On the Evolution of Product Portfolio of Cooperatives versus IOFs:

An Agent-Based Analysis of the Single Origin Constraint

Wendong Deng
George W.J. Hendrikse[1]

Abstract

An agent-based model is developed to address the relationship between the ownership structure of an enterprise and the evolution of its product portfolio. The coherence and evolution of a product portfolio is operationalized by transition rules regarding the Moore environment. The distinguishing feature of a cooperative is the single origin constraint according to Cook (1997), which is modelled as a cooperative assigning an infinite lifetime to the first product in its product portfolio, while all other products have finite lifetime. All product of an investor-owned firm (IOF) are assumed to have finite lifetime. Our simulation results show that the single origin constraint pulls the activities of the cooperative in one cluster centered around the first activity, while the IOF's product portfolio develops in a centrifugal way. The cooperative and the IOF are more diversified in a mixed duopoly.

Keywords: Diversification, agent-based model, coherence, single origin constraint, cooperatives.

1 Introduction

One of the fascinating aspects of enterprises is the evolution and composition of their product portfolios. Product portfolios evolve due to enterprises expanding current product lines, adding new products, divesting products, conducting mergers and acquisitions, and so on. An important feature of the evolution and composition of product portfolios is coherence. 'Firms are coherent to the extent that their constituent businesses are related to one another' and 'firms over time add activities that are related to some aspect of existing activities (Teece et al., 1994:2-3). In other words, firms seem to choose to enter industries that are close to their existing line of business. However, coherent product portfolios of different enterprises may develop in different directions and in different clusters of related products. Therefore, the mechanism driving the evolution and composition of the product portfolio is a central issue to understand any firm's strategy.

[1] Wendong Deng, Schattdecor AG, wendong7@gmail.com; George Hendrikse, Erasmus University, Rotterdam School of Management, ghendrikse@rsm.nl.

Teece et al. (1994) also poses that ownership structure of enterprises is important in the product portfolio composition of an enterprise. Empirical evidence indicates that there is a relationship between ownership structure and diversification behaviour. For example, the Dutch sugar industry consisted of two enterprises: the cooperative SuikerUnie, nowadays cooperative Royal Cosun, and the investor owned enterprise Centrale Suiker Maatschappij (CSM), nowadays Corbion. Both companies started with processing sugar beets, but their product portfolios evolved. Cosun is still processing sugar beets, but it processes also potatoes, produces ingredients and products for food in general, and produces increasingly ingredients for non-food products. The product portfolio of CSM evolved in a different way. CSM diversified in products adding value to sugar, was briefly active in baby food production, specialized in bakery products, and sold its bakery activities in order to have a focus on biological food ingredients and biochemicals. Hendrikse and Van Oijen (2001) show that these diversification differences between cooperatives and IOFs are not limited to the sugar industry. Cooperatives are significantly less diversified than IOFs in unrelated activities (two digit industries) as well as related activities (four digit industries) in a sample of 114 companies in many sectors in the Netherlands. In addition, van der Krogt et al. (2007) find that dairy cooperatives and IOFs have different expansion strategies. In general, ‘cooperatives prefer mergers, collaboration agreements, joint ventures, and licensing, while IOFs focus on take-over strategies – acquisitions and share holdings’ (p453). Gomez-Mejia et al. (2010) shows that there are also product portfolio differences regarding other ownership structures. They show that family firms diversify less both domestically and internationally than non-family firms. However, Kamshad (1994) does not find a statistically significant difference between the diversification policies of IOFs and labour managed firms. Similarly, Lane and Lubatkin (1998) concludes that corporate ownership structure does not affect its diversification strategy.

Hansmann (1996) observes that ownership of enterprises is usually characterized by one group of stakeholders. Examples of such groups are the providers of input to the enterprise, the providers of capital, the buyers of the output of the enterprise, the government, a family, and so on. This article compares cooperatives and IOFs. A cooperative is an enterprise owned by either the providers of the input to this enterprise, or by the buyers of its output. Owners of a cooperative like to use the cooperative to add value to their portfolios of assets, which includes each owner’s (upstream or downstream) enterprise. An IOF is owned by the providers of capital. The investors of the IOF like to use the enterprise in order to generate a maximum return on their invested capital. This difference between a cooperative and an IOF is expected to have an impact on many aspects of enterprise behavior, such as pricing and production decision (Sexton, 1986), principal-agent relationships (Vitaliano, 1983), and transactions (Bonus, 1986). Cook (1997, p87) formulates the single origin view regarding agricultural cooperatives in order to distinguish them from IOFs. He observes that “… cooperatives … are “single origin” in that their objective is to optimize the utilization of their member owners output, not to originate products in another area or country. Most cooperatives have ties to producers/members within a particular region, and they do not have the same freedom as IOFs have." This article analyses the impact of the single origin constraint of cooperatives on the evolution of its product portfolio, and compares it with the product portfolio evolution of an IOF.

