Vertical Coordination Mechanisms in a Cobweb Economy: A System Dynamics Model of the Champagne Industry

Francis Declerck, Ph.D.
Associate Professor, Department of Finance and ESSEC-IMIA
ESSEC Business School
B.P. 50105
95021 Cergy-Pontoise Cedex - France
Tel. 33 1.34.43.32.66 Fax. 33 1.34.43.32.12
E-mail: declerck@essec.fr

L. Martin Cloutier, Ph.D.
Department of Management and Technology
School of Management
University of Quebec at Montreal
P.O. Box 6192, Downtown Station
Montreal, QC H3C 4R2 Canada
Tel.: (514) 987-3000, ext. 3732#
Fax.: (514) 987-3343
E-mail: cloutier.martin@uqam.ca

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We have modeled vertical coordination in a cobweb economy in order to forecast economic agents' decisions along processing chains when they transfer product and negotiate volumes and prices.

The model is applied to the Champagne industry. Grape producers and wine makers coordinate grape production and trade by forming expectations about final consumption, price and stock risks. The coordination mechanisms involve long feedback due to the 3 year wine process. A nonlinear and dynamic system dynamics model is used to simulate short and long term production of Champagne with lagged supply adjustments.

Simulation results are crucial for stakeholders since the area under Champagne protected designation of origin has reached its legal size limit.

Short Title: Vertical coordination mechanisms in a cobweb of strategic relationships

Keywords: vertical coordination, system dynamics, price expectations, Champagne wine.

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The system dynamics modeling of key stock-and-flow relationships within an industry, and their effects on the short-term and long-term supply response, in face of a growing demand, provide insights that help explain past economic cycles and contribute to apprehend the causes of future ones within an industry. In modeling key variables underlying the vertical informational dependencies amongst the actors of an industry, and taking time delays into account, it is possible to interpret underlying behavioral dynamics within a given economic environment, set of resources, and decision rules embedded in institutions. The goal of the system dynamics (SD) model introduced in this paper is to show how the microstructure of an extended organization can explain its macrobehavior (Sterman, 2001). Analogous to prototypes designed by engineers, SD models often are used to evaluate the repercussions of the structure that generates dynamic behavior over time (Cloutier and Rowley, 2003; Crossland and Smith, 2002).

This paper examines the dynamics of vertical coordination in the Champagne industry using system dynamics modeling. It takes about three years to produce Champagne from raw grapes. Champagne makers face price risks and uncertainty when buying grapes, the most important input in that process. Furthermore, wine must also be produced within the protected designation of origin (PDO) area according to specific rules. The cycling adjustments of supply to demand lead to jumps and drops in retail prices, during economic booms and busts, respectively. This cobweb phenomenon at the production interface disturbs consumers and seriously affects the strategic position of vine growers and wine makers, which have typically responded by introducing, or amending, vertical coordination rules. This resource constraint will bring additional pressure into the functioning of the industry. The Champagne production model is based on the specification of vertical coordination constraints followed by economic agents (vine growers producing grapes and wine makers who buy grapes to make Champagne) in a cobweb economy (the Champagne market). A simulation model is particularly useful now because the area in PDO used for grape production is nearing saturation and additional pressure will be placed on vineyard values with the set of expected consequences on the supply response of that system.

The model can demonstrate how decision-makers and strategy researchers identify drivers and levers in the industry to manage risk and uncertainty, and to maintain the value generated by vertical coordination efforts that have evolved over time. Organizations often are subject to profound structural change and the data required to inquire about the repercussions of change over time, using classical statistical methods, actually require that the change has occurred and that it can be measured. Decision-makers often cannot afford that time, as they need to learn as they go (Roy and Dutta, 2002; Sterman, 2001). The Champagne industry case presented shows what can be accomplished with system dynamics methods. In particular, taking into account feedback loops in the modeling process would lead to the identification of leading indicators of structural performance prior to their measurement with lag indicators and the unfolding of events.

Thus, the purpose of the paper is threefold: (1) to characterize the dynamics of information coordination in a situation where the supply response contains tremendous inertia and demand is growing, while key production resources are increasingly limited, (2) to illustrate the dynamics of vertical coordination relationships between grape producers and Champagne makers, and (3) to explicitly take time lags into account in the coordination of decisions in the industry and the formation of price expectations and distribution across the value chain.

The results of the research have important implications for supplier/customer vertically coordinated systems more generally to ease their decision-making for sustaining the performance of their business system. As these systems become more tightly horizontally and vertically coordinated, more emphasis must be placed on the multifaceted understanding of the underlying causes for these cycles in connection with vertical coordination mechanisms. The illustration of this paper stress the interest in using the approach, not necessarily as a confirmatory framework, but rather to explore, and help apprehend, the unfolding of possible future outcomes.

The remainder of the paper is organized as follows. The next section presents a literature review of the concepts associated with vertical coordination and the cobweb economy, and an overview of strategic issues associated with the Champagne industry value chain. Following this, the research methods section details the model design, data sources and model calibration. Subsequently, simulation results are presented to illustrate the functioning of the model. A discussion concludes.

LITERATURE REVIEW

The literature review focuses on: (1) the vertical coordination in the theory of contracts, and transaction costs, and on (2) the examination of expectations in cobweb models used to examine the lagged supply adjustment. Following this, stylized facts about the Champagne industry is provided on: (1) the contracts, or institutional framework, between Champagne grape producers and wine makers, that set the specific legal rules of vertical coordination between the parties, with the set objective of meeting consumer demand, and (2) the Champagne market cycles caused by the short-term and the long-term lagged adjustment of Champagne grape supplied by the vine growers to Champagne makers who need three years, on average, to get the bottles to consumers.

Vertical coordination (transactions costs, theory of contracts)

To generate a sustainable competitive advantage, decision-makers achieve economic cost minimization of production and transaction costs via organizational design selection (Klein et al., 1978; Mahoney, 2004; Teece, 1984; Williamson 1975, 1985, 1991b; Milgrom and Roberts, 1992). Vertical coordination may be reached through different forms along a continuum ranging from short-term contracts to complete financial ownership, to achieve: increasing returns (Scherer and Ross, 1990), cost reduction (D'Aveni and Ravenscraft, 1994), and risk reduction (Chatterjee et al., 1992; Helfat and Teece, 1987). In a study on the food manufacturing industry, Peterson et al. (2001) suggest that the vertical coordination strategy continuum can take five major forms: spot markets, specification contracts, relationship-based alliances, equity-based alliances, and vertical integration.

