System dynamics and time series analysis

Two approaches for a convergent answer

JOÃO FERREIRA DIAS, RUI MENEZES E FRANK ASCHE

ABSTRACT: Norway and Portugal are the biggest players in the huge worldwide cod market. Norway is the largest producer and exporter while Portugal is the largest importer and consumer. Moreover they are the only countries in the world with an important salting and drying cod industry.

The extent to which demand and supply shocks are transmitted along the value chain is an important topic for economic and managerial fields. Theories of the strategic actions of economic agents have relied more and more on mesoeconomic models of market structure and price behaviour. For system dynamics scientists the focus is on the structure of the whole system chain that links producers, processors, retailers and consumers; prices are a mere result of local equilibria. For econometricians, price behaviour is the key to understand the nature of the economic system itself, by using sophisticated time series techniques to analyse the price series properties along the underlying value chain.

Within the European Project Salmar, we were lucky enough to have system dynamics and statistics expertise together in the same team. Thus, we were able to apply both techniques to characterize and analyse the same issue – the international cod value chain – getting insights from two different approaches and cross-validating the results.

The results indicated that (i) the international cod market is an integrated and competitive one and (ii) the price of wet salted cod exports from Norway is influenced both by the ex. vessel price in Norway and the retail price of dried salted cod in Portugal.

Key words: Value Chain, System Dynamics, Cointegration, Cod Market

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TÍTULO: A dinâmica de sistemas e a análise de séries temporais: Duas abordagens convergentes

RESUMO: Portugal e Noruega são os principais actores no mercado mundial do bacalhau. A Noruega é o maior produtor e exportador e Portugal o maior importador e consumidor. São, também, os maiores processadores de bacalhau seco e salgado.
A intensidade dos fluxos do comércio internacional do bacalhau entre os dois países cria as condições ideais para o estudo da transmissão dos choques externos, ocorridos na procura ou na oferta. Trata-se de um tópico da maior relevância para compreender a actuação estratégica dos agentes empresariais ao nível agregado da indústria. Nos últimos anos, a análise do comportamento estratégico dos agentes económicos tem-se concentrado nas estruturas de mercado, no encadeamento das cadeias de valor e no comportamento dos preços ao nível meso-económico (indústria). Para os especialistas em dinâmica de sistemas, o foco é a estrutura do sistema de valor mundial que liga produtores, processadores, distribuidores e consumidores; os preços são uma resultante deste equilíbrio agregado. Para os econometristas, o comportamento dos preços é a chave para compreender a natureza do próprio sistema económico, através do uso de sofisticadas técnicas de análise de séries temporais que evidenciam as propriedades da cadeia de valor subjacente.
A oportunidade de ter especialistas de dinâmica de sistemas e de econometria a trabalhar no mesmo projecto europeu – Salmar – e na mesma temática – a cadeia de valor internacional do bacalhau – permitiu a rara aplicação simultânea e cruzada dessas duas técnicas. Foi, assim, possível evidenciar os pontos fortes e fracos de cada uma e os seus contributos cruzados.
Quanto ao mercado mundial do bacalhau, os resultados mostram que: (i) se trata de um único mercado, integrado e competitivo a nível mundial e (ii) que o preço mundial do bacalhau salgado verde é fortemente influenciado pelos comportamentos quer da captura na Noruega, quer do consumo de bacalhau salgado seco em Portugal.

Palavras-chave: Cadeia de Valor, Dinâmica de Sistemas, Cointegração, Bacalhau

The analysis of market integration and price transmission in domestic value chains has received a great deal of attention from researchers across the world. To a much less extent, however, such analyses have been extended to cross boundary value chains where the exchange rate between different currencies may also play a role in the explanation of the behaviour of price transmission (Asche *et al.*, 2003). In most cases, the findings converge to an overall conclusion that both domestic and international markets tend to be more and more integrated as time goes on. There seems to be a great support of the idea of market globalisation in many sectors of activity.

The vast majority of the empirical analyses made in this context have used a framework based on time-series cointegration analysis. The basic framework of these models, based on regression analysis, remains the same since a long time. That is, one makes assumptions about the relationship and functional forms of the model, which is then estimated and tested on the basis of historical data. We infer about the structure of the model on the basis of the estimated results.

An alternative way to model the value chain involves the direct modelling of the structure of the system that determines the behaviour of prices and other variables. This methodology can be used in combination with the set of econometric techniques to enhance our capability of making strong inferences about the functioning of the market chain. And this is a new and valuable way to analyse the behaviour of price transmission over domestic and international value chains, providing stronger tests and more convincing conclusions. It is this combination of techniques that we have adopted in this study and recommend for investigation and testing in different economic activity sectors.

The rest of the paper is organised as follows. Section 2 presents a short description of the international value chain for codfish products. Section 3 describes the data used in our empirical analysis. Section 4 discusses briefly the two methodologies confronted in our study. Section 5 displays and discusses the empirical results, and Section 6 concludes. Annex III present the main equations of the stock and flow diagram in quantity for the Portuguese value chain of cod with extension of the wet salted supply to Norway; the full set of equations and the models can be seen in Salmar (2002).

