply network. Each of these parties is learning about its own new contribution to the chain as a whole, and how to attune its activities to those performed by others in the network. Inevitably this constitutes an iterative trial and error process, in which new knowledge and accumulating experiences are exchanged up and down the chain, inducing gradual alignment of expectations and views. One can conceptualize this as a supply chain incubation process, in which actors build connections and together orchestrate the emergence of a co-ordinated production and knowledge network. If it goes well, the innovation around which the network was formed will be improved and perfected to the point where a viable market niche develops. By then, the innovation can sustain itself commercially in a specific market segment and the key processes and actors in the supply chain are more or less defined. At this point in the process, conventional supply chain design methods and techniques (such as those mentioned in the Introduction to this paper) become useful for further optimisation. SNM provides an analytical structure for viewing and handling the chaotic processes that precede this stabilisation phase.

Case methodology

The case study is a qualitative research strategy which concentrates on generating in-depth insights into the behavioral aspects and the dynamics present within a single setting. The case study as a methodological technique is particularly suitable for application in new research areas or research areas for which existing theory seems inadequate (Eisenhardt, 1989). The latter is the case in the underlying study. Within the supply chain management literature the adopted methodological approach is dominated by optimization techniques and simulation modeling (Chang and Makatsoris, 2001; Kleijnen, 2005; Towill, 1991; Towill *et al.*, 1992; Wikner *et al.*, 1991). This research strategy seems to be inadequate in situations in which completely new supply chains are being developed, since many elements that form the input for quantitative analysis are yet unknown and subject to constant change. Hence, case study research in this field provides a necessary complementary methodology. In this paper the case study technique allows us to apply existing theory, generated by evolutionary innovation studies, to another field of practice, namely supply chain development.

The case research on which this paper is based involved substantial fieldwork in different parts of Tanzania during March-June 2005[1]. Field data about all the key concepts used in SNM were gathered through interviews with all important actors involved in Jatropha-related activities. Existing literature was used as a secondary source of information, particularly for the landscape and regime analysis. The niche analysis is entirely based on our own interviews. A comprehensive account of the research can be found in van Eijck (2006).

We tried to identify all significant socio-technical energy related SNM experiments with Jatropha in Tanzania by talking to local people who were knowledgeable about the budding sector, primarily officials from the Ministry of Agriculture and Minerals and the National Biofuels Taskforce, NGO representatives, academics, and private entrepreneurs. For identifying these key informants we relied on the snowball method, starting with a few known experts, and identifying others through these people. An "experiment" in this context should be understood as an activity undertaken by an individual or a group aimed at growing Jatropha, seed pressing, or developing one or more end-use applications for the oil or the seedcake. Most of the experiments took the form of development projects led by local NGOs and governmental agencies, but there were also a few for-profit ventures run by commercial companies. Some had foreign connections involving financial support or knowledge transfer, while others were purely local affairs. In total, 17 experiments were found, of which 16 were visited and one contacted through e-mail. Most experiments were situated in the Arusha and Kilimanjaro regions in the northeast. Others were situated in Morogoro, Dar es Salaam, and in Tunduru in the South. In total, we conducted interviews with 28 participants in these 17 experiments. They included representatives of a local university, two local branches of transnational companies, seven NGOs, and a micro-credit organization. The remainder were mainly individual farmers and farmer groups who participated in development projects run by the earlier-mentioned agencies or companies. Several Government representatives were also visited, but since the Government is not involved in actual Jatropha experiments, these people did not form part of our survey about niche processes. The free-flowing interviews held with them predominantly focused on contextual information about Tanzania's energy bottlenecks and strategy, and the government's views on the role of biofuels. Participants located outside Tanzania (such as international donors and car manufacturers) were not interviewed. The interviews with the 28 survey participants were held face to face, with the help of a detailed standard checklist of open-ended questions. Each interview covered information about the goal, history and nature of the Jatropha activities undertaken. The respondents were requested to provide considerable details about the development trajectory of their Jatropha activities over time, in order to get a sense of the evolution of the sector. The three key SNM niche-formation processes were covered: actor network activities, people's learning processes, and the dynamics of their expectations. Considering the complexity of the processes, the experimental nature of the research, and the low level of literacy and capacity for abstract thinking present among some respondents, we confined ourselves to gathering mostly qualitative information through informal discussions, loosely guided by our checklist. We did not ask respondents to rate issues on qualitative scales. We did, however, try to collect quantitative estimates from them about the costs and benefits of each major Jatropha-based activity.

