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Strategic Early Warning System for the French milk market: A graph theoretical approach to foresee volatility

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Abstract

This paper presents a framework for developing a Strategic Early Warning System allowing the estimation of the future states of the milk market. This is in line with the recent call from the EU Commission for tools which help to better address such a highly volatile market. Furthermore, since the first April 2015, the new Common Agricultural Policy ended quotas for milk which led to a milk crisis in the EU. Thus, we collaborated with milk experts to get their inputs for a new model to analyse the competitive environment. Consequently, we constructed graphs to represent the major factors that affect the milk industry and their relationships. We obtained several network measures for this social network such as centrality and density. Some factors appear to have the largest major influence on all the other graph elements, while others strongly interact in clique. Any detected changes in any of these factors will automatically impact the others. Therefore monitoring ones competitive environment can allow an organisation to get an early warning to help it avoid an issue (as much as possible) and/or seize an opportunity before its competitors. We conclude that Strategic Early Warning Systems built with graph theory can strengthen the governance of markets.

Keywords: Strategic Early Warning System, Scenario Analysis, Graph Theory, Foresight, Milk Market.

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1. Introduction

Under the influence of globalisation, deregulation and the fast growth of information communication technologies (e.g. the Internet), the economy is becoming more complex and uncertain [31, 45]. Thus, organisations are experiencing "turbulence" in the form of fast and unpredictable changes that occur in an organisation's environment which affects its performance [37]. Yet, Gilad [27, p.3] emphasizes that, "despite the fact everyone knows the world has become riskier, fully 92 percent of the managers surveyed reported that their company was recently (last 5 years) surprised by at least one event that was significant enough to affect their organisation's long term market position". Likewise, it is not surprising to see that intuition is still considered to be very useful when making decisions in situations of great uncertainty [17]. However, in attempting to face this growing "age of discontinuity" [18] and "mess" [2], current strategic decision tools are limited [1, 28] and allow at best a reaction to threats or opportunities [6]. In such conditions, managers are informed too late, and too often decisions are made on the basis of heuristics [5]. Therefore, these strategic systems increasingly lead to ineffective decisions and low performance [12].

When trying to overcome these limitations and strengthen strategic planning and governance, the importance of Strategic Early Warning Systems (SEWS) has been raised [25]. Indeed, SEWS can help decision-makers anticipate market changes, and allow organisations to have a strategy that fits the market reality and avoid industry dissonance [60]. Furthermore, Roland Berger Strategy Consultants survey [55] emphasises that the lack of SEWS is one of the key causes of failure in strategic planning.

SEWS integrate scenario analysis approaches which aim to create alternative pictures of the future that are analytically coherent [11] and "simplify the avalanche of data into a limited number of possible states" [58, p.27].

The general framework of SEWS [6] for a given market is: 1) Define the scope, i.e. the time frame, analysis to be done and participants; 2)Determine all drivers of change and evaluate their impact and probability; 3) generate scenarios through possible combinations of drivers ; 4) Make a War Game for each scenario as a simulation (see for example Gilad [28]); 5) Implement the system by scanning one's environment allowing the detection of movements of drivers of change (use of competitive intelligence methods and tools for this) which could lead to the appearance of a pre-determined scenario. Finally to allow the organisation to launch an alert to anticipate either a threat or opportunity. Yet, the SEWS requires updates to maintain its performances as inputs might change with time [5]. Our research focuses on the first three steps of the framework as we do not intend to implement it here.

If qualitative methods of SEWS (see for example Schoemaker [58]) have been developed and applied in various sectors and companies (e.g. Shell, Kraft) there is room for improvements concerning SEWS based on quantitative analysis [25]. Moreover, it is underlined that the existing research on SEWS is very restricted [60]. Noting this we apply graph theory to allow the creation of scenarios for SEWS.

Most of the research on forecasting markets use time series data [57]. These methods and tools include but are not limited to regression analysis and neural networks. However, the deterministic model most frequently does not predict well at macro level as there is nothing stable in the economy [45]. Yet, Amer et al. emphasise that quantitative methods are adequate for short periods [3]. In this paper, instead of time series data, we have a graph representing the established interrelationships between chosen factors which can be construed as a foresight method [53]. This gives us the freedom of referring to a much broader range of major and minor factors that affect our market. Therein, our graph analysis indicates "what might plausibly occur, in contrast to forecasting techniques that aim to predict as accurately as possible what is likely to happen" [21, p.4].

We chose the milk sector in France as our case study. This is in line with the call from the European Commission [22] for more robust tools to anticipate changes in this market, which is a strategic sector for the EU and for France. Yet, the milk price is highly volatile and the European Union's milk market is currently in crisis [54]. Indeed, the new Common Agricultural Policy (*CaP*) which went into effect the first of April 2015 has ended quotas for the milk. In July 2015, many cities in France were blocked by milk producers as a protest against the very low milk price which is currently below the cost of production for most of producers [48]. Thus, the current situation underlines that there is a lack of risk management tools of the *CaP*, of the threats for farmers and concerning the food security [42, 67].

Hence, our research aims not only to fill a scientific gap by applying graph theory for the first time in the frame of SEWS, but also to help better foresee changes in the milk market to strengthen its governance. In addition, the qualitative inputs given by experts, on which we applied the graph theory, were provided in accordance with a new model dedicated to analysing the competitive environment [6] which was applied previously by Author et al.[8], to milk producers.

The remainder of the paper is organised as follows: we will explain the importance of milk market for France, the EU and provide a background about SEWS, scenario analysis and the use of graph theory in network analysis. Then, we will underpin the methodology of our research. Next, our findings will be outlined and discussed. Finally, our conclusion will emphasise the implications of our findings for academics as well as for managers and for further research to be undertaken.