THE INTERNATIONAL VALUE CHAIN

Portugal holds the 4th place in the world ranking of seafood consumer countries, with approximately 60 kg lwe *per capita*/year (lwe = live weight equivalent), (FAO, 2000). About 40% of this consumption refers to codfish (*Gadus morhua L*) in the form of dried salted cod. Portugal is the biggest worldwide codfish market and the main client of Norway, the biggest worldwide codfish supplier.

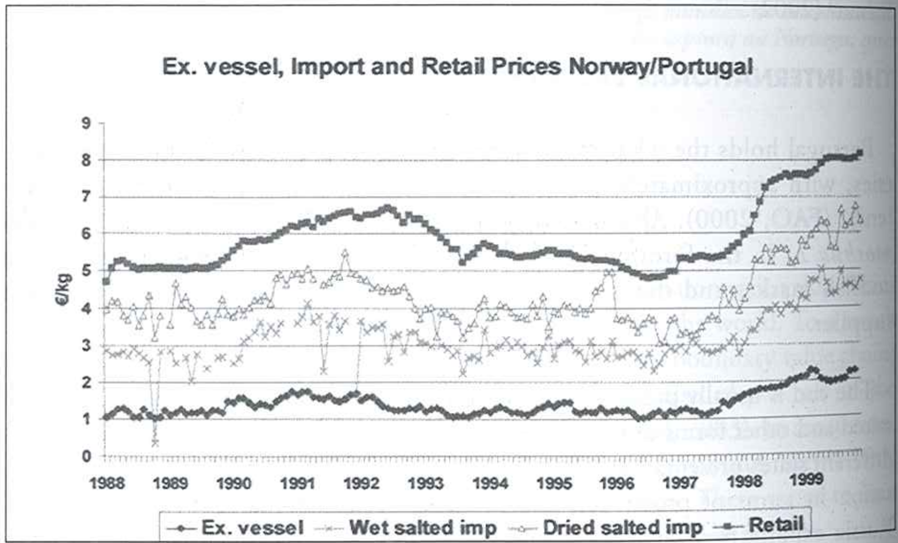
The cod is usually presented in the forms of fresh, frozen, wet salted, dried, dried salted and other forms of lesser importance. It is important to take into account the different states/presentations of the product because there is at great extent a specialisation in terms of production and in terms of consumption. Roughly speaking, Russia exports fresh and frozen cod, Iceland exports wet salted cod and Norway exports cod in all states/presentations. On the demand side, Portugal and Brazil consume basically dried salted cod, Spain consumes wet and dried salted cod, Italy consumes dried cod not salted and the UK, the USA and other countries consume fresh or frozen cod.

Portugal is the only consumer country in the world that for historical reasons has an important salting and drying industry. The Portuguese long-distance vessel fleet, used for catching the cod, was very important until recently but it is now almost inexistent. However, the consumption of codfish remained fairly stable around 70 KTon, over decades until 2001, when it suffered a sharp fall of 20%. Cod (Bacalhau in Portuguese), cooked in different ways, has been the Portuguese national dish for centuries and this cultural root seems to be the key to understand the weird behaviour of the Portuguese cod market demand elasticity, which is inelastic by levels (Dias *et al.*, 2001). Thus, the 20% fall in demand occurred in 2001 could be caused by the overpass of a price threshold in the low market segment (Figure 1).

Looking at the international value chain of codfish we can see that Portugal is the destination of both frozen and wet salted cod, used by the national industry of salting and drying, as well as dried salted cod that goes directly for final consumption. This particularity – multiple kinds of inputs for the same kind of output – facilitates a systemic analysis, both structural and dynamic, of the international value chain.

FIGURE 1

Prices in the Norway-Portugal value chain for cod



Source: INE (Portuguese Trade Statistics) and Norges Raafisklag (Norwegian Trade Statistics)

DATA

In our analysis we use data on prices for the period January 1988 to December 1999 (Figure 1). The Norwegian ex. vessel prices were obtained from Norges Raafisklag, the Norwegian external trade from the Norwegian Trade Statistics. The Portuguese external trade and retail prices were obtained from the National Institute of Statistics (INE). All the data was originally available in national currency – Krones for Norway and Escudos for Portugal – and was then converted to Ecu/Euro using exchange rates from International Financial Statistics.

As can be seen in Figure 1 (p. 110), prices increased substantially after 1997 at all levels of the chain. The main trend of price movements appears to be similar in all series, but there is substantial short-run variation. The main reason for the distance in price levels over the chain is the weight difference of the presentations due to differing preservation technologies. However, that distance largely vanishes when we convert all prices into their live weight equivalents.

For modelling the system dynamics of the Portuguese value chain we use several technical coefficients – processing time, wastage rates, etc. – given by the Portuguese General Board of Fisheries and the Portuguese Sea Research Institute. Market indexes, like coefficients of seasonality, were obtained from industrial and retailer data. For modelling the system dynamics of the Norwegian value chain we use technical and market coefficients provided by experts, some of them working together with the Norwegian Seafood Export Council.

Equally important was the qualitative information, from contextual to specialized one, given by industrials, consultants, retailers, officials and other professionals.

