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The Fishmeal Market: An Integrated Part of the Vegetable Oilmeal Market?

by

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

This report is part of a EU project concerning organic salmon production. The use of pressured wild fishery resources in salmon feed is one of the aspects that have been discussed in relationship to organic salmon farming. This was the basis for this report. The fishery resources in question, which are converted to fishmeal, are primarily used in different feeds. The report tries to identify who demands fishmeal by examining which markets fishmeal belongs to. We use high-frequency price data to delineate the market for fishmeal, and use this as a basis to examine what impact the aquaculture sector has on this market, and thus on the demand on wild fishery resources.

I would first of all like to thank my supervisor, Kjell Vaage, for much good advice and his comments during the writing process. I would also like to thank Frank Asche who in practise has functioned as my second supervisor, and who has been generous with his time, giving much good advice concerning the empirical testing amongst other. My brother Ragnar Tveterås has also contributed with good advice. I would also like to thank IFOMA for providing the data for this thesis in addition to helpful comments on these markets. Erik Hempel at KPMG also gave me valuable advice and input on these markets. Finally, I would like to thank the Centre for Fisheries and professor Trond Bjørndal for providing office facilities and financial support.

1 INTRODUCTION

The global fishmeal market plays an important role as a strategic input in animal feeds and aqua feeds due to its high protein content. The fishmeal production is characterised by an unstable raw material situation, which has led to concerns in the feed industry; in particular the fish feed industry. The natural high variability of the "industrial" fishery stocks combined with insufficient fishery management and lack of stocking options cause the fishmeal supply to fluctuate strongly. Moreover, the weather phenomenon known as the El Niño has on occasions led to total collapses in some of the most important "industrial" fisheries stocks causing even further instability in the supply situation.

The global demand for fishmeal has increased in the last decades. Thus, further increasing the pressure on this market. In particular, the fishmeal demand from salmon and shrimp aquaculture has increased. But the major demanders are still the meat-producing sectors for poultry and pigs. The virtue of fishmeal is its high protein content together with amino and fatty acids that are essential in some of the fish and livestock breeding. The intensive production systems used for fish farming and breeding of these animals rely heavily on rich protein feeds. Fish farming in particular relies on fishmeal as its most important source of proteins and this sector has expressed concerns regarding the unstable and limited fishmeal supply (Kaels and Hempel, 1999; Tacon, 1994).

However, there are technical possibilities to substitute fishmeal for other protein sources in the feeds for poultry, pigs and fish. The most obvious candidate is soybean meal, since it is the oilseed meal that has most similar features as fishmeal (Hempel, 1997; Torsvik, 1998). Although soybean meal has a lower protein content and not identical nutritional structure with respect to amino acids and fatty acids, it has the highest protein content of the vegetable oil meals.[1] Some traders in the feed market have in fact operated with a long-run equilibrium ratio of 2 between the fishmeal and soybean meal prices (Durand, 1994), and others with a slightly higher ratio (Hempel, 1997). This suggests that there exists an equilibrium price for fishmeal that is twice the size, or slightly higher, than the soybean meal price. Hence, the

[1] Other vegetable oilseed meals that are used as protein supplements in feed include amongst other sunflower meal, cotton meal, linseed meal, groundnut meal and rapeseed meal.

possibility of an equilibrium price indicates that the demands for the two products are strongly related. Soybean meal is already the major protein source in livestock feeds on a global basis, but only on a small scale in aquafeeds, which is still dominated by fishmeal.

In this report we test the hypothesis that fishmeal and soybean meal in fact constitute one market. If the two markets are integrated, then fishmeal and soybean meal are in reality economic substitutes. Moreover, the concerns expressed by the feed and meat industries concerning scarcity of fishmeal are unfounded since low fishmeal supplies can be replaced by soybean meal. Thus, the fishmeal price is only allowed to diverge from the soybean meal price on a short-term basis. Therefore scarcity can only be considered to be a short-term problem. The reason why fishmeal is only tested against soybean meal sums up to the fact that soybean meal is by far the most important protein source in animal feeds. In addition it also has the highest quality of the vegetable oilseed meals.