Modelling product portfolio evolution is challenging because it has to incorporate the above features. We capture the ownership difference between a cooperative and an IOF by the single origin constraint and develop its implications for the evolution of product portfolio. To be more specific, agent-based methodology is adopted to address the impact of ownership of an enterprise on the evolution of its product portfolio. One reason for this choice of methodology is that formulating a closed form solution for models of "evolving systems of autonomous interacting agents" (Tesfatsion, 2003:263) is often not possible. Numerical approaches in terms of solutions are used in such circumstances to determine the implications of the model (Ericson and Pakes, 1995). Another reason is that a simulation study enables us to study alternatives and possibilities which are not observed and evaluate them. This may serve theory development as well as formulating recommendations. Agent-based simulations allow us to model the single origin constraint, portfolio coherence, and its evolution, which has not been done before to the best of our knowledge. Additionally, we incorporate agents' decision-making process and product output decisions in order to study product portfolio evolution of an IOF and a cooperative in different competitive settings. As such, this agent-based model is able to address the following question: How does the evolution and composition of the product portfolio of an IOF and a cooperative differ? By comparing cooperatives with IOFs, this paper provides an explanation for the impact of governance structure on product portfolio.

This paper is organised as follows. In section 2, we present the model. Section 3 presents the results. Section 4 concludes and formulates directions for future research.

2 An agent-based model

An agent-based model consists of three elements: the agent, the state of the agent, and the transition rule that governs the evolution of the agent's state. The relationship between these three elements is that each agent is characterized by a state, while actions of the agent regarding the state are governed by transition rules. The agent in our model is either a cooperative or an IOF. The action of the agent consists of adding new products to its product portfolio, i.e. diversification, or remove existing products when the product reaches its lifetime, i.e. divestment.

The state of an agent is defined as its product portfolio. A product in the product portfolio is represented as a cell in a two-dimensional grid, while the set of all products is called the 'Portfolio Matrix'. Each product in the Portfolio Matrix is characterized by its output level and lifetime. A product's lifetime starts at the period when it is added to the portfolio. The first product of an agent is called the 'Original Product'. The single origin constraint of cooperatives is modelled by assuming that the lifetime of the Original Product is infinite, i.e. a cooperative will never divest its first product (which is to be interpreted as the product requiring the input of owners). By contrast, the Original Product of an IOF has a finite lifetime and will be divested when its lifetime is reached, i.e. the single origin constraint is absent in an IOF. All other products have the same finite lifetime in both enterprises.

A transition rule produces a new state for the agent as a function of the agent's current state. Our basic transition rule is the concentric diversification strategy. It entails that the agent will only diversify into new products related to its current product portfolio.[2] Specifically, agents diversify their product portfolio by picking one of the cells randomly from the set consisting of the existing products and their Moore neighborhoods (Hegselmann and Flache, 1998), where the Moore neighborhood of a cell consists of the cell itself and the eight adjacent cells. In other words, the transition rule specifies that the agent randomly selects a new product in the local neighborhood of its current product portfolio in each period.[3] The probability of a cell being selected in the next period is calculated based on the content of the current product portfolio and is stored in the 'Probability Matrix'. The locality of an agent's transition rule regarding new products serves to capture the coherence feature of a product portfolio, while the transition rules will drive the evolution of the product portfolio.

Figure 1 provides an example of a Portfolio Matrix and a Probability weight matrix of an agent at the start, period 1, and period 2 with a grid of 5x5=25 cells.[4] It will be convenient to label each cell with a number, starting with number 1 for the cell at the top left, the number 2 for the cell to the right of this cell, and so on. At the start, there is only one product (the Original Product) at the center of the Portfolio Matrix, i.e. cell 13, with an output level of 1 unit. The Moore neighborhood of this product consists of the eight cells adjacent to cell 13, i.e. the cells 7-9, 12, 14, and 17-19. This determines the weights in the probability distribution regarding the choice of a new product / unit / cell in the next period. The probability weight matrix reflects that the new unit / product is selected from the set of cells consisting of the cells 7-9, 12-14, and 17-19 with equal weight 1, and therefore probability 1/9.

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[2] Modifications of the transition rule allow to incorporate additional aspects of cooperatives versus IOFs.

[3] Notice that the randomness entails that a divested product can be chosen again by the agent when it is in the neighborhood of the products in the Product Portfolio.

[4] This example is adapted from the example in Hendrikse, Smit and de la Vieter (2007:427).

Start

Portfolio matrix

0	0	0	0	0
0	0	0	0	0
0	0	**1**	0	0
0	0	0	0	0
0	0	0	0	0

Probability weight matrix

0	0	0	0	0
0	**1**	**1**	**1**	0
0	**1**	**1**	**1**	0
0	**1**	**1**	**1**	0
0	0	0	0	0

Period 1

Portfolio matrix

0	0	0	0	0
0	0	0	0	0
0	0	**1**	0	0
0	0	**1**	0	0
0	0	0	0	0

Probability weight matrix

0	0	0	0	0
0	**1**	**1**	**1**	0
0	**2**	**2**	**2**	0
0	**2**	**2**	**2**	0
0	**1**	**1**	**1**	0