2. Background

2.1. Importance of the milk market in France and the EU

Agriculture and the agri-food business are key sectors of the French economy together with the automotive (e.g. Renault and Peugeot) and aeronautics (e.g. Airbus) sectors. Thus, the milk market is an economic engine for the French economy as it represents 27.7 billion turnover (i.e. the second highest after meat in the agri-food business). Refer to Figure 1 for the shares of the French agri-food industry [44]. There are 250.000 jobs located on the whole territory [39]. It has a 3.8 billion euros trade surplus while the French external trade has a 67 billion euros deficit [44]. Moreover, the world consumption increases yearly by 2.5 percent mainly thanks to emerging countries (such as China and Russia).

$[InsertFigure1]$

Furthermore, France has 5 companies among the 25 biggest in the milk sector worldwide [69]. These companies are: Lactalis (ranked no.1), Danone (No.4), Sodiaal (No.17), Bongrain (No.18) and Bel (No.24). France is the second biggest European milk producer after Germany [23].

The EU represents 28.1 percent of the world milk production and occupies the first rank as producer and second as exporter after New-Zealand [69]. After the end of milk quotas in the EU on the 1st April 2015, the market entered into a new era and companies (especially the big ones) seem to be now the game masters. Thereby, the milk market faces structural changes but also conjectural ones. Indeed, the Chinese economy is currently slowing down. This is a very important outlet for EU milk producers. At the same time the Russian embargo is still in place. The milk market is nowadays very volatile and it requires new tools, new methods to tackle these challenges, and to reinforce its governance.

Strategic Early Warning Systems (SEWS) can be deemed to be one solution of these problems since "if an organisation is able to detect trends and understand them, this organisation is more likely to move from merely reacting to trends to even shaping them, that is influencing a trend while it is evolving" [60, p.28].

2.2. Strategic Early Warning Systems

SEWS is based on the fact that surprises in the organisation's environment rarely emerge without a warning [65]. While the development of SEWS is common among international companies, such as Kraft foods and Shell[31], the experiments and their details are rarely provided. Indeed, SEWS are central to governance, and their implementation can result in competitive advantages synonymous with growing market shares and profit increases [6]. Overall, SEWS makes it possible to anticipate and/or to react faster to events, detect strategic opportunities and risks [60], reduce cognitive bias and intuition in the decision process, and allow for more effective contingency plans [27].

Several types of SEWS have already been used, particularly in industry. For instance, DASA, a division of Daimler Chrysler, developed a SEWS that "enabled them to respond rapidly to the Boeing/McDonnell Douglas merger with an immediate action plan, reassuring their workforce, customers, and shareholders" [31, p.13].

SEWS are nowadays deemed to be able to deliver great value to private organisations to help them survive and/or thrive [25, 28]. Yet, it can be argued that public organisations are also facing growing international competition, compelling them to most efficiently utilise tax funds (see, for example Author [7]). As a result, public organisations would benefit from implementing SEWS as well [5] as demonstrated by the steel sector in the North American region of Pittsburgh. Indeed, companies were closing one after another in 2008, due to the worst financial and economic crisis since 1929, and the sharp decline of the American automotive industry. Thus, the Steel Valley Authority

(SVA) through a Strategic Early Warning Network has permitted to save and to create nearly 8,000 jobs, and has impacted indirectly many other workers and communities [62]. Hence, a SEWS that is well developed and implemented can help both private and public organisations to succeed by allowing them to make better and faster strategic decisions in comparison to their competitors.

SEWS method is in fact based on scenario planning which integrates scanning and business war games instead of brainstorming to discuss consequences of scenarios. A business war game is a dynamic strategic simulation, which aims to test scenarios as much as possible in real conditions and goes far further than brainstorming [28]. Yet, early signals of possible environmental change are detected thanks to environmental scanning which is the continuous process of monitoring of the organisations' environment according to predefined topics [4]. Thus, scenarios analysis is at the heart of SEWS and constitute a major foresight technique [21].

2.3. Scenarios Analysis

The use of scenario as a tool for disciplined thinking and problem solving is pretty recent, as it started in 1942 with the Manhattan project during the second World War [72]. From a military use, scenario planning was adapted and integrated for the first time into a business tool for Royal Dutch/Shell, allowing them to respond quickly to the oil crisis of 1973 [65]. During the last 40 years, various approaches to scenario planning have been developed [11]. Yet, Schwartz, van der Heijden and Shoemaker are the most often cited academic approaches [3, 15].

Scenarios have many significations as "it ranges from movie scripts and loose projections to statistical combinations of uncertainties" [57, p.194]. In the context of SEWS, scenarios can be defined as "hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision-points" [33, p.6] which aim to create alternative pictures of the future [50] and to challenge assumptions [71].

The scenario methodology requires a "social-reasoning process which utilises dialogue and conversation to share participants' perceptions of the environment in a process of sense-making through theory building and storytelling" [70, p. 817]. Yet, scenario analysis does not target prediction but instead "allows structured thinking on the future based on the evolution of aspects such as driving forces, trends, themes, events and cause effect logics" [45, p.43].

Unlike foresight techniques, forecasting is based on the fact that no radical changes are expected in the future (see, for example Enserink [21]) and is thereby predictive. Therefore, deterministic models (e.g. linear programming) are not appropriate when facing high complexity[57] which can be better faced by using scenarios as one examine various trends and related potential underlying forces allowing uncertainty to be bounded [45].

Scenario analysis combines inductive and deductive methods as scenarios appear step by step from data, and the scenario narrative is constructed by a top-down approach from the framework developed at the start [32].

Frameworks for strategy creation need to follow a systematic process which incorporates specific strategy tools, and they need to be adaptable to environmental changes [26].