Fluctuations in the upstream stages of the food processing chain induce time delays that affect the global performance of the value chain (Lee et al., 1997). Time uncertainty leads to fragmented markets vertically coordinated and favors short term tactics rather than long term strategies (Cloutier, 1999). Managers forecast consumer demand and anticipate the reaction of other suppliers to the market to adjust their own supply. Economic business fluctuations and imbalance due to external shocks are amplified by endogenous mechanisms of production and marketing, because of uncertain information and time delays in adjusting supply to demand (Ruth et al., 1998). A long term strategy is in the economic interest of agents in a given sector, from producers to consumers. A long-term strategy fosters: (a) better performance of operations, (b) stable quality standards, (c) sound financial situations and (d) risk-sharing among the different operators along the processing chain (Sterman, 2000).

Economic expectations and the 'cobweb' phenomena

The expectations held by economic agents perform a key role in shaping dynamic behavior in economics and finance. They affect outcomes and further influence expectations through assimilated learning and feedback. The role of expectations is crucial in speculative markets such as the one of the Champagne grape. Due to grape annual production and the time required for wine maturing, markets operate from year to year. But long-term investments in productive assets create a lagged supply adjustment to demand. Ezekiel (1938) describes the 'cobweb' phenomena, with the introduction of a theorem to explain how supply reacts to the lagged price, and the demand adjusts to the current price. Nerlove (1958) observes adaptive expectations for the cobweb phenomena. Cobweb strategy experiments have been used by researchers interested in the formation of expectations and of their impacts. Subjects in experiments formulate a complete strategy with price forecasts for all possible states of the world. From period-to-period, experiment subjects may learn the market supply and demand from past period experience and begin to form expectations (Sterman, 1988, 1989).

Since the effort by Muth (1961), the Rational Expectations Hypothesis (REH) was introduced to generate estimates to explain price and production cycle induced by the cobweb phenomena. A unique equilibrium is formed at a steady-state price where demand and supply meet, even when demand and supply are unknown and agents only observe past prices. But Cuthberston (1996) found the existence of multiple rational expectations equilibria in the form of 'speculative bubble solutions'.

Two major limitations have been formulated against the REH: (1) it seems unrealistic to assume that agents have perfect knowledge of underlying market equilibrium equations, and more simply to assume they derive expectations from time series observations (Sargent, 1993), and also (2) it seems out of reach to suppose that agents have perfect knowledge about the beliefs of all other agents in the market (Schmalensee, 1976). Several authors have investigated alternative schemes with heterogeneous naive or adaptive expectations for agents in different evolutionary dynamic markets for the cobweb model. In such a model with nonlinear but monotonic demand and supply curves, adaptive expectations with a finite past, also called fading memory learning scheme with a constant gain factor, may lead to higher order stable periodic cycles or even chaotic price fluctuations (Chiarella, 1988).

Within a cobweb economy, Brock and Hommes (1997, 1998) and Hommes (1998) show that evolutionary competition between heterogeneous forecasting rules can destabilize the rational expectations steady-state and lead to periodic, or chaotic, price fluctuations. Following Sterman (1988, 1989), Hommes et al. (2000), Sonnemans et al. (2004), and Colucci and Valori (in press) examine feedback in agents' expectations by introducing alternative learning rules to understand actual human behavior in experiments on expectation formation in a cobweb economy. These experiments have shown that prices do not converge to a unique rational expectations steady-state, but fluctuate irregularly around an unstable state. They tested of how decision-makers forecast the future in situations of knowledge scarcity, how the economic environment works, but there is a strong feedback of their predictions and decisions on the observed state. The conclusion is that decision-makers may have a strong ability to understand the impact of their expectation feedbacks. Agents form expectations repeatedly and have ample opportunity to learn and change their expectation, strategy and behavior.

Vertical coordination between grape producers and Champagne makers

On the supply side, much prior to market constraint arising from consumer demand, the Champagne industry must comply with the legal restrictions on materials, method and location, concerning both quantity and quality. Champagne grapes must be harvested from a strictly defined production area termed Protected Designation of Origin (PDO) with specific technological and agronomic requirements, including the variety of vines grown, manual-only harvest, maximum authorized yield, etc. But weather fluctuation is a risk factor affecting the production of grapes at certain critical stages. For example, spring frost can damage buds and the lack of sunlight can alter the ripening of grapes.

The principal features of the Champagne market include barriers to entry and exit, technological and storage constraints. Specific barriers to entry are related to PDO rules, the three-year processing time from the grape harvest to the sale of bottles. These characteristics induce specific technological constraints, and the storage of a little over one billion bottles aging in cellars must be financed. The specificity of the product and the management of information about the balancing of its relative scarcity in supply, and growing worldwide demand trends overtime, contribute to the preservation of its value. Because it takes about three years from the grape harvest until ready-to-drink Champagne bottles can be sold, Champagne makers face market risk and uncertainty when buying grapes.

Within the industry, Champagne makers only own 10% of the vineyards but they sell 66% of the bottles. To fill the procurement gap, grapes are purchased from grape growers and grape growers cooperatives. Optimal procurement and inventory policies have been detailed and examined by Gaucher et al. (2000). Further, Gaucher et al. (2002) have analyzed quality incentives and supply contracts in chains of bulk wines. Giraud-Héraud et al. (2003) have examined the legitimacy of supply regulation mechanisms for PDO products in a collective approach as in the present research work. They argue that such mechanisms reduce uncertainty, thus encouraging investment in product quality improvement. Declerck (2004) shows that Champagne makers operating profit depends on selected distribution networks, which affect retail prices.

Champagne prices are obviously at the center of the relationship between vine growers and wine makers. Wine makers fear more repercussions from end-consumers if prices are not managed. To regulate both grape and wine prices at various stages, and procurements according to different vintages, representatives of grape producers and wine-makers negotiate every September, prior to harvest, within the context of an interprofessional committee, the *Comité Interprofessionnel du Vin de Champagne* (CIVC). These agreements are subject to an authorization by the French Government within the framework of the EU regulations.