Period 2

Portfolio matrix

0	0	0	0	0
0	0	0	0	0
0	0	**1**	0	0
0	0	**2**	0	0
0	0	0	0	0

Probability weight matrix

0	0	0	0	0
0	**1**	**1**	**1**	0
0	**3**	**3**	**3**	0
0	**3**	**3**	**3**	0
0	**2**	**2**	**2**	0

Figure 1: An example of the evolution of the product portfolio during 2 periods

The agent will start the evolution of its product portfolio from this Original Product in period 1. Each product cell in the set consisting of the Moore neighbourhood and the Original Product has an equal probability of 1/9 of being chosen at the beginning of the next period because there are 9 cells / units / products covering the Original product and its Moore neighborhood. Suppose that the product south of the Original Product, i.e. cell 18, is chosen at the beginning of period 1. It entails that the agent chooses a project which diversifies the portfolio of projects. The new product in cell 18 changes the portfolio of products, and therefore the probability weight matrix. There are 9 cells related to the Original product, i.e. cell 13 and the eight cells of its Moore neighborhood, and 9 cells related to the new product in cell 18, i.e. cell 18 and the eight cells of its Moore neighborhood. Notice that 6 cells overlap, i.e. the cells 12-14 and 17-19. Each of these cells is therefore twice as likely to be selected in period 2 than one of the cells in the set of cells consisting of the cells 7-9 and 22-24. This is reflected in the second Probability weight matrix. For example, cell 7 will be selected with probability 1/18 in period 2 because it is only in the Moore neighborhood of cell 13, while cell 19 is selected with probability 2/18 because it is in the Moore neighborhood of cell 13 as well as cell 18.

Period 2 in figure 1 illustrates that an additional unit of an existing product can be chosen, i.e. cell 18 is chosen again. The impact of this choice on the probability distribution for the choice of cell in the third period is reflected in the Probability weight matrix. Consider three examples. First, the Original cell and the cells selected in the periods 1 and 2 have cell 17 in their Moore neighborhood. The probability that cell 17 is selected in the third period is therefore 3/(9+9+9)=1/9. Second, cell 9 is present only in the Moore neighborhood of the Original product and has therefore probability 1/(9+9+9)=1/27 of being selected in the third period. Finally, cell 24 is part of the Moore neighborhood of cell 19. The probability that this cell is selected in the third period is 2/(9+9+9)=2/27 because product 19 has 2 units due to being selected in period 1 as well as period 2.

3 Results

This section will highlight the impact of the single origin constraint of cooperatives on the composition of the product portfolio. The product portfolio consists of the number of products and the output regarding each product. Consider the following simulation setting.[5] The initial output level of the Original Product is set to 1 for the cooperative as well as the IOF. The lifetime of the Original Product of the cooperative is set to infinite, whereas the lifetime of the Original Product of the IOF is set to 40. The same lifetime of 40 will be assigned to all other products. At the beginning of each period, the agent will choose randomly a product from the local Moore neighbourhood of its current product(s) according to the Probability Matrix. If the chosen cell is a new product, the new product will be assigned an initial output level of 1 unit. If the chosen cell is an existing product already in the agent's portfolio, the agent will increase the output level of the product by 1 unit. The agent will keep a product in the portfolio until its lifetime is reached, and then the product and its output will be removed from the portfolio. We simulate the process of an agent's portfolio evolution over 500 periods.[6] The results of 100 simulation runs are averaged. This section presents the results regarding the evolution of product portfolio in a monopoly (section 3A) as well as a mixed duopoly (section 3B).

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[5] The source code of the simulation models in this paper is available online at: http://hdl.handle.net/1765/77449.

[6] The choice of 500 periods is sufficiently large compared to the lifetime 40 in order to have a clear pattern in the evolution of the product portfolio.

3A Monopoly

The evolution of the product portfolio of both enterprises is identical during the first 40 periods. The size of the enterprise grows due to adding new products or adding output to existing products to the product portfolio. The evolution of the product portfolio of a cooperative and an IOF start to diverge after period 40. Figure 2 depicts a typical product portfolio composition of a cooperative after 500 periods. The single origin constraint is responsible for the concentration of products around the Original Product and the output of this product being large.