To build scenarios is deemed as a complex process in the light of the lack of standardisation of most scenario approaches [71]. Indeed, many scenario experts share the belief that scenarios cannot be created from recipes [59] which entails a "methodological chaos" [14, 40]. Therefore, standardised tools exist only in very few scenario approaches and only for selected process steps [58, 63].

This lack of a standardised approach explains why scenario planning has been used most of the time in long range planning processes i.e. at least five years [65, 59].

Regarding quantitative methods for development of scenarios, the most popular ones are the Interactive Cross Impact Simulation (INTERAX), the Interactive Future Simulations (IFS), Trend impact analysis (TIC) and Fuzzy Cognitive Map (FCM) based scenario planning approach [3, 14].

Yet, the use of "complex scenarios" [64] involves combining qualitative and quantitative methods in the analysis of trends and unfolding themes which constitute the frontier of scenario research today [52].

Hence, our research is in the same vein as we revisit scenario methodology by applying graph theory for the first time in the frame of SEWS based on qualitative inputs provided in accordance with a new model to analyse one's competitive environment.

2.4. Graph Theory

Graph theory has been widely utilised by social network scientists to learn about the social structure under consideration [66]. Using the graph model allows us to detect the presence or absence of network ties and to find an optimal way of constructing a connection between two or more given factors. Furthermore, it permits the uncovering of new trends and major influencers, to determine the leading factors and identify inactive factors. For each of the structures mentioned here, one can use graph theoretical analysis to detect it. For usage of graph theory in network analysis, we refer the reader to [34] and [35].

The connection between graph theory and social sciences was first noted in 1953 by Harary and Norman [30]. Later on Barnes and Harary [9] gave a survey in 1983. Since then it has been much more widely used especially in the last few decades with an interdisciplinary approach. To name a few of these fields: marketing (to uncover new trends [19, 51]); epidemiology (for intervention in the case of an outbreak of a contagious disease [68]) and intelligence (identifying insurgent networks and determining leaders and active cells [61].

Within a social network the importance of a factor is determined by the number of factors that link to it weighted by the importance of those factors themselves and the degree of their impact. Consequently the graph theory approach can deliver further information about sharp trends and the key uncertainties which are the general criteria used to build scenarios [58]. In Section 3.3, we provide the most important measures related to social network analysis represented by a graph that describe the milk network in France.

3. Methodology

It is advocated that the theoretical foundations of foresight, as well as foresight studies, should be multidisciplinary [46]. Thus, our approach to carry out scenario analysis for SEWS is congruent with this statement. We firstly used a new model developed by Author [6] dedicated to evaluate the competitive micro and macro environment which was previously applied in the frame of research to carry out a strategic analysis of the milk producers' competitive environment in the French milk market [8]. Secondly, we collaborated with 7 French milk experts and prospective specialists to provide the inputs to be analysed. This team can be deemed as strong since the average experience in the milk sector is 15 years and the average level is a MSc either in agriculture or economics. See the Table A. 1 for the experts' profile.

For each stated driver of change determined from factors and sub-factors drawing on the milk producers' competitive environment [8], experts provided its current impact and probability. Finally, we carried out graph analysis to create the potential scenarios that may appear, and to see if the scanning system was detecting some changes in the milk market competitive environment. Thereby, our design, application and approach to the process aim to deliver diverse and robust scenarios [45].

To ensure a proper determination of drivers of change and the evaluation of their impacts and probabilities by the milk experts, we used the Delphi Method [10]. Thus, two rounds of online questionnaires and feedback were sent to the milk experts. The first round was done 20th November 2014 and the second one two weeks later. It is important to underline that we received their inputs before the end of milk quotas. After agreeing on the drivers of change, participants answered questions using a 6 likert scale, from 0 meaning null, 1 for very low, up to 5 for very high. The median scores of the final round determined the results for each driver of change as our distribution was not symmetric [43]. Hence, we refined during two rounds the inputs until we get the gist, thereby allowing us to feed our graph analysis.

3.1. Graphs G and H

In this paper, we represent the major factors that affect the milk industry and their relationships with two graphs. By analysing these graphs we give results on the relationship measures for this social network.

With this aim we first considered 14 major factors or variables that have an effect on the milk industry. These factors are given as follows (together with their abbreviations): Policy (Po), Economy (Ec), Regulation (Re), Social Framework (So), Technology (Te), Environment(En), Bargaining power of Workers (Bw), Bargaining power of Suppliers (Bs), Bargaining power of Customers (Bc), Substitutes (Su), Complementary Products (Cp), Rivalry (Ri), Health (He) and Lobbying (Lo). Explanations and motivations for choosing these factors are given in Section 3.3. By assigning a vertex for each factor we obtain a graph of size 14 and call it G.

To further our analysis by looking at a much larger data set, we detected 44 subfactors (or subvariables) affecting the milk market and constructed a second graph of size 44. Each of these subfactors fall into one of the fourteen main factors given in the previous paragraph. We call this graph H. Please refer to Table A.2 and A.3 for these subfactors, their abbreviations and a short description for each of them. The table also exemplifies each factor in the diary market. Note that the graph H contains all of the inter relations between the 44 subfactors; thus it is a weighted directed complete graph of size 44. The corresponding definitions of the graph terms are given in the next subsection. Notice that H is much more complex than G, given in Figure 2.

$[Insert Figure 2]$

Similar work has been done before for the food market through observing the underlying network by various authors. Thus, the interrelationships of climate change (environment) and population health, and their common effect on food prices in Australia was examined by Bradbear and Friel [13]. Yet, Eloffsson et. al. [20] carried out a study on the effect of the climate on the milk demand in Sweden. Note that our research is systemic and much broader in terms of the variables considered compared to these former researches.