From 1959 to 1990, a contract governed all prices for grapes and also the allocation of stocks to wine-makers; that is, vertical coordination linkages between grape producers and Champagne makers were rigid. Two major setbacks challenged this arrangement. First, ‘required’ prices were not maintained when shortages of grapes were expected. Second, insufficient grape procurement during growing seasons 1989-1990 fostered an active and disproportionate speculative market for the maturing wine. Shipments of wine increased while Champagne makers coordinated with grape producers who sought to limit supply. Producers attempted to forward integrate to capture part of the increased value added. In particular, access was sought to a parallel market for maturing wine, and encouraged by higher prices for wine and the apparent ease of marketing bottled products, integrated forward into bottling and distribution.

Inevitably, the prior arrangement collapsed and was replaced in April 1990 by a more flexible coordination mechanism with fewer restrictions, similar to the ones found in other French wine industries. Some supply smoothing over time has been anticipated since 1992 by a simple mechanism through which qualitative reserves of Champagne from good quality vintages are stocked in anticipation of poor harvest years (for example, when frosts cause difficulties), and then make up the yield to the legal limit. Since 1990, grape prices were set in private bargaining between grape producers and wine-makers, and thus were susceptible to expectations in supply and demand. However, prior to harvest, the CIVC proposes an indicative price. Three constraints persisted: (a) harvests were limited to 15 days, (b) vineyards could not extend beyond the 35,155 hectares of the protected designated area of origin set in 1927, and (c) grape yields cannot exceed the 13,000 kg per hectare.

The grape market consisted of about 18,000 sellers and 200 buyers in 1,200 locations. Persistence with an indicative price was motivated by three basic concerns: (a) allow a ‘proper’ allocation of value added between producers and buyers of grapes, (b) facilitate equal (competitive) access in grape procurement, while respecting the diversity and variety of participants, and (c) moderate swings in prices in consumer markets and thus avoid excesses that might threaten the fragile supply chain. After 2000, the indicative price was abandoned in accordance with competition rules within the EU.

In recent years, four-fifths of grape purchases have been conducted using individual contracts, and the remaining purchases occur on the spot market at the time of harvest. A typical four-year contract enables undersigned producers a priority access to grapes at a price of about 35% of the final bottled price sold by wine makers. The market remains loosely oligopolistic since six major wine makers purchase about 60% of grapes. Transactional transparency is strongly fostered by a notification system, in which the CIVC receives information on the volumes and prices set for each transaction in the market: the names of the sellers and buyers, prices, quantities, and villages are documented. Further, the average price per village (also referred to as “cru”) is computed, updated daily and publicly available in real-time, subject to adjustment until final purchase prices are clarified about eight months after harvest.

Consumption-Production cycle of Champagne: Stylized facts about vertical coordination

Market sales of Champagne amounted to 3,9 billion euros in 2004 (CIVC, 2005). On the demand side, shipments of bottles from wine makers to the retailers vary from year to year because of swings in economic growth in developed countries (CIVC, 1992 - 2004). The question of market access (due to the product’s alcohol content) and high volumes demanded by the six major supermarket operators in France requiring constant quality and tastes may be a strong barrier to entry and exit (cost of being unlisted leading to high amounts of unsold bottles). Further, swings in economic growth in Europe and North America affect consumer demand, and therefore the annual shipments of bottles from wine makers to the retailers. Often, a drop in Champagne sales occurs three or four years after an economic boom, when the grapes used to make the bottles on sale were purchased at a peak price because wine makers and vine growers expected ongoing expansion. Consequently, wine makers’ profits may fluctuate a lot from year to year (Declerck, 2004, 2005).

On the supply side, decisions about the area of production and authorized yields, together with short-term adjustments to demand pressures by principal wine makers, seem to lead to a cobweb phenomenon. As seen on figure 1, over the past three decades, one can observe that patterns of consumption have exhibited three asymmetric production cycles with peaks of sales, and price per bottle in 1979, 1989 and 1999, while sales and prices lows, following these peaks, occur following a three-year time lag (Declerck, 2004, 2005).

In 1982, 1992 and 2001, the industry faced a lower selling price and high production costs for bottles elaborated with grapes harvested three years earlier, and purchased at a historic high price when the consumer demand for Champagne was high. Following each cycle, the mechanisms of vertical coordination in place to mitigate temporal uncertainty and financial risks, mostly associated with the storage of bottles, were not sufficient to adjust to short-term pressures in demand, and were amended.

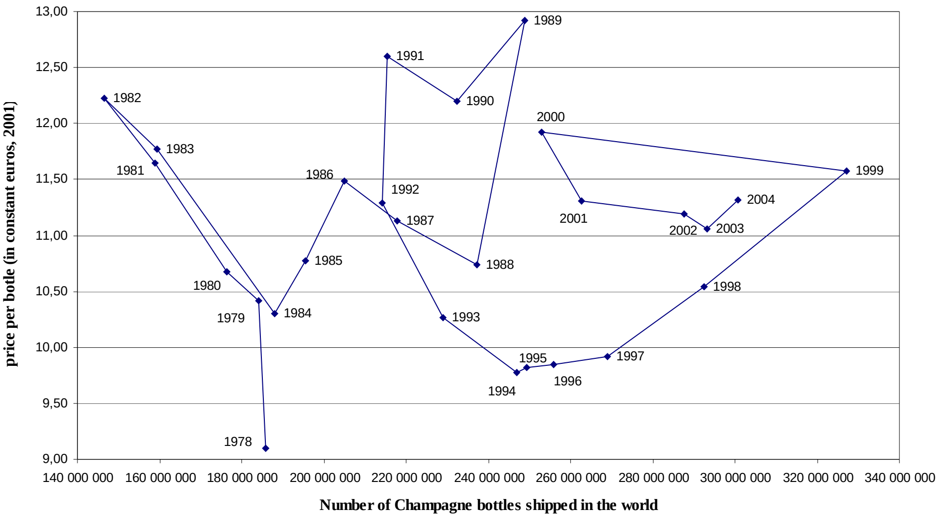


Figure 1. Cycle of world shipments of Champagne bottles versus the price per bottle (in constant euros), 1978 - 2004 (Source: Declerck, 2005)