MODELLING THE VALUE CHAIN

Econometric Approach

The basic starting point for the analysis of price transmission over the value chain is to test for the degree of price transmission. This is a test for to what extent a price movement at one stage in the value chain is passed on to the next stage. The price transmission is complete if prices move proportionally to each other along time.

The degree of price transmission can be tested on the basis of a simple functional relationship between price variables. When the variables are measured in logarithmic terms in an additive model, the corresponding coefficients represent the elasticity of price transmission, and the anti-log of the constant term measures the inter-temporal relationship between prices (Asche *et al.*, 1999). When the constant term is different from zero and the elasticity is unity we say that the prices move proportionally but differ one to each other due to different transportation costs, mark-up, etc.

We can extend the basic static long-run relationship between prices to another one that takes into account the likely effects of the historical values of the variables. One advantage of this dynamic model is that it allows for a distinction between a measure of instantaneous transmission and a measure of long-run price transmission between the levels in the supply chain (Ravallion, 1986; Goodwin *et al.*, 1990). The basic equation is given by:

$$\ln p_{1t} = \Theta + \sum_{i=1}^{n} \Psi_i \ln p_{1,t-i} + \sum_{j=0}^{m} \Lambda_j \ln p_{2,t-j} + \Xi_t ,$$

where Θ, Ψ and Λ are parameters and Ξ_t is a random disturbance. The variables P_{1t} and P_{2t} represent prices at different levels of the value chain. The number of lags of the two prices considered in the previous equation is chosen so that the residual term Ξ_t is white noise. One can say that P_{2t} causes P_{1t} if the null hypothesis that all parameters Λ_j are simultaneously zero is rejected. Similarly, interchanging the role of the price variables in the equation one can obtain a test of the null hypothesis that P_{1t} causes P_{2t}. If the null hypothesis is accepted in both cases, then there is no causal relationship between the prices of the two goods and it is said that they do not belong to the same market.

Conventional inferences for the regression model under study are only valid if the price series P_{1t} and P_{2t} are stationary (Granger and Newbold, 1974). If the price series are non-stationary in levels but integrated of the same order and there is a linear combination of these variables that is stationary, then the series are said to be cointegrated and the usual tests remain valid. To test the order of integration of the price series one can use a conventional Augmented Dickey-Fuller test (ADF).

The cointegrating relationship between prices can be analysed under a VAR model, where each price is a function of its own lagged values and the lagged values of the other price series. In this context the usual approach to be used is the Johansen methodology, which is based on the study of the cointegration rank of the model (Johansen, 1988; Johansen and Juselius, 1990). By testing parameter restrictions of the model one can ascertain whether the joint variation of prices is reflected in terms of proportionality. In this case, the LOP holds. Using alternative parameter restriction tests it is also possible to test for weak exogeneity of the variables in the model.

System Dynamics Approach

System dynamics is a methodology that is rooted in the systemic paradigm and was firstly developed by Forrester (1961). Contrasting with the traditional econometric models, described above, that start from the relationships that attempt to model the behaviour of the variables in order to estimate the underlying relational model, system dynamics starts from modelling the structure of the system that determines the behaviour of the variables (Sterman, 2000).

The structure of the system is built on the basis of two types of primary variables – stocks or levels and flows – and auxiliary variables. Each stock is represented by the integral of the net difference between input and output flows. Since stocks are accumulators, the system activity is given by flows. Flows are determined by algebraic equations that express decisions based on the information of any variable in the system, namely the stock levels. Quite frequently, the net of relationships has feedbacks and delays that introduce nonlinearities in the system in such a way that renders the analysis almost intractable analytically. In such cases, the system can only be studied by simulation based on computer technologies. In system dynamics, simulation consists of numerical integration step by step, using for example Euler's method.

For modelling purposes in system dynamics, the assumptions have to be explicitly stated. Being a simplified representation of the reality oriented by a specific problem, the model is validated by analogy, i.e., it is required that the structure of the system be accepted by experts and the behaviour of certain variables be similar to its historical values in a process of controlled simulation (Forrester, 1961).

System dynamics has been largely used to define robust policies, forecasting, impact analysis, and so on. It is also a very powerful tool for learning, for two main reasons that facilitate the double cycle of learning, in Argyris sense (Argyris, 1985): the modelling process to build the virtual world is an interactive and iterative one; the simulation process uses and eventually changes that transitive object that someway reflects our mental model carrying us in a reflexive learning process (Sterman, 2000).

EMPIRICAL RESULTS

Step I – SD Modelling of the Portuguese Part of the Cod Value Chain

The system dynamics methodology was used to model the Portuguese part of the cod value chain and to simulate its behaviour over the period 1992-1999 (months 1 to 96). To this end, we constructed two models – quantities and values. To build these models we considered the following assumptions: (1) import prices are exogenous as there is a world market for cod and all cod consumed in Portugal is dried salted; (2) exports are made directly by the processing firms; (3) the domestic market is supplied both by the imports of dried salted cod and by the local processing from frozen and wet salted cod. The production processes, with their wastage rates, were deducted from the technical coefficients for conversion to live weight equivalents. The processing, de-costuming and storing times were obtained from information provided by firms of the sector.