Initiating biofuel production: an illustration

Currently, there is a lot of interest in biofuel production driven by increasing awareness of the need to reduce CO_2 emissions and incentives to achieve this as formulated in the Kyoto Protocol. African countries in particular are seen to have a lot of potential for growing biofuels in view of abundant land resources and favourable climatic conditions. Several western companies are currently exploring the possibilities of starting biofuel production in different parts of Africa. A plant that has attracted particular interest for producing biodiesel is *Jatropha curcas*.

This section starts with some basic facts that are already known about Jatropha and its cultivation. Then, using the strategic niche management framework, we examine the prospects and difficulties faced by a Dutch company, Diligent, that has recently started to develop a new supply chain utilising this crop in Tanzania.

Basic facts about Jatropha

The Jatropha plant is easy to establish and drought resistant. It can grow up to eight meters high, and is not browsed by animals. Therefore, it has been traditionally used in African countries as a hedge, and for producing soap and lamp oil on a small scale for local use. Recent experiments have also been initiated with the oil for use in cooking stoves. The plant can live up to 50 years and can produce seeds up to three times per annum (Chachage, 2003; Openshaw, 2000).

Figure 1 shows that a commercial Jatropha supply chain would need to comprize three main stages, from seed to end product, i.e. biodiesel, cultivation, oil production, and distribution/use. In Tanzania, Jatropha is grown in nurseries from seeds by women's groups. Villagers also growth Jatropha from cuttings. The seed yields reported vary widely from 0.1 to 15 t/ha/y (Heller, 1996; Daey Ouwens *et al.*, 2007). Yields depend on water, soil conditions, altitude, sunlight and temperature. No research has been conducted yet to systematically determine the influence of these factors and their interactions. Seeds are harvested during the dry season, normally a quiet period for agricultural labour. They contain about 35 percent oil. The seeds contain a toxic substance, curcasin, which is a strong purgative (Chachage, 2003). Seed storage is important for continuous processing, since the availability of the Jatropha seeds is seasonal. Two options are bulk storage and bag-storage. Only bag-storage is practised in Tanzania currently. Storehouses should be well ventilated in order to prevent self-ignition. Location plays an important role, since it has a considerable impact on transport and storage costs (UNIDO, 1983).