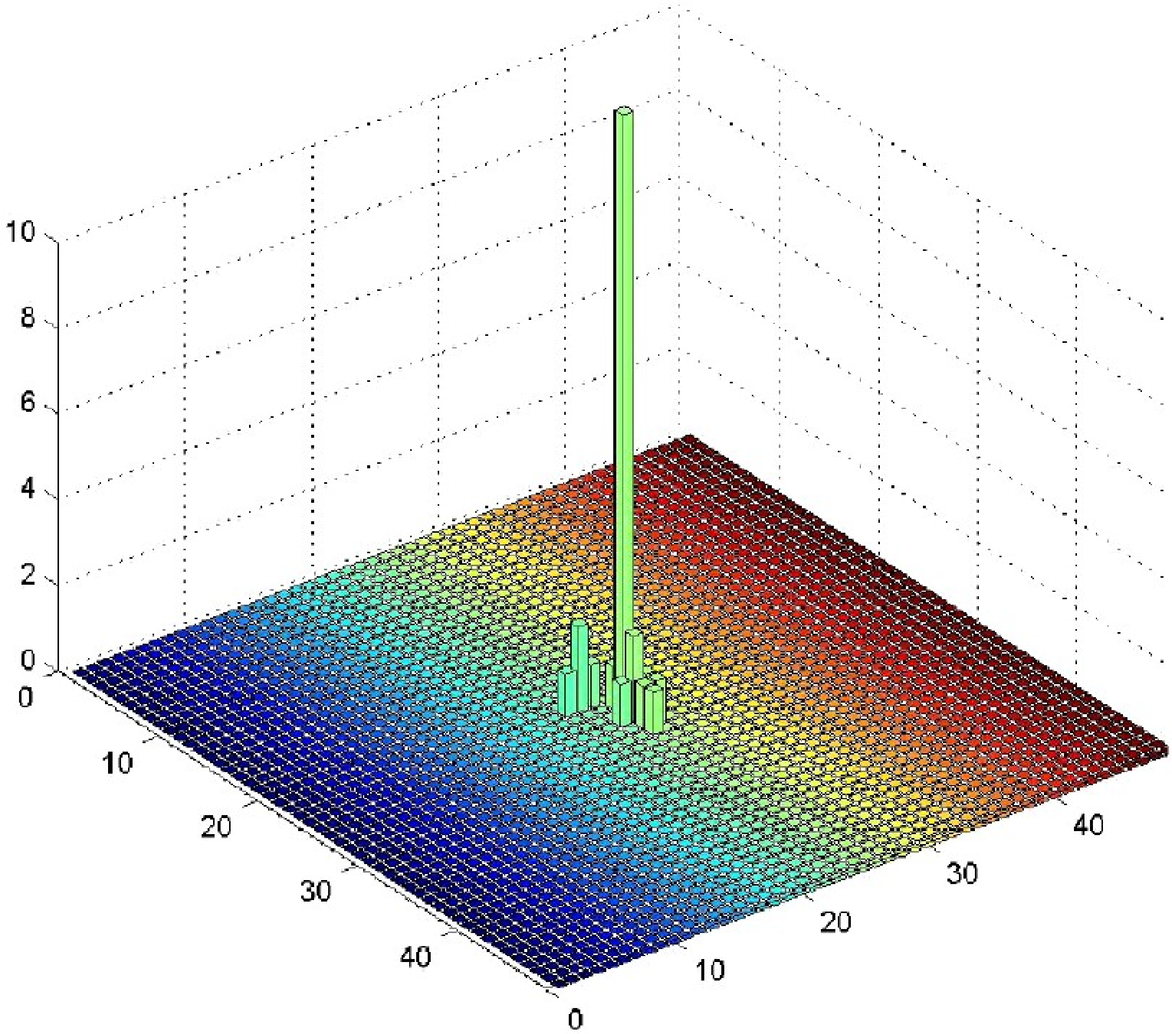


Figure 2: Product portfolio evolution of a cooperative in a monopoly market

Figure 3 depicts a typical product portfolio composition of an IOF after 500 periods. The Original product will be eliminated once it has reached its lifetime of 40 periods. This decreases the probability that the Original Product will be chosen in period 41, but it will not decrease to zero due to products being present in the Moore neighborhood of the Original product. The probability that other products are chosen increases, and therefore that products enter the product portfolio which are less close to the Original Product. The IOF's product portfolio evolves into (clusters of) products which are unrelated to the Original Product.