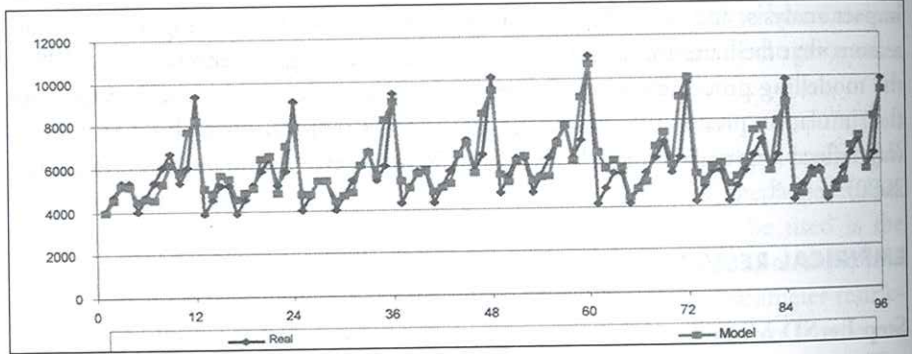
The stock-flow diagram and the main equations for the model in quantities are shown in annexes I (p. 119) and III (p. 121). It is a quite simple supply chain from imports to consumption. The ´push´ logic works because cod is a scarce but popular product deeply rooted in the Portuguese gastronomy. The main supplier is Norway, so retroactions will only be described in the value chain extended to Norway in step III.

The modelling of the retail policy that supports consumption seasonality – in Easter, summer holidays (when a large inflow of emigrants and tourists occur) and Christmas – was the major problem. During those periods there are selling peaks of higher quality cod that is stored continuously along the year and represents about 10% of the imports. This cod is stored to this specific end. Without considering this storing process it is not possible to explain the structural basis of the oscillations in the retail market.

The validation of the model was firstly made both by experts and the comparison between the actual and simulated retail price series (Figure 2). The model was considered to be adequate.

FIGURE 2

Retail prices of dried salted cod in Portugal



Step II – Econometric Modelling of the Portuguese Part of the Cod Value Chain

The next step is to consider the econometric results of the cod value chain for price transmission based on the cointegration techniques described above. To this end, the log transformed price series for production in Norway, imports from Norway, and retail in Portugal were firstly analysed by using ADF unit roots tests. The results obtained indicate for all series non-stationarity in levels but stationarity in first differences, i.e. the series are integrated of first order (Annex IV, p. 122).

The following stage consists of analysing the cointegrating relationship between the variables. Thus, to analyse the relationships between prices along the various levels of the value chain we performed bivariate cointegration tests based on VAR models specified with two lags. The usual Johansen tests are based on the VECM form (no constant or trend) of the system. In all cases, we found that the series are cointegrated (Annex V, p. 123), thus concluding that we have an integrated price system at the level of the international row.

We have next tested for proportionality of the bivariate relationships. The prices in all combinations indicate that the prices are proportional that, except for the ex. vessel prices vs. import prices of wet salted cod from Norway. In the remaining systems we found that price variations are proportional, indicating the price transmission are complete and the markups (the ratio price less cots margin by price) that are invariant over the period.

Finally, we tested for weak exogeneity in all the relevant price combinations. The null hypothesis of weak exogeneity is rejected in all combinations at the 5% level except for the relationships of the wet salted import prices from Norway both with the ex. vessel prices in Norway and the retail prices in Portugal (the latter being weakly exogenous relative to the former). This means that the wet salted import price is influenced both by the ex. vessel prices in Norway and the retail prices in Portugal.

Looking at the results of steps I and II, we conclude that cointegration between cod import prices and cod retail prices in Portugal is the expected behaviour of a direct supply chain like the one modelled in step I. And extending the previous SD model to integrate all the wet salted value chain is required to get a structural explanation for the double ´influence´ in Norwegian wet salted cod prices both from Norwegian production prices and the Portuguese consumption prices.

Step III – Norway-Portugal Model of the Wet Salted Cod Value Chain

The previous SD model, representing the Portuguese industry of cod, is now extended to the wet salted part of the Norway-Portugal value chain of cod.

Two models – quantities and values – were again built. The Norwegian part of the value chain was constructed in quantities live weight equivalent in order to separate the processing of wet salted cod from the other processing flow that was designated by «other destinations». Figures for exports and imports are similar to the external trade data. So, the wet salted cod exported to Portugal («wet to PG»), once converted to product weight, is the import flow in the SD model of the Portuguese part of the value chain in step I. Such internalisation is in line with the econometric results of step II where we proved that the wet salted cod process in Norway are endogenous and receive influence both by the landing side in Norway and the retail side in Portugal.

In the modelling process we assume that in the processing firms there is no storage at the input level but at the output level its level is determined by the export flows and consumption. We also assume exogeneity in the ex. vessel cod price, which coincides with the cointegration results and the conclusion of Asche *et al.* (2002). The eventual internalisation of this variable is possible in theory, but it would imply at least the inclusion of biological variables associated to cod stocks and the economic ones representing the white-fish world market, which are obviously outside of the scope of this study.