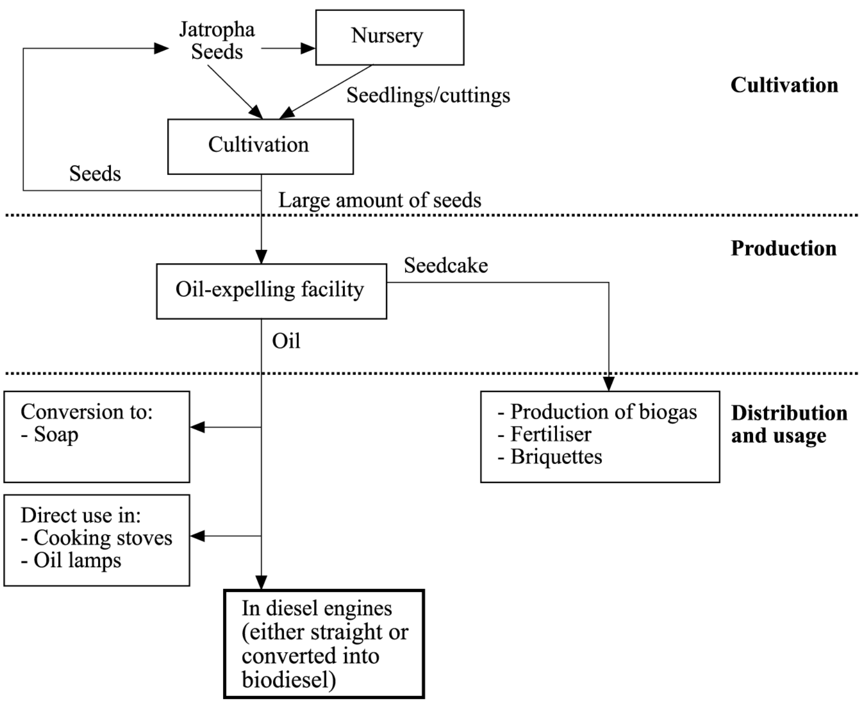

Figure 1.
Jatropha-biodiesel supply chain

The production stage involves pressing of seeds to expel the oil, leaving seedcake. In Tanzania, oil is currently extracted with small manual ram-presses and power-operated screw-presses (van Eijck and Romijn, 2008). The extraction rate of the ram-press is quite low. About 5 kg of seed is needed for 1 litre of oil (Henning, 2004). The ram-press is only suitable for the processing of small quantities, e.g. for lamp oil for local village use, or for small-scale soap-making. The extraction rate of power-operated screw-presses is higher, and the cake residue is dryer. The Sayari oil expeller, of German design, has a capacity of about 20 l/hour (60 kg/hour) and can extract 1 litre of oil from 3 kg of seeds. It is manufactured in Tanzania itself by a non-governmental organization (NGO) in Morogoro. A Chinese screw-press capable of processing 150 kg seed per hour was installed by another NGO in 2005 (van Eijck and Romijn, 2008).

At the distribution and usage stage, the oil and the seedcake are consumed or further processed to generate final products. The product of interest is biodiesel (or straight use of the vegetable oil in engines). Since the viscosity of Jatropha oil is much higher than that of conventional diesel fuel, using it pure in engines causes problems, despite claims that it is possible in many engine types (Heller, 1996). Problems encountered include premature wear of parts and clogging, and inability to start, especially in cool weather. Search for adequate solutions is ongoing. Options include adaptation of the oil through transesterification, i.e. by mixing with methanol and caustic soda (Research Group International Programs (IP), 2002); fitting vehicles with dual fuel tank systems; performing engine adaptations; and blending pure unmodified Jatropha with conventional mineral diesel, which reportedly works well up to a proportion of 40-50 percent Jatropha (Pramanik, 2002).

The seedcake is also potentially valuable. It can be used to produce biogas for cooking, as fertilizer, or - in briquette form - as cooking fuel (Openshaw, 2000). The remaining sludge from biodigesters can still be used as fertilizer as well (Daey Ouwens *et al.*, 2007). Chachage (2003) identifies the current activities in Tanzania based on Jatropha oil as soap-making on a limited scale, and use in oil lamps. Transesterification of Jatropha oil generates glycerine as a by-product, which can be used for soap production, skin creams and lubrication.

The impact of the landscape on investment prospects for Jatropha

Since 2005, Diligent Tanzania Ltd, a subsidiary of the Dutch company Diligent Energy Systems, has begun to establish a supply chain for Jatropha-based biofuels in Tanzania.

A number of landscape factors influence the scope for viable investment in Diligent's supply chain. The global oil price has been a major factor. It has increased sharply during the last years and is expected to remain high or to rise even further in the near future. In 2003 the benchmark Brent crude was under US$ 25 per barrel, rising to over US$ 60 in 2005 and US$ 63 in 2006. Dependence on countries in the (unstable) Middle East is also increasingly considered to be a risk. This is strengthening demand for biofuels, and stimulates new investments in the sector. The biodiesel-sector grew by 25 percent per annum between 2000 and 2004 (Renewable Energy Policy Network (REN21), 2005).

However, a severe drawback to foreign investors in Tanzania constitutes the poor infrastructure. Most roads are hardly sufficient for lorry transport. Government support for investment in the sector is also lacking. Policies to promote and regulate the production and use of biofuels are still in their infancy. There is a lack of a clear and fair biofuel tax regime. The country's current National Energy Policy (in 2005) merely affirms the desirability of promoting "development and utilisation of appropriate new and renewable sources of energy", without specifically mentioning biofuels, but no significant actions have been taken. The Diligent staff, as well as other Jatropha-investors in Tanzania, pinpointed this problem as the main current bottleneck to their business. In addition, standards of political governance need to improve for directives and institutions to work effectively.