Over the 1978 to 2004 period, the average unit price per bottle, expressed in constant terms, has remained somewhat unchanged. Meanwhile global shipments have nearly doubled from about 150 million bottles in the late 1970s to about 300 million bottles in the early 2000s. On average, this represents a 3% growth per year in demand. Productive capacity has doubled due to two factors: (a) the increased yields per hectare following the introduction of herbicides, fungicides and pesticides, leading to short-term decisions of increasing the authorized yield per hectare, and (b) the long term factor of extending the vineyard in production. But, the area in vineyard is reaching the Champagne PDO size limit established in 1927. Clearly the rigid geographical constraints impinge on real-estate prices in PDO areas, and thus, this is expected to put an upward pressure on the price of grapes and bottles (Declerck, 2004).

The Champagne industry current stakeholders (vine growers, wine makers, policy makers) have management over the course of several decades, cobweb cycles through the introduction of alternative and evolving vertical coordination mechanisms to avoid strong price swings that my affect their profitability and bankruptcy risk.

MODELING VERTICAL COORDINATION IN THE CHAMPAGNE INDUSTRY

System dynamics models have been employed to inquire about dynamic commodity and price cycles (Meadows, 1970; Sterman, 2000). In the model presented below, the supply response and demand relationships have been modeled using historical data fits. The interest in using this approach is to anticipate how events may unfold in the future, and not to predict the future.

Research methods

Grape producers and Champagne winemakers design and implement their respective strategies to reduce risk and increase operational efficiency. They identify vertical coordination mechanisms and discover means of interaction to manage the determinants of product, financial, and information stock-and-flow fluctuations through time. The principles of system dynamics (SD) support empirical work by modeling the material, financial/economic and informational stock-and-flow, interactions over time (Morecroft, 1994; Sterman, 2000). In this paper, this method is employed to model the interaction among stocks of bottles of Champagne wine, flows of grapes, processing time delays due to grape production, wine aging in cellars, and information management along the Champagne wine production and processing value chain.

System dynamics model design

The objective is to design a dynamic model of the grape and Champagne production to understand the effects of time delay adjustments in supply after the occurrence of an exogenous event or shock. The model calibration process and associated estimated parameters are described in the following section.

The SD model as seen in figure 2 was designed and calibrated in Powersim©, a software dedicated to dynamic modeling and simulation, that generates results using the Euler forward integration method. The model structure is inspired from Meadows's (1970) and represents a particular type of "smooth" or regular cycle and has been applied to hog, beef, and poultry productions. SD comprises a set of principles that capture feedbacks within systems. Feedbacks loops are models within the stock-and-flow interactions of state and rate variables (Forrester, 1994; Morecroft and Sterman, 1994; Sterman, 2000). The model was designed by incorporating the major structural elements of the production and wine making structure with the appropriate time delays. The model, in mathematical form, is detailed below.

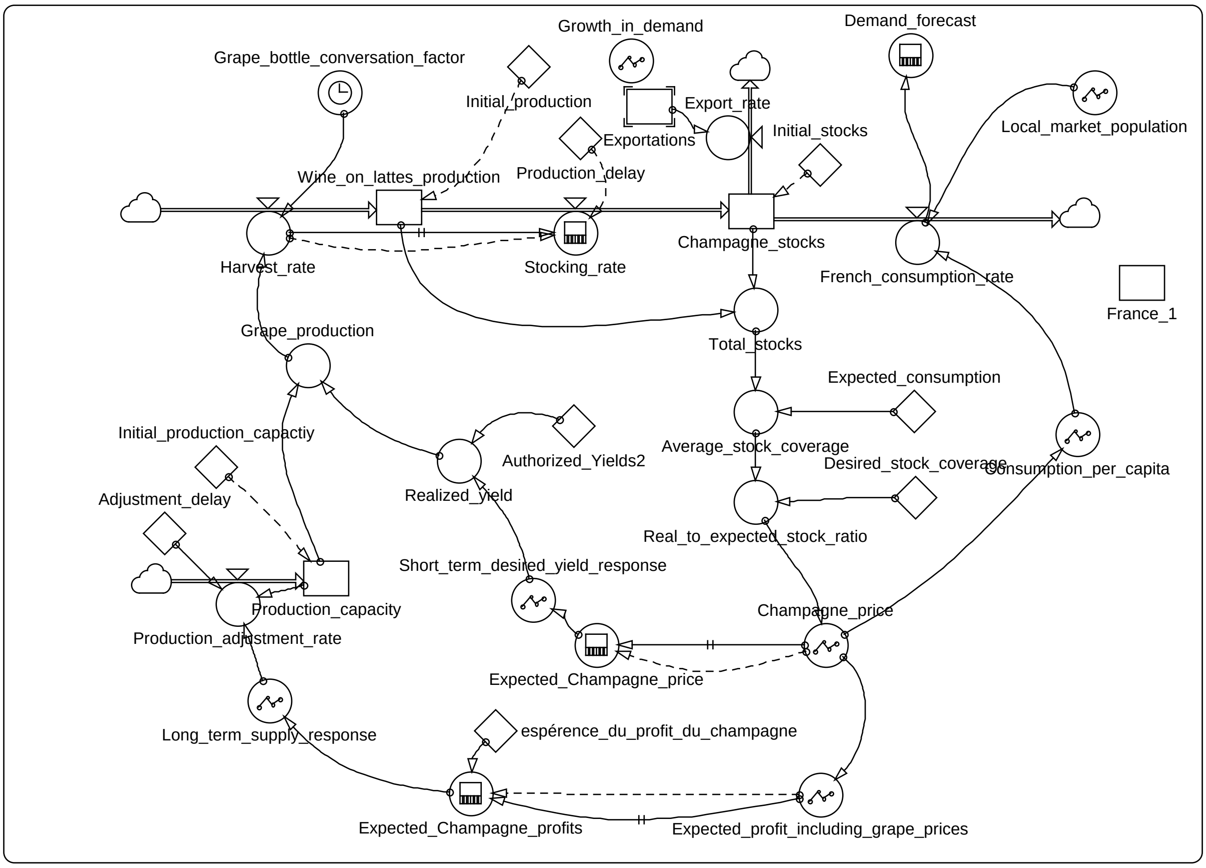


Figure 2 Model of Champagne making coordination with production

Model equations

Adjustments in the Champagne stocks state variables, denoted Φ, changes as a result of the stocking rate (r). The Champagne wine inventory is lowered by the consumption rate (c) on the local market, and by exports (x). This relationship is represented in equation (1)