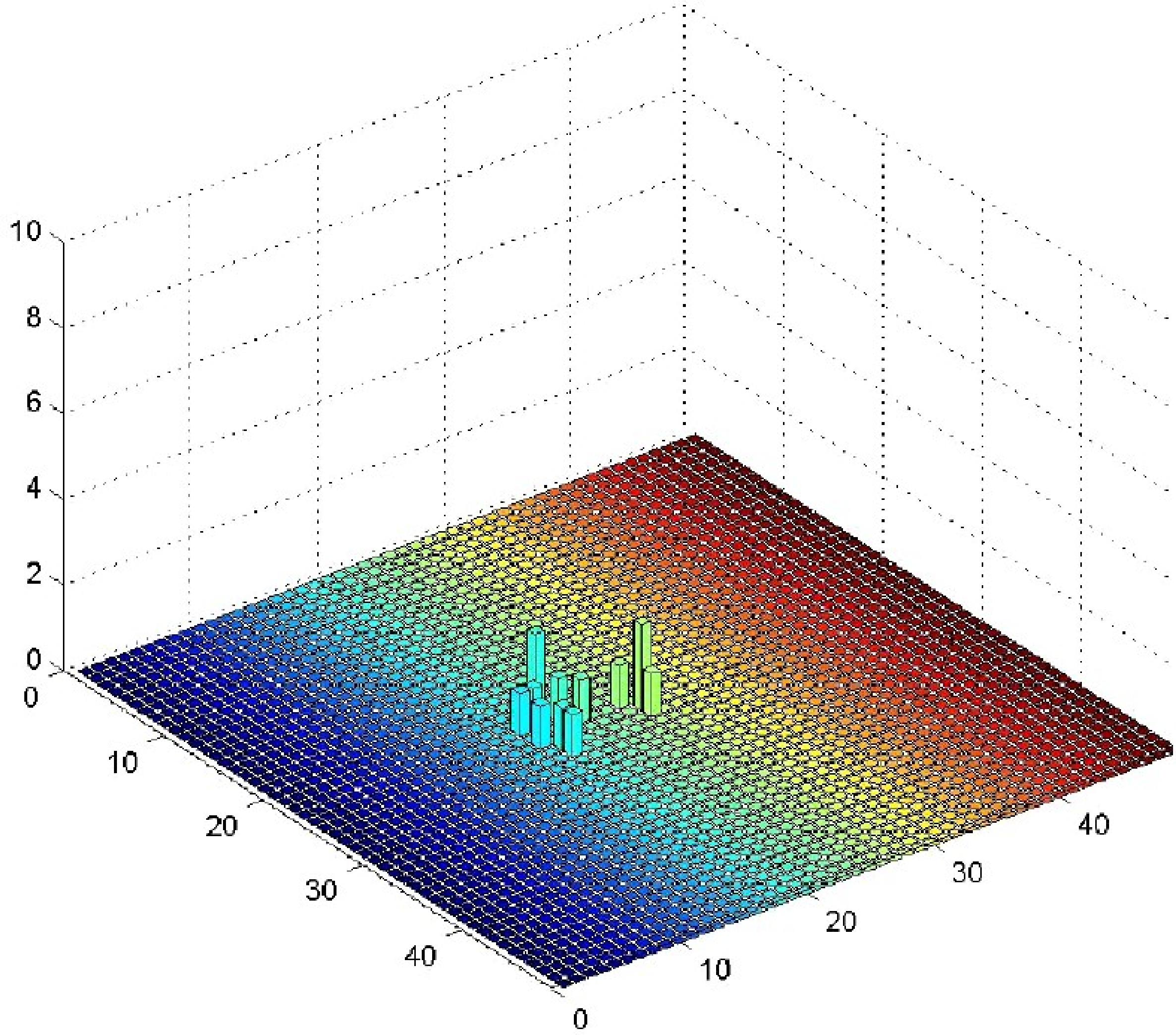


Figure 3: Product portfolio evolution of an IOF in a monopoly market

Figure 4 presents more details regarding the differences between a cooperative and an IOF regarding product portfolio evolution. The evolution of the product portfolio of an agent is described by several measures, such as the number of products, total output, and average output per product. To capture the relatedness of products in the evolving portfolio, two measures are defined: the average product distance and the average weighted product distance. The average product distance assigns the same weight to all products, while the average weighted product distance weights according to the output of the product.