Regime dynamics and lessons for supply chain organization

Three different regimes affect the potential success of commercial Jatropha activities and the best way of organizing the supply chain.

Instability in the fossil fuel-based energy regime is growing under the influence of the landscape factors discussed above. This is generating significant scope for demand growth for biofuels as well as for other renewable energy sources, both in foreign and domestic markets. Biofuels like Jatropha seem to have certain advantages over solar and wind power. Initial investment requirements could be quite low, since many Jatropha activities can be started on a small scale. Another advantage is versatility. In principle, Jatropha oil can be used for all the main purposes for which energy is needed, i.e. for transport, electricity generation, direct lighting, and cooking.

However, the world's current transport regime is still entirely based on fossil fuels. A change-over to Jatropha biofuel would need to involve some adaptations, either to the oil, or to vehicle engines. Diligent is currently experimenting with its own vehicle which has been modified to run on both conventional diesel and Jatropha oil. However, it is clear by now that the additional cost to vehicle owners associated with conversion to a dual fuel tank system would engender considerable resistance, especially in low-income countries like Tanzania. Local technical knowledge required for these modifications is not widespread either. Even in high-income markets a transition is unlikely to be smooth and quick. Evidence from the UK indicates that the use of E85, a blend with 85 percent bioethanol, is limited to specially biofuel enabled cars like the Ford Focus flex-fuel or the Saab Biopower (Madslien, 2006). When Jatropha oil is converted into biodiesel, vehicles require almost no modification (only the fuel hose needs to be resistant to biodiesel), but this requires chemical conversion, which is also not easy to manage locally. Experiences from India indicate that cost-effective transesterification requires a medium to large scale operation, capable of processing 30,000 tonnes per annum. This greatly exceeds current demand (Venkataraman, 2005). Jatropha oil could also be blended with normal diesel fuel and sold at petrol stations. People would not even know they were driving on biodiesel. Hence, consumer resistance for this option could be expected to be low. Pump holders at petrol stations, however, might less co-operative. Most service stations are operated by the fossil oil industry which is "pathologically opposed to going down the biofuel route" (Madslien, 2006). With the benefit of a few years of experience, Diligent now says that blending seems to be the best option for the near future, but even developing this option – and corresponding supply chain organization – will need considerable effort and persuasion. In the remainder of the article, our focus will therefore be confined to biodiesel blending.

Another major problem is that with the current price constellation, even the blending option is not yet financially attractive in areas where fossil diesel is widely and easily available. For example, in Tanzania itself, the diesel pump price in Dar es Salaam in July 2005 was TZS 1,100 per litre, compared with TZS 2,000 per for litre of Jatropha oil. This will take time to change. In the meantime, only a small minority of environmentally aware consumers might be willing and able to pay, say, 30 to 50 percent more for Jatropha-blended diesel than for conventional diesel. Diligent also explored western export markets, but also found these to be unviable at current prices. Hence, Diligent started to explore up-country markets in the East African region, for example, Uganda, where fossil diesel prices are higher due to the large distance to harbours. However, this strategy has encountered logistical problems. This clearly implies that Jatropha investors such as Diligent have to look for ways to achieve cost reduction in order to achieve competitiveness, both in local and in export markets. Early indications are that this has significant consequences for the way in which investors should organize their Jatropha supply chain. Initially, Diligent emphasized that it wanted to rely substantially on external outgrowers. However, in order to be viable, it has learnt that it must also have its own plantation and centralized processing plant. In 2006 Diligent announced that it had leased 7,000 hectares wasteland from the Kilimanjaro International Airport authority, which it has planted with Jatropha. It is also looking into possibilities for mechanised harvesting (van Kollenburg, 2006).