Although graph theory has been previously chosen as a social network analysis medium, it should be emphasised that the graph theoretical approach has never been used previously for supporting strategic early warning systems.

In order to determine the edge weights we collaborated with French milk experts and prospective specialists as explained in the previous section. They provided the input (e.g. impacts and probabilities of impacts) to evaluate the environment for milk and to determine the drivers of change [6]. Their data is based on multiple surveys applied for the chosen factors for a determined period of time. Thus, although different in nature, this type of data and time series data stem from similar kinds of sources.

3.2. Graph Terms

An *edge weighted directed graph* is a triple $G = (V, E, w)$ where V is the vertex set $V = \{v_1, v_2, \ldots, v_n\}$, E is the edge set $E = \{e_1, e_2, \ldots, e_m\}$ where each edge is an ordered pair $e_{ij} = (v_i, v_j)$. For $e_{ij} = (v_i, v_j)$, v_i is called the *initial vertex* and v_j is called the *terminal vertex*. For each edge a weight is assigned through the weight function $w : E \mapsto \mathbb{R}$ where $\mathbb{R}$ is the set of real numbers.

The *size* of a graph is the number of vertices in it. A *complete graph* of size n, denoted K_n, is a graph of size n in which all available edges exist. Thus in a $K_n = (V, E)$, we have $|V| = n$ and for each $v_i, v_j \in V$ we have $e_{ij} = (v_i, v_j) \in E$.

In an undirected graph the *degree* of a vertex is the number of edges containing that vertex. We define the *weighted indegree* (resp. *weighted outdegree*) of a vertex v as the sum of the weights of all of the edges that contain v as a terminal vertex (resp. initial vertex.)

In both of our graphs G and H the vertex v_i corresponds to the factor i, i.e. to a variable or a sub-variable. If any change in one factor, represented by v_i, affects another factor, represented by v_j, then we put a directed edge $e = (v_i, v_j)$ with the terminal vertex being v_j. Each edge $e_{i,j} = (v_i, v_j)$ has a weight w_{ij}. The weight w_{ij} corresponds to the impact of the factor v_i on the factor v_j where w_{ij} is from the set $\{0, 1, \ldots, 5\}$. Here a weight of 1 corresponds to a very minor effect; a weight of 5 corresponds to a very major effect and the other weights are distributed according to the level of inter dependence. In case of no effect, the weight is assumed to be zero.

A *clique* of size k in a graph $G = (V, E)$ is a subset of k vertices where these vertices induce a complete graph in G. We define a *weighted clique of size k with weight h* in a weighted graph $G = (V, E, w)$ as a clique of size k, $C_k = \{u_1, u_2, \ldots, u_k\} \subset V$, for which the sum of the weights of the related edges, $e_{i,j} = (u_i, u_j)$, where $u_i, u_j \in C_k$, is equal to h.

For a fixed clique size k, assume that the maximum total edge weights over all cliques is T. We define a *large clique* as a weighted clique with weight at least $0.8T$. Similarly, a weighted clique with weight at most $0.2T$ is called a *small clique*.

3.3. Data for the Graph G

Now, let us provide a brief discussion of why we choose the mentioned factors to represent the milk market. First, we used the 7 forces of Author [6] to evaluate the micro environment. These are the indicators based on the prominent 5 forces of Porter [49] to which were added two new forces (*Bw and Cp*):

- The rivalry between established firms (*Ri*)
- The barriers to enter the market
- The products / services / technologies of substitution (*Su*)

- The bargaining power of customers (Bc)
- The bargaining power of suppliers (Bs)
- The bargaining power of skilled workers (Bw)
- The complementary products (Cp)(e.g. they are sold separately but are used together).

Indeed, there is an increasingly competitive landscape for recruiting and retaining talented employees [41]. Concerning complementary products, it is in line with the fact that they constitute a major factor of products, services and technologies dominance [56]. The French milk experts agreed on the fact that only the barriers to enter the market (from the 7 forces) are not a variable for milk in the coming years, as they will continue to be high [16]. Therefore, from the micro environment we consider 6 variables.

Secondly, to understand the macro environmental changes, the well known PESTEL analysis [36] was used and adapted to the milk sector by Author et al. [8] to uncover 2 new important factors for this sector, Lobbying and Health, to become PLESHTEL.

- Political factors (Po): These refer to government policy such as the degree of intervention in the economy, governments attitude and tax policies.
- Lobbying factors (Lo): some groups defend specific interest (producers, green party, consumers) and intervene with decision makers in order to influence the decision in their favour. Thus, lobbying is very important in agriculture and especially in the EU.
- Economic factors (Ec): These deal with for example economic growth, credit accessibility, interest rates and inflation.
- Social factors (So): These are concerned with changes in social trends and lifestyle, population demographics (e.g. ageing population), distribution of wealth and educational levels among others.
- Health factors (He): These are concerned with human and animal health. In the case of milk, 'Bovine spongiform encephalopathy', for instance, commonly named 'the mad cow' disease can deeply impact the milk market. Likewise, listeria can contaminate non pasteurised milk products (e.g. milk, cheese) and infect people.
- Technological factors (Te): These are about the pace of technological innovations and obsolescence, new technological platforms and the importance of technology in the market.
- Environmental factors (En): These deal with recycling, air and water pollution, popular attitudes towards the environment among others.

- Legal factors (*Le*): these are related to the legal environment in which the company operates such as employment regulations, Intellectual Property regulations, health and safety regulations and product/service regulations.

Therefore, we obtain 14 drivers of change, by combining the 6 drivers of change from the micro environment and 8 from the macro environment. These drivers of change are the base to build scenarios [59, 63]. Therefore, our graph of size 14 is a "multidimensional model that interrelates forces which are technological, social, political, even cultural, along with the economics" [57, p.198].