The approach in this report is based on the theory of market integration, which is the study of the extent of a market and the Law of One Price. Due to cointegration methods that have been developed during the last decades, empirical testing of market integration has found new relevance. The amount of information available from these procedures is larger than those applied before. In addition, the statistical properties of time series in many cases favour cointegration estimation methods compared to classical estimation methods like the ordinary least squares (*OLS*).

The number of applications of cointegration test procedures has grown quite formidable, also in the field of market integration (Ardeni, 1989; Asche, Bremnes and Wessels, 1999; Asche, Salvanes and Steen, 1997; Baffes, 1991; Godwin and Schroeder, 1991; Gordon and Hannesson, 1996; Hanninen, Toppinen and Ruuska, 1997; Murray and Wear, ,1998; Zanias, 1999). Actually, cointegration tests between fishmeal and soybean meal have already been done by Durand (1994). Durand found clear evidence of market integration by using the Engle and Granger cointegration approach on fishmeal and soybean meal prices from Hamburg. In this report the Johansen procedure for cointegration tests will be used. In addition to Hamburg market prices that Durand used, US market prices for fishmeal and soybean meal are also included in the analysis.

The structure of this report is as follows: Chapter 2 presents the markets for fishmeal and soybean meal. In this chapter the markets are described through the production and the demand of these products. In Chapter 3 there is given an overview over some of the elements in the theory of market integration. The criterias of market delineation and the “law of one price” are central here. Chapter 4 presents some of the basic concepts in time series analysis. Moreover, the Johansen procedure is presented in this chapter. In Chapter 5 the data and empirical results are presented. A summary and conclusions are provided in Chapter 6.

2 GLOBAL OILMEAL MARKETS

This chapter provides a description of global oilmeal markets. The focus is on fishmeal and soybean meal. Other oilmeals are not analysed in the same detail, because they are of less importance compared to soybean meal. The demand and supply structure of the oilmeal markets is important to understand if a test for market integration shall make sense between two qualitatively different products as fishmeal and soybean meal. Firstly the supply side of fishmeal is interesting because of its dependencies on the fisheries. Secondly the interrelationship between the two products is quite complex since they are ingredients in a number of different animal and fish feeds where they sometimes complement and at other times substitute each other. In this chapter a picture of the differences and similarities of fishmeal and soybean meal will be drawn. In Section 2.1 I will give a description of the fishmeal production, demand and international trade. The soybean meal sector is described in Section 2.2 where it is also compared to the fishmeal sector.

2.1 FISHMEAL

2.1.1 FISHMEAL PRODUCTION

In 1998 the estimated fishmeal production was 4.75 million metric tons (mmt) (OW, 1999). However, the fishmeal production usually varies between 6 and 7 million tonnes. The exceptionally low output in 1998 was mostly due to the El Niño weather phenomenon outside the West Coast of South America. The El Niño contributed to the collapse of the fisheries in these waters, which dramatically decreased the world production of fishmeal. In comparison the production in 1997 was 6.2 mmt. Figure 2.1 shows the large variations in the catches of pelagic species used for fishmeal. The relative importance of the South American fisheries can also be observed in this figure. Anchoveta, South American Pilchard and Chilean Jack Mackerel are almost exclusively caught in these waters. By adding these together it is evident that they account for almost half of the catches, and even more in the latter part of the period.