Moreover, it has become evident that the viability of starting a Jatropha-based biofuel business also depends on finding a lucrative use of the by-product, the seedcake, since this constitutes between 65 and 70 percent of the physical output from the oil processing. Considering its weight in relation to its potential value, most likely this should be found in the local market. In principle, there could be interesting opportunities for replacement of the dominant cooking fuel, wood, which is becoming increasingly scarce and expensive. A local NGO has been providing several women's groups with a biogas cooking system that uses Jatropha seedcake. However, this experiment illustrates that the development of alternative cooking systems is not quick and easy. The women were unhappy with this system, complaining about longer cooking times, lack of gas pressure and possibly poisonous smoke. Another major factor is the extra cost of having to acquire a Jatropha biogas cooker, which costs TZS 10,000. In conclusion, the dominant cooking regime is quite strong, and alternative systems have not been able to meet people's demands and priorities well enough. A potentially more promising use for the seedcake is as fertilizer, since it has a high nitrogen content, but this still remains to be explored.

The Tanzanian agricultural regime is relevant in so far as it affects the financial attractiveness of Jatropha cultivation by independent farmers, which in turn affects the possibilities for, and constraints on, building relations with local farmers as sourcing agents. These farmers might become regular suppliers to foreign Jatropha investors such as Diligent, who wish to supplement their own plantations with supply from independent outgrowers as a secondary production feedstock. Using external suppliers is important for a company's corporate social responsibility image, because it can generate a significant number of local jobs (Strydom, 2006). Diligent says that it works with almost 100 farmers who earn a decent income from supplying Jatropha nuts to it (van Kollenburg, 2006). For this sourcing strategy to work, Diligent had to become aware that farmers' decisions to enter into Jatropha outgrowing contracts are greatly influenced by the prices of other crops that they could also choose to cultivate. It turned out that Jatropha cultivation is expected to yield at least as much per hectare as conventional crops such as maize, wheat, sweet potato, cassava, cashew nuts, bananas and sisal (van Eijck and Romijn, 2008), suggesting that cultivating Jatropha as a cash crop could be profitable for farmers. The main difference between cultivating Jatropha and other crops is that Jatropha is a multi-year crop which starts yielding seeds only one to two years after planting. This can be a major problem for poor farmers in a country like Tanzania. Intercropping of Jatropha with other crops could help alleviate this problem, but introducing this successfully will require experimentation, on-site training and demonstration. Most Tanzanian farmers are conservative and risk averse, and can also not be expected to have high literacy and ready access to relevant documentation. Diligent learnt that establishing successful sourcing relationships with such local partners must be actively nurtured.

Another major aspect of the agricultural regime pertains to the selling of seeds. Currently there is no well-established commercial market for Jatropha seeds because cultivating the plant as a cash crop is still too recent. The current system of local collection points and buying at weekly markets is becoming unwieldy as the supply of Jatropha seeds increases, especially in view of the poor roads and inadequate transport facilities. This points once again towards the requirement of larger-scale centrally located plantations, at least in addition to independent outgrowers as a sound basis for a viable supply chain.

The vegetable oil regime proved not to be an overriding constraint on the development of a Jatropha supply chain. Tanzania already produces and processes substantial quantities of oil-seeds for edible purposes and for industrial use. Oil presses used for these crops are in principle also suitable for Jatropha pressing, and local capabilities for press manufacturing and maintenance exist.

In conclusion, the case of Diligent indicates that a lot of factors affecting the organization of the new supply chain only manifested themselves after the company actually began operations, and started to try out ways of organizing its activities and explore market prospects. It is still in the process of gravitating towards a viable and efficient supply chain design, by flexibly adapting its strategies and operations in response to accumulating experience, through continuous learning-by-doing. More details of this learning process follow below.

Niche dynamics and its effects on Jatropha supply chain development

In this subsection we explore the recent Jatropha-activities at the niche level. We also assess what would be required in terms of niche experimentation for a viable supply chain to develop, and we pinpoint deficiencies and weaknesses that still need to be addressed by the company in collaboration with other supply chain actors.