Thereafter, graph theory was applied to the evaluated change drivers to enhance the major factors that affect the milk industry and their relationships.

4. Results and Discussion

4.1. Graph Measures for G

In this part, we provide several measures related to graph G and comment on each of these measures as a foresighting term in the context of the milk market.

In order to measure the extent to which the chosen factors for the milk market are connected among themselves, we first calculate the density D of this network given by the following formula :

$$D = \frac{\Sigma_{i=1,j=1,i\neq j}^{n} w_{ij}}{n(n-1)}$$

Applying this to our graph G, the density is found to be 2.12 which is in the interval $(2, 3)$. This implies that overall the factors are fairly evenly chosen. Thus, this shows that the factors in the graph have tight relationships. Furthermore, it implies that a collection of these factors will have a major effect on the milk industry and that the chosen factors represent the milk industry well [66].

The major centrality measure in a directed edge weighted graph is given by nodal indegrees and nodal outdegrees. For a better analysis of the graph model, we calculated the nodal degrees using the summation method and the average method; and compared the corresponding results. According to the summation method, *En* (with a sum of 38), *Te* (sum of 35), and *Bc* (sum of 34) have the highest nodal outdegrees, in the given order, followed by *Ec* (sum of 30) and by *Ri* (sum of 29). This shows that these three factors (*En*, *Te*, and *Bc*) have the largest major effect on the other factors; meaning that a change in any one of them will affect the milk industry more drastically than the other factors.

In the average method, one calculates the mean value of the edge weights different from zero. When the average method is used, we see that the top 3 major factors remain the same (with a decreasing order now for *En, Bc*, and *Te*), and they are followed by *Bs*. This match between the summation method and the average method is another indicator of the graph G being balanced, and hence the model representing the market.

Let us comment briefly on these indicators. The environmental constraints, due for example to periods of draught (e.g. summer 2003 in France) have the greatest impact on the other factors of the market. This is followed by technological innovations such as improvements in cows, new robots used to milk cows, and the ability for customers to easily shift to other milk producers. Furthermore, it is worth underlining that milk can easily be transformed into powder, allowing it to be conserved for several years and also to be carried easily. Dairies can make their products with milk coming from various and remote places, which reinforces competition between milk producers.

As far as nodal indegrees are concerned, according to the summation method *Ri* (sum of 38) has the maximum value followed by *Te* (sum of 31) and *En* (sum of 28). Thus, the summation method captures *Ri* as the recipient of the most attraction with varying intensities, thus, ranking *Ri* as "the most popular" factor. On the other hand, when the average method is used *Ri* (followed by *Te*) still remains the highest but *Lo* is the third largest factor in terms of indegrees. Thus, *Lo* has more intensive ties than *En* with the other factors affecting the milk industry. Thereby, we uncover *Lo* as a strong factor in the milk market as it is highly impacted by changes of other variables.

It is worth noting that according to both of the methods, *Bw* has the lowest indegree and the lowest outdegree. This implies that the bargaining power of workers is very weak compared to all of the other factors and thus, it should be strengthened in order to have a more balanced milk network. We therefore observe that the war for talent [41] has not occurred yet in this market.

Hence, the most dominant variable (i.e. the one that has the highest impact on the others) is *En* since it has the highest outdegree; and the most popular (i.e. the variable that is affected the most from the others) is *Ri* as it has the highest indegree. Furthermore, we see through the nodal indegree and nodal outdegree calculations, that any change in the mentioned impacting factors above can trigger a scenario with a positive or a negative outcome, depending on the nature of its impact.

4.2. Weighted Cliques of H

Further analysis is carried out by looking at the weighted cliques of H. Looking at paired relations (i.e. the edge weights) corresponds to examining cliques of size two. In the coming parts, we look at cliques of size three, whose number is cubic in n, the number of vertices. In total there are $\binom{n}{3}$ cliques which is approximately n^3 in a complete graph of size n. Notice that as we increase the clique size, the problem may become computationally hard (further depending on n). In this paper, we examine the next larger clique size, 3, which is a tractable clique size and gives a wide range of information to be used in the SEWS model. We wrote a code in MATLAB to detect the set of large cliques and the set of small cliques.

From now on since we only consider cliques of size 3, for ease of understanding, instead of *weighted clique of size* 3 *with large (resp. small) total weight*, we will use the term *large (resp. small) clique.*

4.2.1. Weighted Cliques of Large Weight

Knowing the large cliques of the graph H will give crucial information about the firmness of ties between a given subset of factors. A solution to this problem for a fixed number of factors, would reveal the location of the strength of this social network. We can use this information in the SEWS model as follows: If we detect any change in a factor whose corresponding vertex is contained in a large clique, then we know that, automatically, all factors in this clique will be fundamentally affected and therefore must be emphasised in the early warning system that will be generated.

For this end, we reduce the directed graph H into an undirected graph where the edge e_{ij} will have weight $w_{ij} + w_{ji}$. By making this reduction, although we lose directional relations, it allows us to do analysis concerning weighted cliques. Given a graph G and an integer k it is NP-complete to find a clique of size k and of maximum total edge weight. Thus, this problem is computationally hard. On the other hand, since the sizes of our graphs G and H are not too large, we can calculate the large (or small) cliques in linear amount of time.

In our present case, the maximum clique is formed by the following factors: Lobbying from dairies (*Ld*), Breeder organisation (*Bo*) and Strategies of Dairies (*Sd*) with a total weight of 30. The next two cliques of large total weight are: Lobbying from milk professional organisations (*LmP*), Relationships of farmers and Dairies (*RfD*) and Breeder organisation (*Bo*) with a total weight of 29; and Quality premiums (*Qp*), Relationships of Farmers and Dairies (*RfD*) and Strategies of the Dairies (*Sd*) with a total weight of 27. Please refer to Table A.4 for more information on cliques of large (and small) weight.