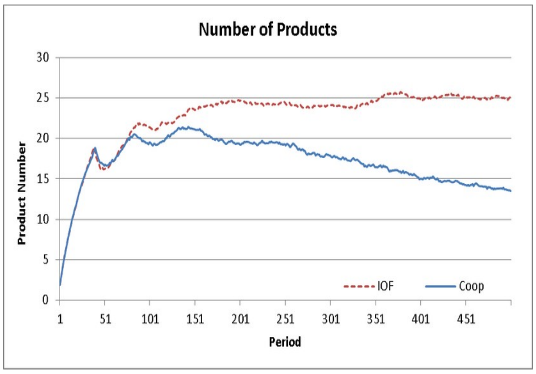


Figure 4a: Number of Products

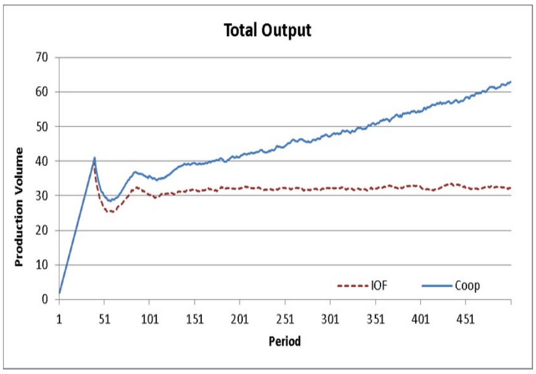


Figure 4b: Total Output

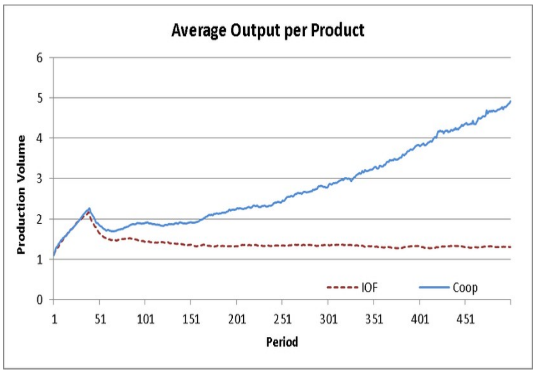


Figure 4c: Average Output per Product

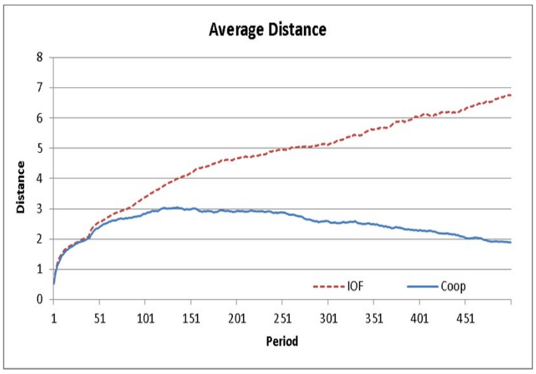


Figure 4d: Average Product Distance

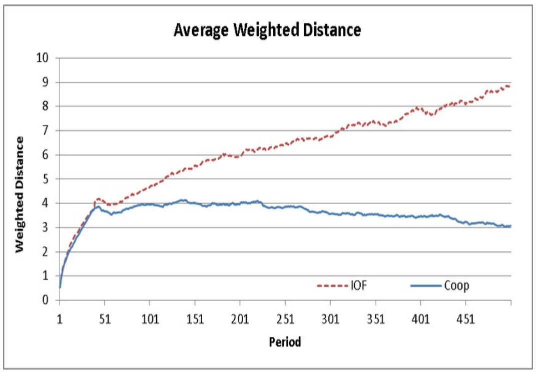


Figure 4e: Average Weighted Product Distance

Figure 4: Various indicators of the evolution of the product portfolio of the IOF (dotted line) and the cooperative (solid line).

Figure 4a illustrates the number of products in the product portfolio over time. The cooperative as well as the IOF adds new products to its portfolio. During the first 40 periods, the number of products increases quickly. Subsequently, some products start to reach their lifetime, and will be divested. The number of products of both agents fluctuates and continues to increase, but the increase will be less. For the IOF, the number of products in its portfolio will level off gradually. Given the same lifetime for every product, the speed of divesting products is related to how many products are in the portfolio. Therefore, when the speed of divesting products is equivalent to the speed of adding products to the portfolio, the number of products of the IOF will become stable. The change of the number of products of the cooperative shows a different pattern. In the course of time, the number of products of the cooperative continues to decrease. The reason is that the output associated with the Original Product will never be removed due to the single origin constraint, while all other products will be eliminated when they reach the lifetime. This will have an increasing effect on the probability of choosing the Original Product and the products close to it, and thus decreases the probability of choosing new products. This results in the decreasing number of products of the cooperative.

Figures 4b and 4c depict the total output and the average output per product. Their development is directly linked to the number of products. For the IOF, the total output and the average output per product will level off along the periods as well. This indicates that the IOF's product portfolio will reach a relative stable composition in the long term. The IOF will keep a certain number of products and maintain a constant output level. By contrast, because the probability of choosing new products is decreasing over time for the cooperative, it will focus on increasing the output of the Original Product. Since the Original Product and its associated output will never be removed, the output of the cooperative will continue to increase.

The increasing average (weighted) product distance of the IOF depicted in Figures 4d and 4e indicate that the area covered by the IOF's product portfolio widens over time. It entails that after the Original Product of the IOF has reached the lifetime and has been divested, the IOF's portfolio gradually moves to those products with a large distance to the Original Product. The results of the analysis of the two enterprises in a monopoly setting are summarized in Proposition 1.

Proposition 1: The single origin constraint pulls the products of the cooperative in one cluster centered on the Original Product, limits the diversification level of the cooperative, and increases the output of the Original Product continuously. The IOF's product portfolio evolves into clusters of products.

The literature regarding cooperatives shows that there are substantial differences between cooperatives in terms of their output policy. Some cooperatives control the input delivered by their members. These centralized cooperatives maximize the members' total surplus, i.e. the total profit of both the cooperative processor and member farms (LeVay, 1983). Other cooperatives accept all the inputs delivered by their members, and turn it into output. These decentralized cooperatives maximise the total output of products and serve the members at cost as long as no loss on its operation is incurred. Deng (2015) has analysed the impact of these different output policies on the evolution of product portfolio in the above simulation model. The decentralized cooperative produces a higher output level per product than the centralized cooperative, but it has a lower total surplus. However, the comparison with the IOF is qualitatively the same in terms of product portfolio dispersion.

3B Mixed duopoly market

Consider now the competition between a cooperative and an IOF, i.e. a mixed duopoly market. Simulating a mixed duopoly market is more involved due to the interactions between the two enterprises. Recall that in the monopoly market, when an agent chooses a product from its local neighbourhood, there are only two possibilities. If the product is already in the portfolio, the agent will simply increase its output level; if the product is a new product, the agent diversifies. In the duopoly market two more possibilities arise, and therefore additional transition rules are required. The first possibility is that an agent chooses a product that is not in its own portfolio but in the portfolio of the rival. If both agents are producing the same product, i.e. they are competing in this product market, then each enterprise has to choose its optimal output level for this product. This output level is determined by the equilibrium output level in a Cournot quantity competition game. It is also assumed that the incumbent producer cannot prevent the entry of the other enterprise. The second possibility is that the chosen product is already in the portfolios of both agents. We assume that an enterprise will adjust its output based on the reaction function of the Cournot competition game until the output of that product reaches equilibrium. If a product’s output level has reached its equilibrium, then the product will not be chosen again in the next period.