We analyze these issues with reference to Figure 1. The activities depicted in this figure are linked to each other in different ways. Some are so strongly complementary that one activity cannot be expected to get off the ground without a simultaneous development of another. Broadly speaking, then, an effective constellation of experiments that could pave the way for the establishment of viable biofuel supply chains based on Jatropha would need to exhibit:

- strong experimentation in each of the three stages in the production chain, and growing interconnections between the activities and actors in these stages;

- engine-related experiments in the end-use stage; and
- substantial experiments with the seedcake, because the viability of the chain is determined in a major way on finding profitable uses for this.

These considerations guide the discussion of the different Jatropha experiments discussed below.

In the cultivation stage, the actor network is expanding quite rapidly. More and more farmers are starting to plant Jatropha, expecting to make a considerable profit. This is happening mainly because they are now able to sell their seeds to Diligent which started operations in 2005. The company pays a guaranteed fixed price for several years, reducing the risk of a price fall. Declining and low prices for existing crops acted as an additional push factor. The actor network is quite diverse. There is participation by NGOs, private farmers, farmer groups, individual larger farmers, and private companies. Only research organizations had not been involved much.

There are many learning processes in this part of the chain, mostly with regard to how Jatropha should be grown and managed (e.g. with respect to watering, intercropping, and pests) but also regarding user acceptance. Some farmers have also started to conduct systematic experiments for gathering specific bits of knowledge. It is becoming clearer where the knowledge gaps are, and how to fill them. Still, there is a long way to go, since many of the lessons are not yet shared among the actors.

The expectations of actors involved in cultivation are predominantly high and positive, and in some cases rising further, in response to yields that turned out to be higher than expected. However, the experience with the crop is still too brief for expectations to stabilize, or to allow very specific conclusions. The positive expectations are based on forecasts of a large market for biofuels. If this market turns out to be smaller, or less profitable than anticipated, farmer prices will drop.

The remaining barriers to the growing of Jatropha as a cash crop mainly have to do with lack of information by local villagers on specific aspects of the cultivation regime and their attitude towards risk. All these barriers seem to be surmountable through training and demonstrations. In sum, the niche processes all seem to be quite positive for the cultivation part of the chain. Diligent, along with other actors, are paying attention to the emerging challenges.

The oil pressing stage of the Jatropha chain shows a more mixed performance. With the involvement of a variety of actors, including NGOs, women's groups (press users), equipment producers and subcontractors, and even a foreign university, a diverse and dynamic network has emerged, but most of the contacts run through one particular NGO, which is rather selective in the information it wants to share. The emergence of Diligent is perceived to be a threat to the NGO's own Jatropha-activities (such as small-scale soap making). The two organizations compete for seed suppliers and do not collaborate smoothly.

The learning processes have been limited to a few technical lessons on the operation of the presses and the quality of the seeds, and regarding user acceptance. There have been no broader learning processes in relation to infrastructure yet, about how best to set up a pressing facility or, for example, how best to store the seeds. Also, a lot more experimentation needs to be done to optimize pressing techniques.

The participants' expectations in the pressing stage vary widely. It is not clear in which direction the Jatropha chain will evolve. Although Diligent is moving to centralized processing, some others still think that it might be best to install smaller expelling units in different locations, perhaps operated by farmer collectives, with the oil then being transported to a central collection point. This will also affect the choice of pressing technology, especially the capacity of presses. Related aspects, such as transport needs, are still to be addressed.

In conclusion, the SNM processes in the pressing stage have not proceeded as well as in the cultivation stage. The network needs to develop more lateral relations for more effective learning to take place. Significant technological efforts still need to be invested in improving the reliability and efficiency of the equipment and its maintenance. From the point-of-view of supply chain design, the choice for centralized versus decentralized oil pressing, and the expelling technologies that should go with this, remains a major unsolved issue.

This brings us to the dynamics at the distribution and usage stage. Diligent does not yet have a distribution system for its biodiesel to speak of. All the oil that has been pressed so far has been used in its own vehicles, and by a nearby NGO for the purpose of soap making. With respect to the use of Jatropha oil in diesel engines, there are mainly just positive expectations, but hardly any actual lessons from experiments. The different potential options for oil use still remain to be explored. The actor network is quite limited, and shows no signs of expansion. There are no significant learning processes on the user side yet.