Notice the re-occurrence of the factors *RfD, Bo* and *Sd* in the totality of these cliques. Thus, any change in one component of these cliques will automatically and deeply affect the others which constitute key uncertainties.

$[Insert Figure 3]$

4.2.2. Weighted Cliques of Small Weight

Detecting the factors which are minimally affecting each other gives rise to another type of data to be used in a strategic early warning system. For this purpose we observe the cliques with small weight.

The minimum weighted clique is formed by the following factors: Common agricultural policy (*CaP*), packaging innovation (*Pi*) and demand for cosmetics (*DfC*). This clique has zero total weight showing that these factors are in fact independent of each other: none of them are affected by any change in the others. This is the only such clique among the set of all cliques.

CaP plays an even role in the milk industry in terms of affecting the others and being affected by others. This is evident from the fact that its indegree and outdegree, in H, are equal. This common sum is 74 which implies that, overall, *CaP* has an upper medium role in our network which consists of 44 variables. When we look at the small cliques of the graph H, we observe that *CaP* is included as a vertex in each of the ten of these least weighted cliques. This is a sign indicating that the policy makers (e.g. the government of each EU country and the European Union Commission) do not plan to have an important role in the milk industry and let the rules of the market rage as seen following the end of the quotas in April 2015.

A second such observation is done on the factor *Qp*: quality premiums. *Qp* is included in the three of the four smallest weighted cliques. Hence, combining this with the previous observation, one can say that under politics, the factors *CaP* and *Qp* are the two factors that must be noted as a target field to be re-discovered as after all, "you are only as strong as your weakest link". Furthermore, the fact that *Qp* is weak indicates that the trend of the market is towards high volume, thus permitting economies of scale which lower the milk price production; then the target is to maximise profits rather than high quality. This is congruent with the fact that Germans apply the same rules of industry to the agriculture sector and are currently becoming increasingly competitive in the EU (on average) compared for instance to French farmers [29].

4.3. Potential impacting scenarios

We have determined in the former graph analysis that environment (*En*), technology (*Te*), bargaining power of consumers (*Bc*), Economy (*Ri*) and Rivalry (*Ri*) are the five variables with the most impact on the others. Yet, we determined that Rivalry, Technology, Environment and Economy are the most sensitive variables to others' changes. Furthermore, we provided five cliques of large weight in which we noticed the recurrence of the three following factors: strategies of Dairies (*Sd*), Relationships of farmers and Dairies (*RfD*) and Breeder organisation (*Bo*). Yet, *RfD* and *Bo* are subfactors of *Bc*; *Sd* is a subfactor of *Ri*.

Among the five most impacting variables, only technology can always have only a positive impact as others can both impact positively and negatively the milk producers.

Thus, based on the five most impacting variables (which are also the most impacted by others except *Bc*) and cliques (of which we only consider the three most influencing ones), and drawing on Shoemaker's recommendation [57] as initial step (and as example for our case study), we build one pessimistic and one optimistic scenario for the French milk producers.

A pessimistic scenario: Environment as a negative trigger on clique (Sd), (RfD), (Qp)

The long period of draught in France (*Ch*) diminishes the available volume of fodder, compelling breeders to import it at high price. Therefore, dairies in France decide to buy milk powder from Poland (*Sd*) where the weather is more humid and the milk price is lower than in France. Thereafter, this milk powder is transformed again to liquid by adding water on site. Automatically, this impacts negatively on the relationship with French farmers (*RfD*) and quality premium (*Qp*) as the milk product made using milk powder can not be of the same quality as fresh milk.

An optimistic scenario: Rivalry as a positive trigger on clique (Sd), (RfD), (Qp)

As globalisation is raging, the strategy of dairies (*Sd*) is to make economies of scale to decrease the costs and make higher profits. Thus, dairies in France decide to invest more in the west of France where there is a high concentration of cows and milk expertise. Indeed, the west of France represents 43.7/100 of the French milk production [44]. Thereby, they get excellent input and can optimise the supply chain. This impacts positively on the relationship with French farmers (*RfD*) and also encourages a quality premium (*Qp*) since these regions benefit from plenty of controlled designations of origin (e.g. cheese). Therefore, in addition to aiming to lower the costs, they aim to improve the quality of their products, to diversify their targeted markets and to obtain higher competitive advantages.

Hence, by scanning its environment based on the model constructed, an organisation in this market will be able to detect early warnings using the proposed graph analysis. This will allow the organisation to anticipate opportunities and/or threats.

This graph analysis will require updates as new inputs will be provided (e.g. new impact of a sub factor).

5. Conclusion

In this paper, we look at the graph representing the milk industry and provide several network measures. These measures indicate a factor's level of involvement in network activities and thus they provide crucial information about the interpretation of the SEWS model. Thereby, whenever a scanning system detects some changes in the milk environment, one can anticipate the coming scenario or at least react very quickly, and therefore act to optimise its actions and avoid issues (as much as possible) or seize opportunities before competitors. Hence, graph analysis can help to better foresee the scenarios of markets in the frame of SEWS.

In a weighted graph representing a social network, large cliques show high level of reachability which is an important issue in terms of communication. In case of an emergency, it is vital to spread the information as fast as possible. Thus, it is sensible that the sectors that are represented by vertices in the large cliques be warned in the first place.

Obviously, the factors and the subfactors to construct the model, as well as their impacts and probabilities must be updated, whenever the structure in charge of the SEWS (most of the time the competitive intelligence department) detects changes, and new graph analysis must be undertaken to create robust scenarios. Indeed, "our forecasts about the future reflect our present level of knowledge and our present feeling for the relevance of problems. Efforts to forecast future developments, therefore, reveal relatively little about the future, but very much about our understanding of the present". [47, p.315].