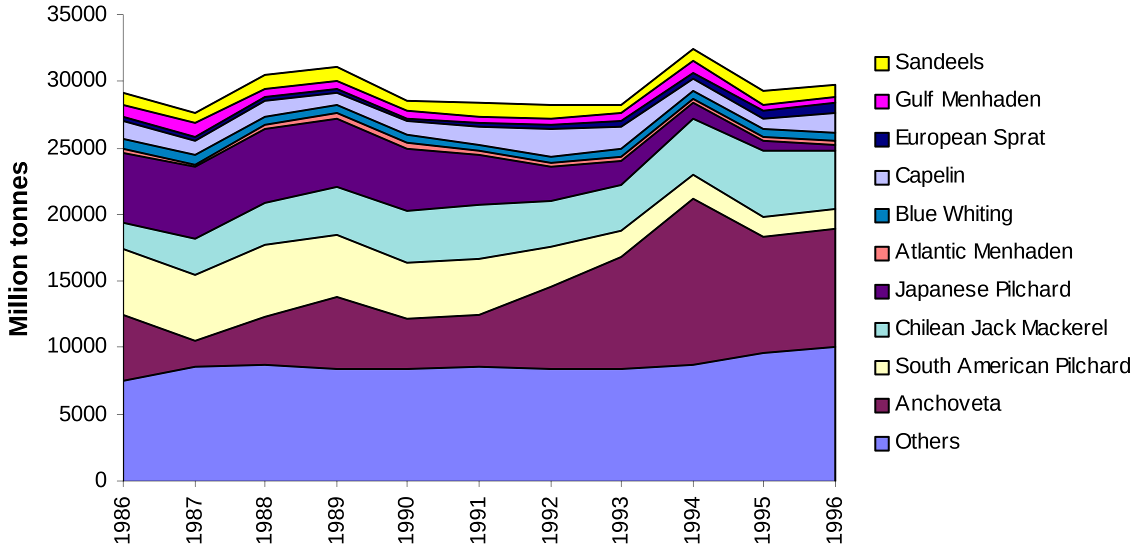

Figure 2.1 Catches of pelagic species for reduction (FAO).

The fishmeal production is situated in proximity to the relevant fisheries due to high transportation costs of unprocessed fish relative to the price of fishmeal. The pelagic[2] species used for fishmeal production are also called "industrial fish" or "fish for reduction". Some of the species used for reduction are unfit for human consumption since they are small, bony and oily. Thus, they are usually reduced to fishmeal and fish oil.

Global fishmeal production since 1970 is shown in Figure 2.2.[3] The sharp decline in the production in the early seventies seen in Figure 2.2 is a direct result of the El Niño in 1972-73. During this period the Peruvian Anchoveta industry collapsed as a consequence of a total collapse in the fisheries. The next El Niño was in 1982-83 and was even stronger than the one in 1972-73. A recession in the catches in the beginning of the nineties also led to a reduction in the global fishmeal production. There were several factors behind this recession. A weak El Niño in 1991-92 led to downfall in the catches in the Pacific coast of South America. At the same time there was a collapse in the pelagic fisheries of Japan and the dismantling of the former Soviet Union's fishing fleet (Durand, 1994).

[2] Free migrating fish species that inhabits the surface waters, as opposed to demersal fish.
[3] Note that the live fish weight equivalent is approximately 5 times the fish meal production volume.

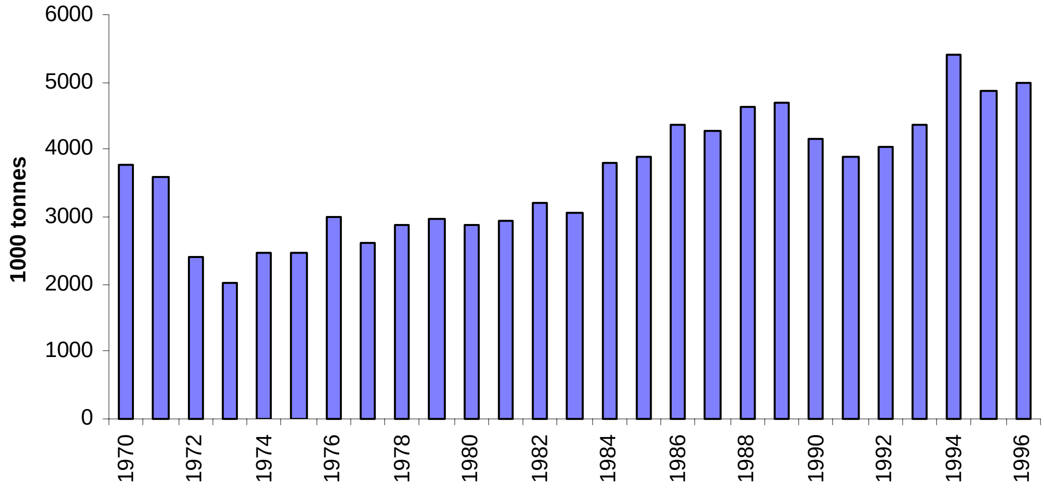

Figure 2.2 Global fishmeal production 1970-97 (FAO).