(1) $$\Phi = \Phi_0 + \int_0^t (r - c - x)\,\mathrm{d}t\,.$$

Equation (2) calculates the consumption rate that results from the domestic (French) per capita consumption, denoted Λ, multiplied by the size of the local market (l),

(2) $$c = \Lambda\, l.$$

Equation (3) calculates exports as a residual of the stock of Champagne bottles minus the consumption rate multiplied by θ, a demand shock,

(3) $$x = (\Phi - c)\theta.$$

The production of wine bottles aging in cellars, denoted Γ, changes as a result of the harvest (of grapes) rate (h). After the fermentation process, that lasts typically three years, the bottles are ready for marketing and to become part of the Champagne inventory, and thus the stock of bottles aging in cellars. Those stocks are lowered by the appropriate stocking rate (r), as defined in equation 1. This relationship is represented in equation (4)

(4) $$\Gamma = \Gamma_0 + \int_0^t (h - r)\, dt$$

The time delay required for wine aging in cellars to transit from the grape harvest rate to the stocking rate of the Champagne wine stock is calculated in (5)

(5) $$\frac{d\mathrm{b}}{dt} = (\Gamma_d - \Gamma) / \beta_d$$

The grape harvest rate h, calculated in equation (6), augments the stock of wine aging in cellars and is the result of the production capacity (Ω) measured in hectares multiplied by the realized yield (γ)

(6) $$h = \Omega\gamma.$$

Fluctuations in the overall stocks of bottle aging in cellars, that is, the total stock (Σ) of bottles, influence the annual average stock coverage (v). The average stock coverage is the amount of bottles that defines the long term equilibrium with expected consumption (m). This is calculated below in equation (7)

(7) $$v = \Sigma / m.$$

A change in the average stock coverage influences the real to expected stock ratio (w). The real to expected stock ratio is calculated by dividing the average stock coverage by the desired coverage (δ) as in (8)

(8) $$w = v / \delta.$$

The average stock coverage is the variable that influences the Champagne price movements. A change, in price, influences price expectations. Wine makers' expectations are calculated with the software using an exponential smoothing function, also known as the 'adaptive' price expectation model (Arrow and Nerlove, 1958; Nerlove, 1958). This method is frequently employed in SD models to account for the time delay in the transmission of information “until persistent or stable delays are detected” (Lyneis, 1980: 435, see also Sterman, 2000). Technically, the adaptive price expectation specification assumes that recent information has more influence on the formation of price expectations than does less recent information. This is consistent with what is practiced by the agents in the industry. The time delay underlying the formation of price expectation for Champagne ($\tau = 1 / t$) is a time span that grape growers and wine makers are considering for making an adjustment production decision. As discussed previously, the formation of price expectations takes somewhere between three to four years. Thus the integral component in (9) divides the difference between the current price (P) and the exponential smoothed Champagne price in the previous period (t - 1), that is (P_0), over a time span (τ) necessary for operators to build their Champagne price expectation (EP). The adaptive price expectation for Champagne in the model is calculated as follows

$$\text{(9)} \qquad \mathrm{E}P = P_0 + \int_0^t \tau(P - P_0)\mathrm{d}t.$$

The price expectation is linked to the short term authorized yield response ($\Psi_{\mathbf{a}}$), which is in turn linked to desired production capacity, denoted (Ψ_d) (number of hectares of vineyard in production) by means of a table function. The yield obtained in the table function is the short term supply response compared by means of a logical function that selects the minimum of the two values, since authorized rates cannot be exceeded, and at times, short term compressions in yields are a possibility due to factors such as climatic conditions. This logical function is stated in (10) as follows

$$\text{(10)} \qquad \Psi = \min \left\{ \Psi_d \, , \Psi_a \right\} .$$

The long term supply response for the production capacity is the result of upward adjustments as a response to profits, denoted Π, that act as future incentives. These incentives are characterized in the model by means of a statistical estimate of profit expectations ($E\ \Pi$), taking into account the price of grapes with the appropriate time lag between the purchase and the sale of a bottle. This profit expectation is used to calculate the long term or desired supply response (Ω_{d}) by means of another table function. The expansion of vineyards in production can occur, at a very slow rate, when market growth conditions are assumed to be favorable in the long term. In the event that economic conditions take a downturn, it is fair to assume that production will continue because assets, in the form of equipment, are specific, and vineyards in production are adjusted over a long period of time. The rate by which hectares are expanded for production (z) in (11) incorporates the time delay associated with the adjustment *(*ξ_d*)* of estimated statistical fits that calculates the difference between the long-term desired PDO levels (Ω_d) and current PDO levels (Ω). The long-term supply adjustment delay (ζ_d) of PDOs, measured in hectares of vineyads, takes into account the time necessary for the decision making process associated with the determination of the appropriate adjustment, given by

(11) $$\frac{\mathrm{dz}}{\mathrm{dt}} = (\Omega_d - \Omega) / \xi_d .$$

The adjustment in the level of hectares for grape production is stated in equation (12)

(12) $$\Omega \quad = \quad \Omega_0 + \int_0^t (z - (y/t))\mathrm{dt},$$

where ξ is the adjustment in the number of hectares as calculated in (11).

Thus, the overall stocking rate (r) is calculated in (13) as follows

(13) $$r = \Omega\ \Psi .$$

The price of Champagne wine also is used to determine consumer demand with the deflated average world price using a table function. This table function is based on a statistically calibrated relationship between the price of a Champagne bottle and the per capita consumption. This table function calculates the consumption rate (c) as shown in (2).