It is evident that, the method constructed in this paper is congruent with the demand for better tools of governance for the milk market which is strategic for the EU and for France [22]. One can understand that EU policy makers want to keep distance from the agricultural market, thereby the *CaP* will keep being more market oriented [38] as for instance, it is foreseen that quotas end as well for sugar in 2017. Therefore, such policies require advanced decision tools to be able to keep under control these markets.

Being a complex network, the milk industry is affected by many other factors that are not present here. On the other hand, we see that our model allows to uncover many previously unnoticed bonds (In section 4). Environment is the most impacting variable on all the others for the milk market followed by technology. Thus, policy makers should take all the necessary measures to fight against global warming and increase the research and development (e.g. genetics and robotics). In addition, the fact that *Qp* is the weaker with *CaP* underlines that high volume production is targeted rather than quality. In such a context, it is obvious that only big milk producers will be able to survive in the long run.

This work can be replicated with other agricultural commodities (e.g. wheat), other economic sectors and any economic region. Thus, in addition to being the first SEWS model based on graph theory, this paper has also important managerial implications.

It would be quite interesting to utilise this SEWS model for the milk sector in the EU. To this end, the model could be reinforced by getting the input of more than 7 milk experts from various countries. Moreover, a longitudinal study could allow a simulation of the decisions relevance through the constructed SEWS. Thereby, this SEWS model could be the foundation of an ambitious EU project aiming to address the upheaval in the milk market as well in the whole of agriculture. Such a project could be adapted to other economic sectors which also face strong turbulence and high discontinuities.

When the system under consideration is much larger, $n \gg 46$, the weighted subclique problem becomes computationally hard. In this case, for future work, heuristics algorithms need to be investigated to provide an approximate answer to the maximum weighted subclique problem. This will result in a better analysis of the graph which in turn leads to a better understanding of the industry under consideration. Further analysis can be done by looking at the betweenness measures defined for edge weighted graphs [24] and geodesic distances [73].

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Strategic Early Warning System for the French milk market: A graph theoretical approach to foresee volatility

1. Appendix

[Table A.1 about here.]

[Table A.2 about here.]

[Table A.3 about here.]

5 [Table A.4 about here.]

Table 1: Profiles of Experts. We were required to keep their organisation confidential.

Name	Degree	Years of Experience
Frank	M.Sc. Economics	20
Pierre	B.A. Economics	30
Vincent	Ph. D. Economics	15
Caroline	M. Sc. Agriculture	10
Gaelle	M. Sc. Agriculture	15
Jose	Ph. D. Agriculture	10
Marius	B. A. Agriculture	25

Table 2: The subvariables Part 1.

Number	Name	Abbreviation	Explanation
1	Common Agricultural Policy	CaP	Common Subisidies for EU members
2	Strategy of EU countries	SeC	National strategy to promote big farms
3	Tariffs	T	A tax imposed on imported milk goods
4	Quality Premiums	Qp	Grants to encourage producers towards higher quality milk such as having low somatic cell count
5	Strategy of Non-EU countries	SneC	Examples of subsidies given to export milk
6	Global Demand	Gd	Examples of Chinese demand for powdered milk
7	EU Demand	Ed	Demand from EU members for butter
8	French Demand	Fd	National demand for cheese
9	Margins between Agricultural Production	MaP	If wheat margin is much higher, some producers might stop the milk production to shift to the production of wheat
10	Parity Euro and other Currencies	PeC	If Euro is strong then the price of EU commodities will be higher for non EU countries. However, the price of petrol will be less high
11	Input Costs	Ic	Price of fodder increases due to scarcity
12	Ease of Access to Credit	EaC	It can help to buy robots which then increase the milk production
13	Lobbying from Non-EU Members	LneM	For instance, lobbying from the USA to support its milk products
14	Lobbying from Consumers	Lc	Consumer organisation promoting pasteurised milk
15	Lobbying from Milk Prof. Organisations	LmO	Adds on TV to consume milk and derivatives
16	Lobbying from Dairies	Ld	Adds to consumption of whole milk cheese
17	Lobbying from Ecologists	LEc	Pressure towards the EU commission to limit the number of cows since they produce methane which is a greenhouse gas
18	Animal Epidemic	Ae	Mad cow
19	Human Disease Linked to Dairy Products	HdP	Listeria due to the consumption of bad cheese
20	Law for the Protection of the Environment	LpE	The discharge of cows' effluents is highly supervised in order to limit nitrogen in the soil and water
21	Regulatory Buildings	Rb	Respect a minimum distance between breeding buildings and dwellings
22	Image of Agriculture and Breeding	IaB	Positive image of breeding
23	Dynamism of the Market	Dm	Low unemployment leading to scarcity of workers for breeders as people prefer easier jobs
24	Age of Farmers	Af	Breeders'age average is high. Therefore, there is a risk of large decrease of milk production
25	Tolerance for the Breeding Population	TbP	People can not stand smells from breeding
26	Attractiveness of Careers in Farming	AcF	Many students choose to study at farming vocational schools
27	organisational Innovation	Oi	Better time management leading to higher production

Table 3: The subvariables Part 2.