The stock-flow diagram and the main equations for the model in quantities is shown in annexes II and III. In what concerns the processing of wet salted cod it makes sense that Portugal influences the price of wet salted cod because it is the biggest world buyer of this product, which is exclusively sold in South Europe for consumption (Spain, France) or drying (Norway, Portugal). Information given by experts, Norwegian and Portuguese ones, converge for the wet salted cod processing in Norway to be composed of two components: basic and variable. The basic processing is given by the average annual value of 250 Kton lwe, weighted by the seasonality over the year. This flow, when converted in cash, reflects the price oscillations in the fresh fish market. The variable component is given by the reduction, within a month, between the inventory level of wet salted cod in Norway and an ideal level that is indexed to the Portuguese consumption level, being equal to a calculated index of 1.4 times the annual moving average of dried salted cod consumption in Portugal, converted in lwe and weighted by the seasonality coefficients.

By extending the wet salted value chain to Norway we were able to compute the aggregated markups, in Norway between production and exports and, in Portugal, between imports and retail. The mean aggregated markup in Norway is 0.16 and in Portugal is 0.15. Up to mid 1997, when the prices started rising sharply, the markups in both countries were in counter-cycle; since then there was a break for both and an autonomous behaviour afterwards, more stable in Norway (Figure 3, p. 117).

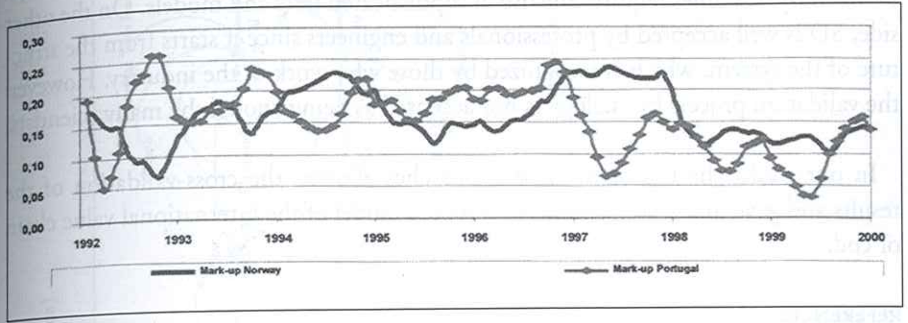
Looking at the results of steps I and III, we see an extended SD model from landing in Norway to the Portuguese consumption, linked by the wet salted flow. The SD model behaviour is compatible with the cointegration results of step II.

CONCLUDING REMARKS

The dialoguing use of two distinct approaches – cointegration analysis and system dynamics – applied to the same problem allowed for an enrichment of their application and a cross validation of the results. In this way, we were able to get a richer and more reliable understanding of the dynamic behaviour of the cod value chain.

FIGURE 3

Aggregated markups in Norway and Portugal (computed values)



Through the cointegration analysis of the cod price series of the value chain for Norway-Portugal we conclude that the degree of price transmission is high and the value chain is competitive. The price of the wet salted cod is influenced both by the ex. vessel price in Norway and the retail price in Portugal.

The system dynamics modelling of the Portuguese part of the value chain allowed us to conclude that the consideration of continuous storage to satisfy the spikes of seasonal consumption is essential to understand the behaviour of quantities and prices in the retail.

By extending the wet salted chain to Norway we were able to understand that the decision of the Norway industry to salt more or less cod is feed by information coming from both the extremes of the integrated value chain of cod, i.e., from the catches in Norway and the retail market in Portugal. This seems to be economically rational because the decision to salt limits the final markets to a few countries that use salted cod, in which Portugal is the biggest client.

Based on the simulation results of the integrated system we compute the aggregated markups in Norway and in Portugal. The mean aggregated markups are quite similar, about 0.15, but with two different behaviours: up to mid 1997, when the prices started rising sharply, the markups in both countries were in counter-cycle; since then there was a break for both and an autonomous behaviour afterwards, more stable in Norway.

Since we have worked and presented the intermediate and final results to very different audiences, it is important to emphasise our own perception about the acceptance of the two contrasting approaches used: econometric analysis and system dynamics modelling.

Econometrics is well accepted by scientists but simply not understood by professionals, since the estimation of the underlying model behind the relationships between the variables requires the use of sophisticated tests and models. On the other side, SD is well accepted by professionals and engineers since it starts from the structure of the system, which is recognized by those who work in the industry. However, the validation process by analogy is not accepted as being enough by many scientists.

In our study, the use of the two approaches allowed the cross-validation of the results and gave important insights to a robust model of the international value chain of cod.

REFERENCES

ARGYRIS, C. (1985), **Strategy, Change and Defensive Routines**. Pitman, Boston.

ASCHE, F.; GORDON, D.V. & HANNESSON, R. (2002), «Searching for price parity in the european whitefish market». *Applied Economics*, vol. 34, pp. 1017-1024.

ASCHE, F.; BREMMES, H. & WESSELLS, C. R. (1999), «Product aggregation, market integration, and relationships between prices: an application to world salmon markets». *American Journal of Agricultural Economics*, vol. 81, pp. 568-581.

ASCHE, F.; FLAATEN, O.; ISAKSEN, J. R. & VASSDAL, T. (2002), «Derived demand and relationships between prices at different levels in the value chain: a note». *Journal of Agricultural Economics*, vol. 53, pp. 101-107.