Data sources and model calibration

The data used in the modeling process were obtained from publicly available sources (*Comité interprofessionnel du vin de Champagne* (*CIVC*), 1978-2004). The CIVC publications include time series data, technical coefficients, and industry expertise in the form of commentaries that makes explicit the industry strategy pursued in response to the economic conditions captured by the model.

There are three state variables in the model, namely Champagne stocks, production of wine aging in cellars, and production capacity. These initial levels constitute baseline figures for the model starting in 1978. Table 1 displays the variable parameter name, the value, and the reference for individual state variables, and parameters in the model.

Table 1 Model state variable for the baseline specification

Symbol	State variables	Specification	Reference
Φ	Initial Champagne stocks (M bottles / year)	190.6	CIVC
Ω	Initial production capacity (ha)	24,254	CIVC
Γ	Initial wine aging in cellars (M bottles / year)	381	Estimated

Table 2 contains the list of parameters included in the model, calibrated specifications, and sources.

Table 2 Model parameter specifications

Symbol	Parameters	Specification	Reference
γ	Realized yield (kg / ha)	See table x1	CIVC
v	Desired stock coverage (years)	3	Declerck (2004)
τ	Price expectation delay (years)	3	Calibrated
α_d	Short-term supply adjustment delay (years)	3	Declerck (2004)
β_d	Delay for the fermentation of wine	2	Calibrated
ξ_d	Long-term supply adjustment delay (years)	9	Calibrated
λ	Local population (individuals in thousands)	See table x1	EuroStat

Five table functions are specified in the model. Each table function expresses a fitted relationship. These equations and their statistical properties are summarized in Table 3. For each equation, F-statistics show that all coefficients of the independent variables are found to be significantly different than zero at the 5% level of significance or greater, using a two tailed t-test.

Table 3 – Statistical estimates of the function tables employed to calibrate the dynamic model[1]

	Dependent variables				
Independant variables	Champagne price (P)	Short term supply response (Ψ)	Expected profits (Π)	Long term supply response (Ω)	Demand (Λ)
Intercept	17.9** (5.39)[2]	-744,718.9** (254,684.9)	-9.85 (1.80)	19,847** (898,9)	5.52** (0.000)
Real to expected stock ratio (*w*)	-18,8 (18.42)				
Real to expected stock ratio squared (w^2)	16.80 (19.92)				
Real to expected stock ratio cubed (w^3)	-4,86 (6.85)				
Price of Champagne wine per bottle (*P*)					-0.280** (0.005)
Log price of Champagne wine per bottle (ln*P*)			6.64** (0.75)		
Price of Champagne wine per bottle lagged one year (P_{t-1})		195,183.2** (70,012.9)			
Price of Champagne wine per bottle lagged two years (P_{t-2})		-16,736.7** (6,381.4)			
Price of Champagne wine per bottle lagged three years (P_{t-3})		476.5** (192.8)			
Expected profits lagged by three years (Eπt-3)				6161.33** (516.7)	
F-statistic	1.85	15.76**	77.50**	142.18**	10,52**
R2	0.38	0,8	0,9	0,96	0,41
R2(adjusted)	0.17	0,75	0,8	0,93	0,37
N	13	16	21	13	17
d.f.	9	12	19	11	15

1 ** indicates significance for p < 0.01
2 number in parentheses indicate the standard error of the coefficient estimate

In figure 3, the average stock coverage in the model is a means to approximate the relative scarcity of Champagne wine aging in cellars with respect to the expected equilibrium consumption amount in a given year. This variable determines the real to expected stock ratio relative to the period of relative coverage. Variations in the real to expected stock ratio influence the price of Champagne directly in the model. Using deflated data at the reference year 2001, that is constant euros, it was determined that the equilibrium price in the model for the historical data available was €10.86 per bottle. The graph showing the estimated equation to arrive at these estimates is shown in figure 3.

The equilibrium "real to expected ratio" (*w*) falls between 1 and 1.2, and the resulting price is somewhere in between €11.16 and €11.27 per bottle (see figure 3). In such a case, real stocks are just above the desired coverage and provide a buffer as a precautionary measure. Within that range, the price of Champagne remains stable. When the real to expected stock ratio falls towards 0.7 or 0.6, it means that the average stock coverage becomes a lot smaller than the desired coverage. Lower stocks lead to a higher price per bottle. As a result, it would limit an increase in Champagne consumption. By contrast, when the real to expected stock ratio is greater than 1.2, stocks are lying higher than the desired level. So, the Champagne price may be lowered to stimulate consumption. The first table function displayed in figure 3 shows the relationship between the real to expected stock price ratio and the price of a bottle of Champagne.

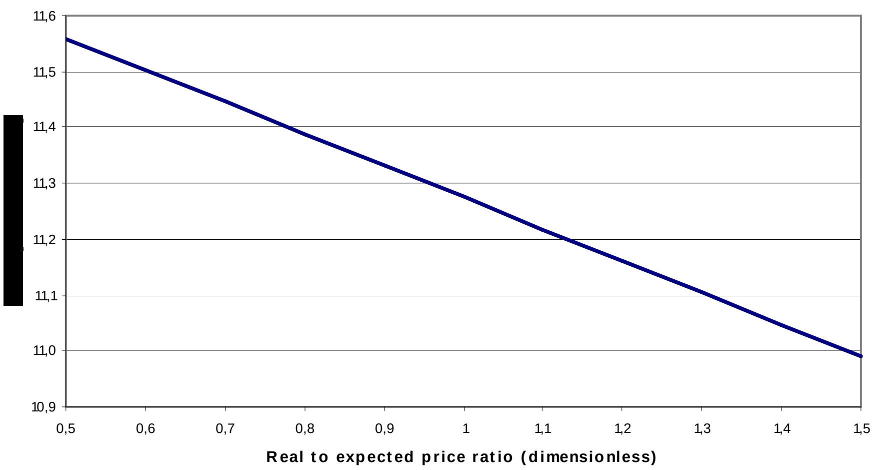


Figure 3. Table function of real to expected price ratio versus price

The table function shown in figure 4 is the desired short term supply response. The desired short-term response yield is based on a quadratic equation as a function of the price lagged by one period. When a stronger short-term supply is desired by wine processors, they become afraid of grape shortages to meet demand and may accept both an increase in grape yield and an increase in grape price. The coordination process works as follows. First, a few days prior to harvest time, the representatives of vine growers and wine processor meet to set an official maximum yield authorized and enforced by the French Government. Grape growers accept higher yields to harvest the volume of grapes they need. Second, any increase in the price of grapes gives incentives to grape producers to sell to Champagne makers who typically pass on higher input costs to consumers by raising the price of the product. In short, any increase in short-term yields is associated with higher expected Champagne price and *vice versa*.