Number	Name	Abbreviation	Explanation
28	Technological Production Innovation	TpI	Creation of robots to automate the milk production
29	Genetic Innovation	Gi	Creation of new type of cows producing higher quantity of milk
30	Dairy Innovation	Di	Release of a new type of yogurt which is successful triggering higher demand for milk.
31	Other innovations	Oi	In terms of manure and other breeding effluents
32	Packaging Innovation	Pi	A new milk package which is very easy to close and open
33	Global Warming	Gw	In New-Zealand, the Ozone layer may be thinner. Therefore, people might be more sensitive to limit the concentration of cows in these areas, as they produce methane which alters the Ozone layer
34	Climatic Hazards	Ch	Draught impacts the volume of fodder
35	Bargaining Power of Suppliers	Bs	Distribution channels for dairy products
36	Relationships between farmer and Dairy	RfD	Dairy can easily get milk powder from a remote cheaper country then add water to the milk locally
37	Breeder organisations	Bo	Cooperative where breeders buy and share some materials among other
38	Products with Plants	PwP	Margarine is preferred to butter
39	Demand for Cosmetic Products	DfC	Milk used to make some creams for the skin
40	Demand for Food Intermediary Products	DiP	Cheese for pizza
41	Strategy to Attract Foreign Investment	Fi	Area with a high concentration of breeders. Local authority provides tax reduction to foreign dairies' construction
42	Strategy of the Dairies	Sd	Dairy goes to a region where there is a high concentration of cows and milk expertise.
43	Strategy for Mix Products	SmP	Breeder producing high quality milk which is bought by a famous brand for its new yogurt. Thereby, the breeder does not supply milk for industrial products and earns more money
44	Strategy for Export	SfE	Milk producers make a common offer to be able to bid in the Chinese market which is huge

Table 4: Five cliques with decreasing weight starting with the maximum clique; and five cliques with increasing weight starting with the minimum clique.

Type	Subvariables (Abbreviations and Numbers)	Total Sum
Cliques of Large Weight	$Ld, Bo, Sd(16, 37, 42)$	30
	$LmO, RfD, Bo(15, 36, 37)$	29
	$Qp, RfD, Sd(4, 36, 42)$	27
	$CaP, RfD, Bo(1, 36, 37)$	26
	$CaP, SeC, Bo(1, 2, 37)$	24
Cliques of Small Weight	$CaP, Pi, DfC(1, 32, 39)$	0
	$CaP, Qp, Pi(1, 4, 32)$	1
	$CaP, Qp, TbP(1, 4, 25)$	2
	$CaP, Qp, Lc(1, 4, 14)$	3
	$CaP, T, DfC(1, 3, 39)$	5

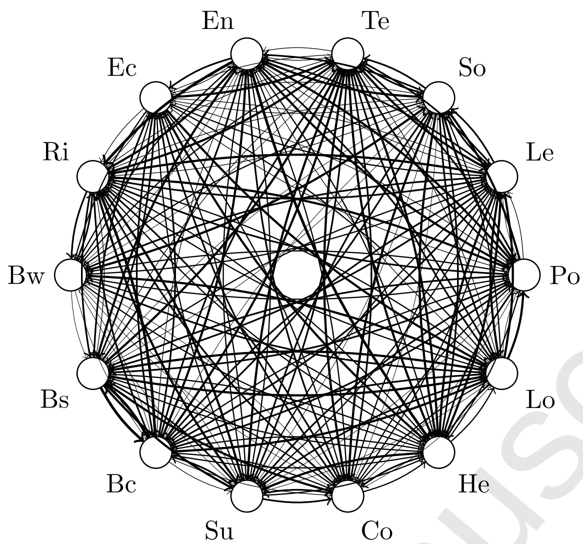

Figure 1: The graph G. The thickness of the directed edge $e = v_i, v_j$ represents the impact of the variable v_i on the variable v_j. The thickest edge has weight 5 and other the edges have thickness accordingly.

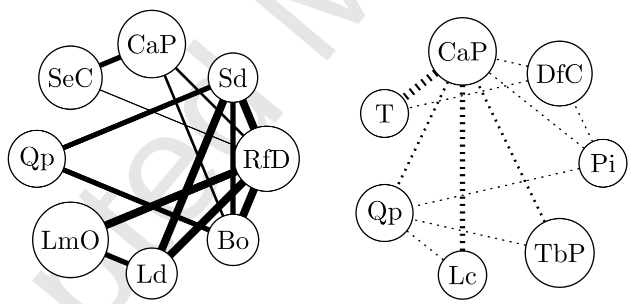

Figure 2: Subgraphs corresponding to the five largest cliques (on the left) and five smallest cliques (on the right). The thickness of each edge represents the total bidirectional edge weight in the graph H.

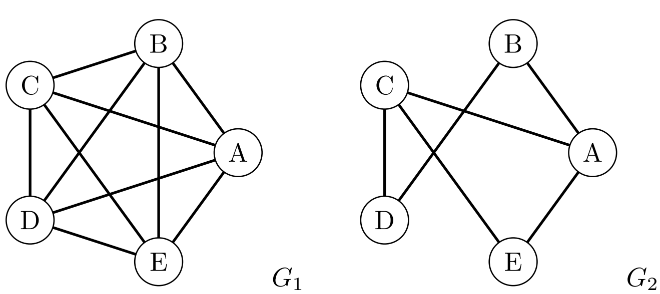

Figure 3: Graphs G_1 and G_2

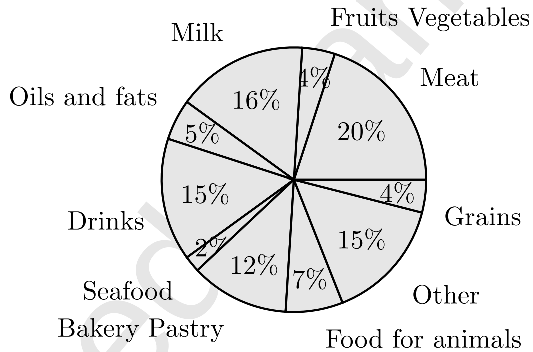

Figure 4: Shares in French agri-food industry