ASCHE, F.; MENEZES, R. & DIAS, J. (2003). **Price Transmission in Cross Boundary Value Chains**. Institute for Research in Economics and Business Administration. Bergen.

CASSEL, G. (1918), «Abnormal deviations in international exchanges». *Economic Journal*, vol. 28, pp. 413-415.

DIAS, J. & FILIPE, J. C. (1999), **Limits on Sardine Catches and the Portuguese Processing Fish Industry: a System Dynamics Study**. Proceedings of the 17th International Conference of the System Dynamics.

DIAS, J.; FILIPE, J. C.; GUIA, F.; MENEZES, R. & GUERREIRO, V. (2001), «A saga do fiel amigo: as indústrias portuguesas de bacalhau (Cod, the faithfull friend: the Portuguese industry of codfish)». *Economia Global e Gestão*, vol. 1, pp. 103-117.

FORRESTER, J. (1961), **Industrial Dynamics**. The M.I.T. Press, Cambridge.

GOODWIN, B. K. & HOLT, M. T. (1999), «Price transmission and asymmetric adjustment in the U.S. beef sector». *American Journal of Agricultural Economics*, vol. 81, pp. 630-637.

GORDON, D. V. & HANNESSON, R. (1996), «On prices of fresh and frozen cod». *Marine Resource Economics*, vol. 11, pp. 223-238.

GRANGER, C. W. J. & NEWBOLD, P. (1974), «Spurious regressions in econometrics». *Journal of Econometrics*, vol. 2, pp. 111-120.

JOHANSEN, S. (1988), «Statistical analysis of cointegration vectors». *Journal of Economic Dynamics and Control*, vol. 12, pp. 231-254.

JOHANSEN, S. & JUSELIUS, K. (1990), «Maximum likelihood estimation and inference on cointegration - with applications to the demand for mone». *Oxford Bulletin of Economics and Statistics*, vol. 52, pp. 169-210.

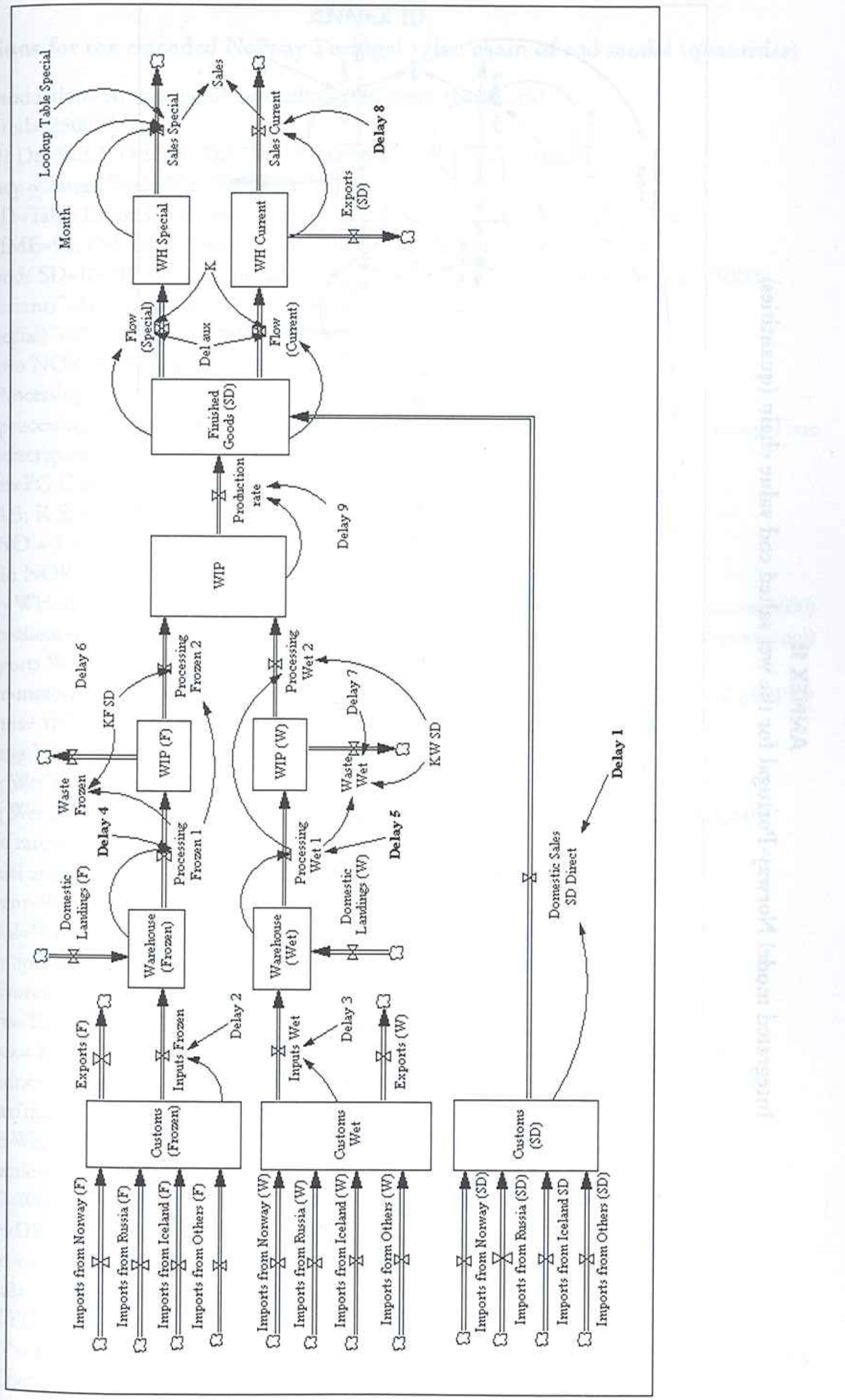
RAVALLION, M. (1986), «Testing market integration». *American Journal of Agricultural Economics*, vol. 68, pp. 102-109.