The results are presented in figure 5. Figure 5a shows that the number of products of the cooperative is still lower than that of an IOF, i.e. the cooperative (IOF) has around 8 (11) products in its portfolio. These products numbers of the enterprises are larger than when they are monopolists. Figures 5b and 5c illustrate that the cooperative has a higher level of total output and output per product than the IOF does. Figure 5d shows that the average product distance of the IOF is higher than that of the cooperative, and it levels off after some periods in the duopoly market. Notice that the average product distance of the IOF keeps increasing in the monopoly market (Figure 2d). This means that, when an IOF is competing with a cooperative, the competition prevents the IOF’s portfolio from deviating from the Original Product. This is because the products in competition are close to the Original Product as the portfolio of the cooperative concentrates around the Original

Product due to the single origin constraint. This part of the IOF's portfolio continues to evolve as a products cluster, which is relatively close to the Original Product. Therefore, the average product distance of the IOF doesn't keep increasing, i.e. the dispersion of the portfolio of the IOF in the duopoly market is lower than that in the monopoly market, due to the interaction between the enterprises. However, Figure 5e shows that the average weighted product distance of the cooperative is higher than that of the IOF.

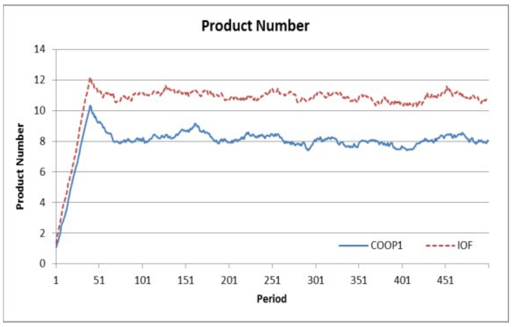


Figure 5a: Number of Products

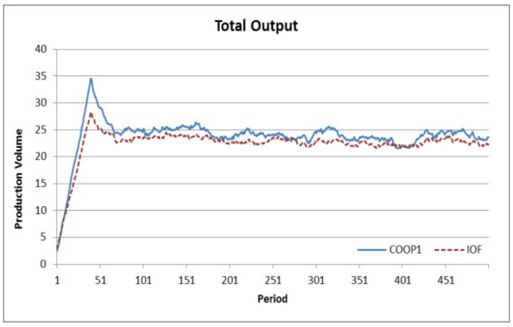


Figure 5b: Total Output

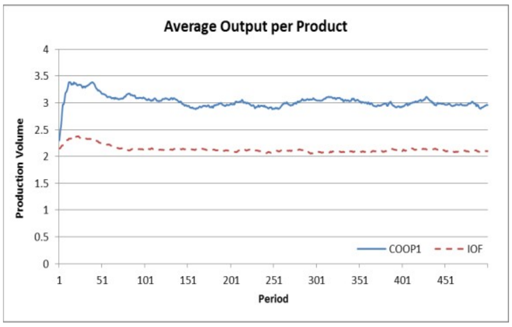


Figure 5c: Average Output per Product

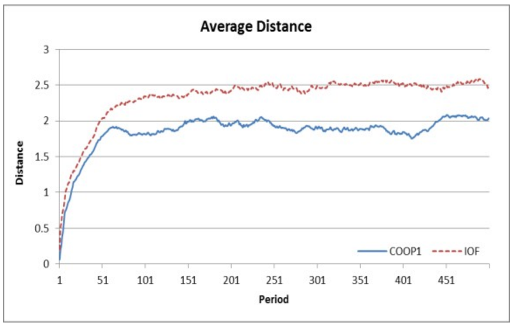
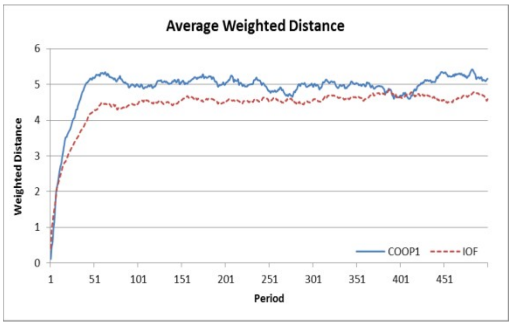