Figure 4. Short-term supply response

The third table function, in figure 5, represents the price expected profit relationship used as the first step towards determining the long-term supply response.

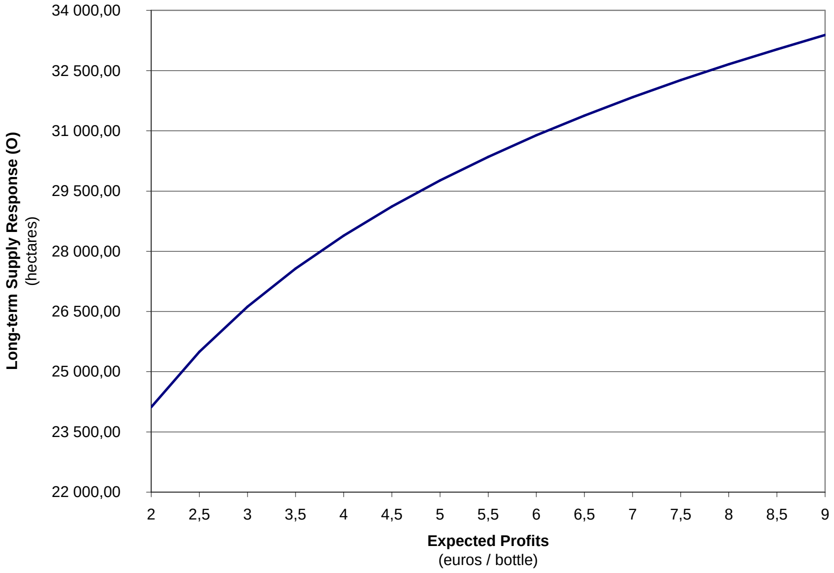


Figure 5. Price expected profit relationship

The cost of grapes is the most expensive input expense in Champagne processing (Declerck, 2004). Recall that most Champagne makers produce less than 10% of the grapes they need and must purchase more than 90% of the grapes they process. For Champagne makers, that do not own any vineyard, the cost of grapes is a major direct variable cost since the production of a 75 cl bottle of Champagne requires 1.2 kg of grapes. So, wine processors' expected profits are a log-linear function of the cost of grapes (see table 1).

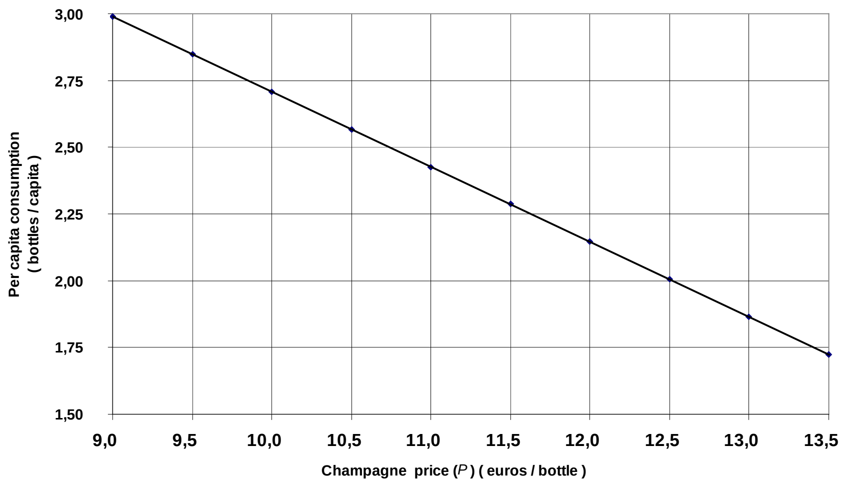


Figure 6. Table function of consumer demand as a function of price

The fourth table function is the statistical estimation of the desired long-term supply response shown in figure 6. This relationship is estimated using the expected profit variable lagged by three periods. This is because Champagne makers are considering three years as the expected long-term horizon between the moments the full benefit from the harvest of three years ago is realized, that is: Bottles of Champagne sold at time *t* are processed with grapes harvested at least at time $t - 3$. Over the past several decades (see figure 1), Champagne makers were able to sell more and more bottles. Shipments of bottles have roughly doubled from the 1970s to the 2000s. Over that period, wine processors have purchased a growing supply of grapes from vine growers. Wine processors and vine growers have jointly requested the French Government and European Commission for an expansion of the Champagne PDO.

The fifth table function is the demand curve for Champagne consumption as seen in figure 6. The per capita consumption is the dependent variable fitted on the price of Champagne.