SALMAR (2003), **Final Report of SALMAR-Margins along the European Seafood Value Chain**. EU Project QLK5-CT1999-01346, http://bonjorn.sc-eco.univ-nantes.fr/~salmar/

STERMAN, J. (2000), **Business Dynamics**. McGraw-Hill.

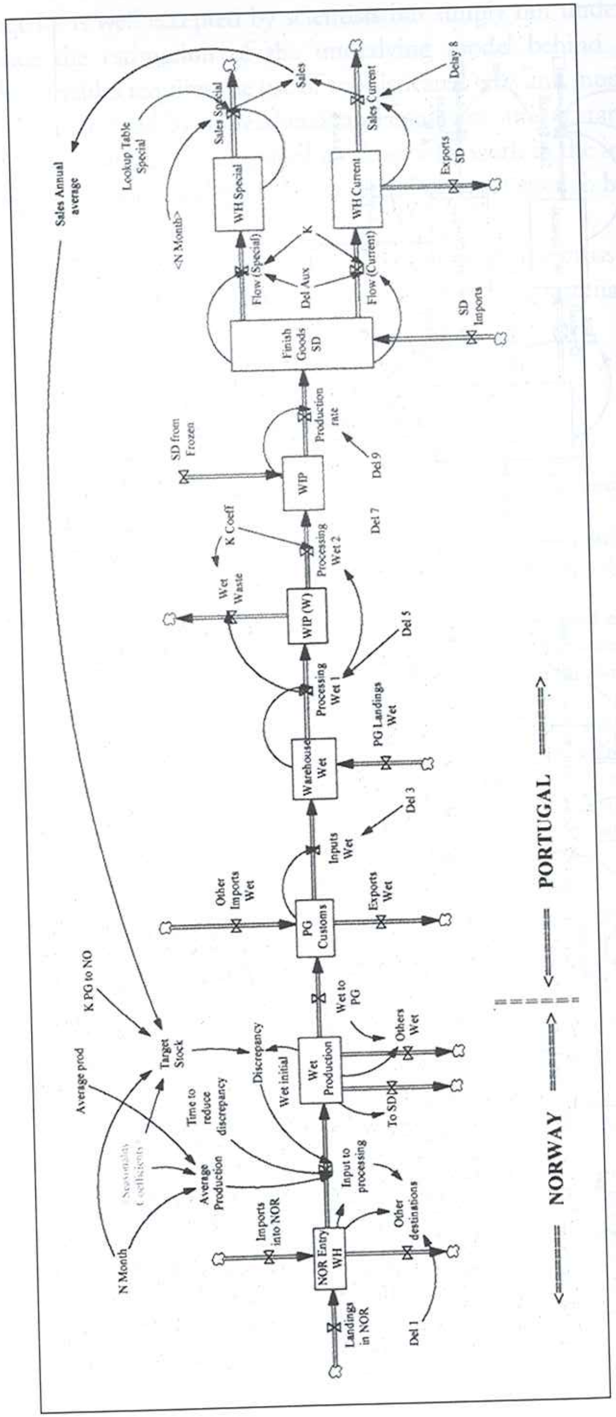
ANNEX I

Model for the portuguese part of the cod value chain (quantities)



ANNEX II

Integrated model Norway-Portugal for the wet salted cod value chain (quantities)



ANNEX III

Equations for the extended Norway-Portugal value chain of cod model (quantities)

Average Production= Average prod*Seasonality Coefficients (N Month)

Average prod= 250000

Del 1=0.1; Del 3=0.2; Del 5=1; Del 7=0.133; Del 9=1; Del Aux=1; Delay 8=1

Discrepancy = Target Stock-Wet Production

Exports SD=Table Exports SD(Time); Exports Wet=Wet PG Exports Table QTY(Time)

FINAL TIME=96; INITIAL TIME =1; SAVEPER=1;TIME STEP=0.0625 Month

Finish Goods SD=INTEG(Production rate+SD Imports-"Flow(Current)"-"Flow(Special)",5000)

"Flow (Current)"=Finish Goods SD*(1-K)/Del Aux

"Flow (Special)"=K*Finish Goods SD/Del Aux

Imports into NOR=NOR Imports Table QTY(Time)

Input to Processing real=NOR Production TOTAL Table QTY(Time)

Input to processing=max(min(NOR Entry WH/TIME STEP,Average Production+Discrepancy/Time to reduce discrepancy),0)