Figure 5d: Average Product Distance



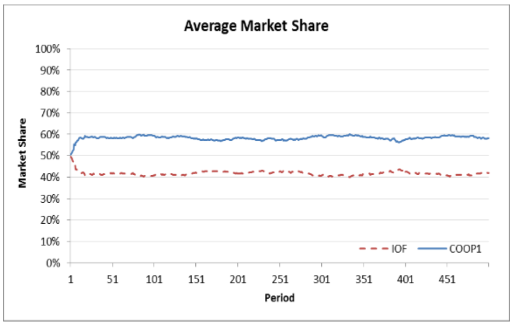


Figure 5e: Average Weighted Product

Figure 5f: Market Share

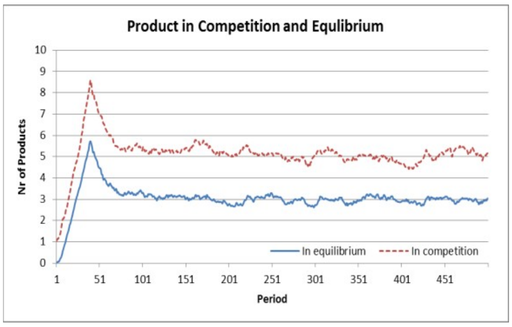


Figure 5g: Products in Competition and in Equilibrium

Figure 5: Simulation results of the mixed duopoly market

Figure 5f compares the average market shares of the cooperative and the IOF. For those products in competition, the cooperative enjoys 60% of the market share and the IOF 40%. This is in line with the result of Tennbakk (1995) that the cooperative will produce more than the IOF in a mixed duopoly market. Figure 5g shows that the number of products in competition reaches 8 at the beginning of the simulation. It means that the competition between the enterprises concentrates on the products around the Original Product at the start. After 40 periods, some products reach their lifetime and are divested. It implies that the number of products in competition decreases and levels off. Approximately, the enterprises are competing in 5 products, and the output equilibrium is reached when there are 3 products. The results of the mixed duopoly market simulation are summarised in the following proposition.

Proposition 2: In the mixed duopoly market

- the cooperative is less diversified than the IOF;
- the cooperative and the IOF have a higher diversification level than in the monopoly market;
- the dispersion of the IOF's product portfolio is lower than in the monopoly market.

4 Conclusion

An agent-based model is developed to investigate the dynamics of the product portfolio of an enterprise. We focus on the impact of the single origin constraint of cooperatives when agents adopt a concentric diversification strategy. Concentric diversification and portfolio coherence are made operational by agent-based methodology. The agents diversify into new products in the Moore environment of the current product portfolio, while the single origin constraint is modelled by assigning an infinite lifetime only to the first product of the cooperative. The simulation results show that the single origin constraint pulls the products of the cooperative in one cluster centered on the Original Product. This centralisation effect decreases the probability of choosing new products and increases the output of the Original Product continuously. This accounts for the lower diversification level of cooperatives. Without single origin constraint, the product portfolio of the IOF evolves in clusters of related products that deviate from the Original Product. In the long term, the IOF will be more diversified than the cooperative and keeps a stable number of products in its portfolio. Competition between enterprises is addressed in a mixed duopoly market. The competition between the enterprises modifies the diversification and divestment process. In the mixed duopoly market, the cooperative still has fewer products in its portfolio, and has a larger total and per product output than the IOF. However, both the cooperative and IOF are more diversified in the duopoly market than in the monopoly market. Another result is that competition induces the IOF's portfolio to stay closer to the Original Product.

There are various possibilities for future research. First, the mixed duopoly setting investigated the impact of competition on the composition of the product portfolio of enterprises in a mixed duopoly. Subsequent research may address the stability of this industry structure when enterprises have the possibility to choose their ownership structure. This requires an analysis of a market consisting of two cooperatives and a market of consisting of two IOFs. Additionally, if enterprises have also the choice of leaving the market, then an enterprise may strategically choose its product portfolio composition to induce exit by the other enterprise. Second, our simulations show that the product portfolio of the Coop shows no dispersion, while the product portfolio of the IOF shows dispersion. Future research may address the robustness of this result. Are there parameter values, or variations in the setup of the model, such that the product portfolio of the Coop shows dispersion, or that the product portfolio of the IOF shows no dispersion? Possible variations of our model addressing these questions are differences in the lifetime between the products of an IOF and a cooperative, enterprise differences in terms of the periods in which new products are introduced, and varying the size of the Moore neighborhood.

Third, the evolution and composition of product portfolios have been addressed, but this does not determine the direction of the growth activities. Modelling the portfolio problem and the horizon problem of cooperatives (Vitaliano, 1983) along the lines of this paper may generate some directionality in the product portfolio. For example, focus in the Moore neighbourhood may account for the difference between related and unrelated diversification (Hendrikse, e.a., 2007), while the lifetime parameter is a natural ingredient of the model for capturing the difference between short and long run projects. Another source of directionality regarding diversification decisions may be the background of the CEO (Ang et al., 2014). In addition, member-dominated leaders have more focus on, and skills regarding, technical-operations than diversification (Cook, 1994). Fourth, according to the resource-based view, resources of firms will shape their diversification pattern (Penrose, 1959). Compared with IOFs, cooperatives are often viewed to be short of two types of resources. Cooperatives have less financial resources at their disposal for product diversification because their equity shares are not transferable and they are not able to raise capital from stock markets (Vitaliano, 1983; van Oijen and Hendrikse, 2002). As a consequence, cooperatives may have fewer means to diversify than IOFs. This may result in the hypothesis that the frequency of product portfolio changes is lower for a cooperative than an IOF. Agent-based methodology is a fruitful methodology to explore these ideas.

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