As far as the utilisation of the seed cake is concerned, much more experimentation and learning about technical properties will be needed for this technology to take off. Using seedcake as fertilizer could be more promising than as cooking fuel, because of its favourable nutritional qualities. This possibility was mentioned by several respondents in our field research, but it remains untested as yet. There are no local learning processes yet, although expectations are slightly positive.

In conclusion, the downstream part of the supply chain is essentially still undeveloped. At this stage, there are only positive but vague expectations due to lack of learning. The next main challenge for Diligent is to set up a oil distribution network, invest in further learning about the properties of Jatropha biodiesel in compression ignition engines, and experiment with the seed cake. Network building will also be essential to achieve this.

Conclusions

A number of theoretical and managerial implications arise. The main theoretical significance of the paper lies in the fact that the use of an unconventional analytical framework derived from evolutionary innovation studies can be helpful for generating insight into the development of complex new global supply chains by means of case studies. The chosen framework, strategic niche management, offers a set of ordered concepts with which one can shed light on three key processes that have to form an integral part of the setting up of a new supply chain, namely networking, learning and the management of actor expectations. It also points up how these processes are embedded into a wider societal context, which forms the setting within which supply chain design decisions have to be made. By directing the focus on the context within which companies and supply chains operate, vital information concerning external threats and opportunities can be systematically taken into account in supply chain decision making. By furnishing a framework for a structured analysis of mostly qualitative case material, SNM helps one to avoid purely descriptive accounts.

Our case study about the setting up of a new supply chain in the biofuels sector in East Africa bears out that new supply chain formation is indeed highly dynamic, and subject to high uncertainties. A framework like SNM, which is rooted in evolutionary theory, is found to be particularly well suited for application to this kind of organic process because it views supply networks as dynamic adaptive systems. In this way, case study research of this type can provide rich insights about socio-technical change processes. In doing so, it complements extant dynamic systems approaches (such as CAS) using simulation modelling.

SNM also yields some valuable practical suggestions as to what a flexible and adaptable supply chain management strategy should look like. Hence, it is not only valuable as an analytical instrument, meant to gain insight into the dynamics of supply chain formation in a structured way, but also as a strategic managerial tool. By focusing attention on three key supply chain formation processes and giving guidance about what constitutes effective niche processes, shortcomings in these processes come to the fore so that they can be dealt with. Strategic management of information flows, knowledge management, and relationship management stand out as key areas for remedial action. For example, SNM would recommend such things as experimentation incentives for employees and partner companies when learning processes are inadequate. Activities such as organization of stakeholder workshops, demonstrations, consultation, and efforts to disseminate information would be appropriate in order to stimulate deficient networking processes. Attention to active and frequent communication with different actors in the supply chain to align people's views, perceptions and priorities is necessary in situations when expectations are unstable and diverging.

This agenda for action looks rather different from conventional approaches to supply chain management, that emphasize major critical functions such as outsourcing (Eccles, 1981; Lonsdale, 1999), supply management (Lambert *et al.*, 1998; Lambert and Cooper, 2000), chain management (Choi *et al.*, 2001), relationship management (Hallen *et al.*, 1991; Arndt, 1983) and power management (Lamming, 1993; Pfeffer, 1981; Geyskens *et al.*, 1996). This does not mean that the management of those aspects is somehow not crucial, but rather that principles of organic and facilitative management through stimulation of learning, networking and expectation alignment should be incorporated in the management of these functions. In conclusion, it becomes evident that a supply chain is to be conceived as a learning organization. In particular, the learning process is a driving force in the development of the chain. Successful innovations are generated when all three key processes are emphasized.

These focal points for action are still tentative. After conducting one detailed case study we have to be careful about undue generalizations. Further research is needed to establish to what extent the processes and problems of supply chain development found in this paper have a wider validity, and to what extent they are case-specific.

Note

1. The case study draws on van Eijck and Romijn (2008).

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