Inputs Wet=PG Customs/Del 3

K Coeff=4.3; K SD=4.3

K PG to NO = 1.4

Landings in NOR=NOR Landings Table QTY(Time)

NOR Entry WH=INTEG (Imports into NOR+Landings in NOR-Input to processing-Other destinations, 3600)

Other destinations=max(0,min(NOR Entry WH/TIME STEP,(NOR Entry WH/Del 1)-Input to processing))

Other Imports Wet=Wet From OTHERS to PG Table QTY(Time)

Others Wet=max(min(NOR Production WET Table QTY(Time)-Wet to PG,Wet Production/TIME STEP),0)

PG Customs= INTEG (+Other Imports Wet+Wet to PG-Exports Wet-Inputs Wet,2700)

PG Landings Wet= Wet PG Landings Table QTY(Time)

Processing Wet 1=Warehouse Wet/Del 5

Processing Wet 2=DELAY FIXED((Processing Wet 1/K Coeff),Del 7,(Processing Wet 1/K Coeff))

Production rate=min(6000,WIP/Del 9)

Sales Annual average=12*SMOOTH(Sales,12)

Sales Current=WH Current/Delay 8

Sales Special=WH Special*Lookup Table Special(N Month)

Sales=Sales Special + Sales Current

SD from Frozen=SD from Frozen Table QTY(Time)

SD Imports=Table Imports SD(Time)

Target Stock= K PG to NO * 4.3 * Sales Annual average * Seasonality Coefficients(N Month)

Time to reduce discrepancy=1; Time to smooth=3;

To SD=max(min(NOR Production SD Table QTY(Time),Wet Production/TIME STEP),0)

Warehouse Wet= INTEG (Inputs Wet+PG Landings Wet-Processing Wet 1,9000)

Wet Production= INTEG (Input to processing-Others Wet-Wet to PG-To SD,20000)

Wet to PG=Wet From NOR to PG Table QTY(Time)

Wet Waste=DELAY FIXED((K Coeff-1)*Processing Wet 1/K Coeff,Del 7,

WH Current= INTEG (+"Flow (Current)"-Exports SD-Sales Current,4000)

WH Special= INTEG ("Flow (Special)"-Sales Special,1000)

WIP= INTEG (Processing Wet 2-Production rate+SD from Frozen,5000)

"WIP (W)"= INTEG (Processing Wet 1-Processing Wet 2-Wet Waste,2700)(K Coeff-1)*Processing Wet 1/K Coeff)

ANNEX IV
Augmented Dickey-Fuller (ADF) Tests

Product	Stats		Stats with trend		Lags
Levels:					
Ex. vessel cod prices in Norway	-0,654		-0,979		6
Dried salted import cod prices from Norway	-1,476		-1,896		1
Wet salted import cod prices from Norway	-0,971		-1,506		2
Retail prices of dried salted cod in Portugal	-0,308		-0,946		2
First differences:					
Ex. vessel cod prices in Norway	-5,984	**	-6,007	**	5
Dried salted import cod prices from Norway	-17,070	**	-17,080	**	0
Wet salted import cod prices from Norway	-13,630	**	-13,640	**	1
Retail prices of dried salted cod in Portugal	-5,566	**	-5,702	**	1

** significant at the 1% level. Critical values at the 1% level = -3.478 (test statistic); –4.026 (test statistic with trend)

ANNEX V
Bivariate Johansen Tests

Product		rank = p	Eigen	Trace		Max		LOP		Weak exogeneity						
Price 1	Price 2									Price 1				Price 2		
										Statistic		p value		Statistic		p value
Ex vessel Norway	Dried salted imp Norway	p==0	0,2134	34,5063	**	34,0838	**	3,5263		7,4983	**	0,0062		22,1209	**	0,0000
		p<=1	0,0030	0,4224		0,4224										
Ex vessel Norway	Wet salted imp Norway	p==0	0,2847	48,3201	**	47,5704	**	4,7092	*	1,4337		0,2312	*	42,3643	**	0,0000
		p<=1	0,0053	0,7497		0,7497										
Wet salted imp Norway	Dried salted imp Norway	p==0	0,2076	33,9959	**	33,0361	**	0,0017		13,2293	**	0,0003		12,0753	**	0,0005
		p<=1	0,0067	0,9597		0,9597										
Dried salted imp Norway	Retail Portugal	p==0	0,1575	24,3670	**	24,3306	**	0,1948		16,5444	**	0,0000		4,1887	*	0,0407
		p<=1	0,0003	0,0365		0,0365										
Wet salted imp Norway	Retail Portugal	p==0	0,2185	35,0355	**	35,0142	**	2,4700		27,1575	**	0,0000		0,6151		0,4329
		p<=1	0,0002	0,0213		0,0213										
Ex vessel Norway	Retail Portugal	p==0	0,1863	29,4138	**	29,2789	**	1,9433		6,5006	*	0,0108		14,8894	**	0,0001
		p<=1	0,0009	0,1349		0,1349										

* significant at the 5% level; ** significant at the 1% level.

Critical values: 15.41 and 3.76 at the 5% level and 20.04 and 6.65 at the 1% level for the Trace test; 14.07 and 3.76 at the 5% level and 18.63 and 6.65 at the 1% level for the Maximum eigenvalue test.