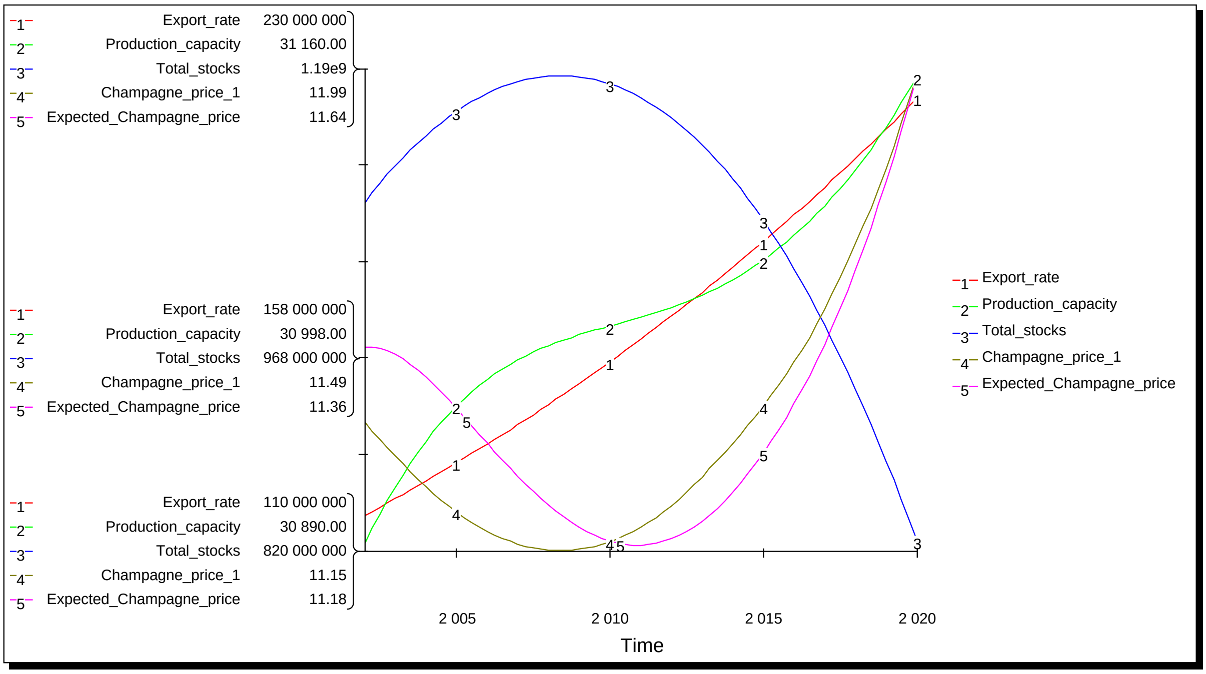
The adjusted goodness of fit measure (R^2) is 0.37. This means that roughly 37% of the variance within this equation is explained by the variation in the price of Champagne alone. Other methods could be employed to estimate the demand as a function of the price of Champagne. However, the results obtained are adequate within the context of this work. The demand for Champagne is a curve with negative slope as it is for any normal good (Declerck 2004).

RESULTS AND DISCUSSION

The results of the Champagne model were obtained in stimulating the demand side. Historically, the demand for Champagne has risen globally by about 3% annually from 1978 to 2002 (Declerck, 2004). Thus, the model specification assumes a 3% compounded growth rate in demand over time. All other technical parameters were assumed constant. The state variables were specified to begin the simulation in 2002. Thus, the stocks of wine bottles and other technical parameters were calibrated for the 2002 observed levels (CIVC, 2003).

The supply side of the Champagne model is constrained first by the size legal limit of the PDO area that will be binding in the long term and second by the maximum authorized yield which is adjusted annually (in the short term).

Figure 7. Champagne wine: Impacts of a 3% growth in demand on price, total stocks and production capacity



In that framework, trends are clearly expressed by the model. Expected deficit in grapes is already perceived, both by the model and in observed trends, since the demand for Champagne is growing by 3% annually while production is strongly constrained. To meet expected growing demand, vine growers and wine makers produce and store as much as possible in an anticipation of the coming production constraint. Consequently, the price of wine may not increase, and even decrease, a little bit in the short term. As long as the demand continues to grow, it becomes increasingly difficult to meet: the harvest of grapes is not sufficient and stocks of ageing bottles begin to deplete. As a result, beginning in year 2010, the price of Champagne wine and grapes takes off. Within less than 10 years from 2002, such an increase will affect the purchase of wine bottles, consumers do not consume more Champagne wine and prefer not to switch to substitutes. The cost of grapes is the major component of Champagne wine making (more than 60%). In reality, the wine makers' profit may not increase as fast as the selling price. The results illustrate that a "race" is taking place between the increase in the grape price, that is, input cost, and the increase in the price of the wine bottle, that is, output. The vine growers and wine makers can no longer improve their business. The long-term physical constraint, that is the PDO area size limit, must be reviewed in order to avoid such an effect. It may take a decade to assess the agro-climatic characteristics of soils in the Champagne region in order to define the areas suitable to meet the appropriate growing conditions to produce Champagne grapes. The administrative and legal process will be slow because it includes negotiations with stakeholders: vine growers, farmers, wine makers, the French State, and EU Commission. In short, each day not spent on working for the enlargement of the PDO area size limit is a day that will delay business improvement.

Furthermore, one can observe that the price of Champagne vineyard has strongly grown during the last fifteen years. Vineyards are mainly acquired by vine growers. Since the price of vineyard is the sum of expected discounted cash-flows coming from the sale of grapes, economic agents anticipate an increase in the price of Champagne grapes. Champagne vineyard is the only French vineyard whose price is growing currently. So, vine growers' representatives are joining wine makers in asking for a revision of the PDO area in order to be less constrained. However, if the value of vineyards grew threefold within 15 years, the model does not anticipate a strong raise in grape price due to substitutions made by consumers. But such an increase in price is a major barrier-to-entry for new vine growers that are afraid of any decrease in Champagne consumers. And they have observed stable consumption in Germany and a decrease in Switzerland demonstrating that the expectation of increased consumption is fragile.

System dynamic modeling may help economic agents to think about the hypotheses they use to form expectations.

CONCLUSION

In terms of theory in a context of economic rupture, the paper models vertical coordination in a cobweb economy in order to forecast economic agents' decisions along processing chains when they transfer product and negotiate volumes and prices that can be passed to final consumers. Supply process takes 3 years and is always trying to adjust to demand. But supply is strongly constrained by limited yield in the short term and in the long term. So, the model provides forecasts in rupture of the past shapes of cobweb cycles.

On one side, the dynamic modelling of a cobweb economy was only explored by Meadow (1970). On the other side vertical coordination is more and more often analysed in the framework of new institutional economics. Here, both ways are unified to forecast a rupture in cobweb cycles, due to strong constraints in the short and medium term (about 10 years).

Empirical results of simulations are robust enough to help Champagne stakeholders (vine growers, Champagne markers, policy makers for PDO rules at the French State and EU Commission) to understand better their cob-web economic cycles. Vine growers and wine makers may take advantage of the model to understand the consequences of their decision:

- their short term decision (every year before harvest) about grape authorized yield and price making, in order to avoid strong swings in volumes and price with negative consequences like bankruptcy among them
- their long term decision about the impact of no revision of the PDO area or of a revision of the PDO area.

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