Figure 2.3 below shows that Chile and Peru are by far the largest producers of fishmeal. Together they have approximately 50 % of the world production. They hold this position because of their rich fisheries of Anchoveta, Chilean Jack Mackerel and South American Pilchard (though the latter is mainly used for canning). Peru produced 1.74 mmt fishmeal in 1997, mainly stemming from Anchoveta, and Chile produced 1.20 mmt the same year.

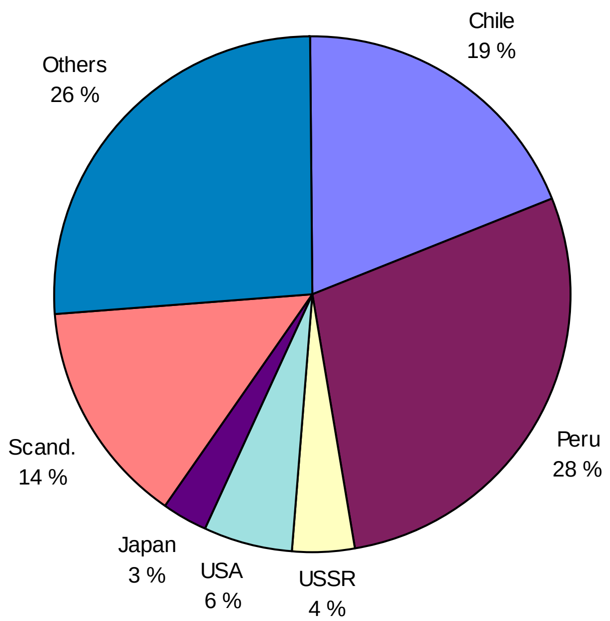

Figure 2.3 World fishmeal production in 1997 (FEO).

Chile and Peru have experienced very large fluctuations in the pelagic fisheries. One important reason is the high natural variability of the fish stocks, but poor fisheries management and the El Niño are probably the largest factors behind the fluctuations in these stocks. The El Niño causes warm surface water to move towards the South American west coast and suppresses the nutritional cold water below. As a result the pelagics are forced to seek other waters to get nutrition, which in the process reduces the reproduction dramatically. Together with poor fisheries management, the El Niño has at times had disastrous effects on the fisheries. Although, the management has improved over the later years, applying more tools to control the fisheries like limiting access, quotas, input factor regulations and bans that are imposed on the fisheries in certain periods and certain areas. The FAO (Food and Agriculture Organisation for the United Nations) has described the stocks over the years from moderately fished to over-fished. Chile and Peru experienced a new collapse in the fisheries due to the 1997-98 El Niño. The governments reacted by imposing bans on some of the fisheries.

The other major fishmeal producers include Thailand, USA, Denmark, Iceland, Norway, USSR, China, Japan. The Nordic countries (Denmark, Iceland and Norway) account for 14 % of the global fishmeal production, and in 1997 their combined production was 0.87 mmt. The major species used for meal production by the Nordics are Herring, Sandeel, Blue whiting, Norway pout, European sprat and Capelin. These stocks have experienced large variations over the years due to heavy fishing, especially the herring stocks in the Norwegian and North Seas (Hempel, 1997). The mobility of these stocks has complicated policy making of the fisheries. National interest conflicts have hindered sound regulations of the fisheries. But the overall landings of pelagic fish have not fluctuated dramatically. The downfall of one species has been compensated by larger landings and extended usage of other pelagic species. At the present time the respective stocks of these pelagics are characterised as moderately or fully fished by the FAO, and are protected by TAC’s (Total Allowable Catches).

The USA fishmeal production mainly stems from the Menhaden fish, which is caught by the Atlantic coast and the Mexican Gulf. The landings are characterised as fully fished by the FAO after a downfall in the early nineties. The landings have since then been stable, giving a fishmeal production of around 0.3-0.4 mmt.

In periods when the supplies of pelagic species are down, the amount going to reduction, i.e. fishmeal and fish oil are greatly reduced. However, the quantity of pelagic species that go directly to human consumption stays relatively constant, even if the supplies are low (Hempel, 1997).[4] Fishmeal production thus absorbs almost all of the negative supply shocks from the fisheries leading to low production volumes of fishmeal and correspondingly increase in prices. The opposite is the case when the supplies of pelagic fish are high. Figure 2.4 gives some support to this assertion. According to the figure, feed production based on pelagics exhibits much larger fluctuations than food production.

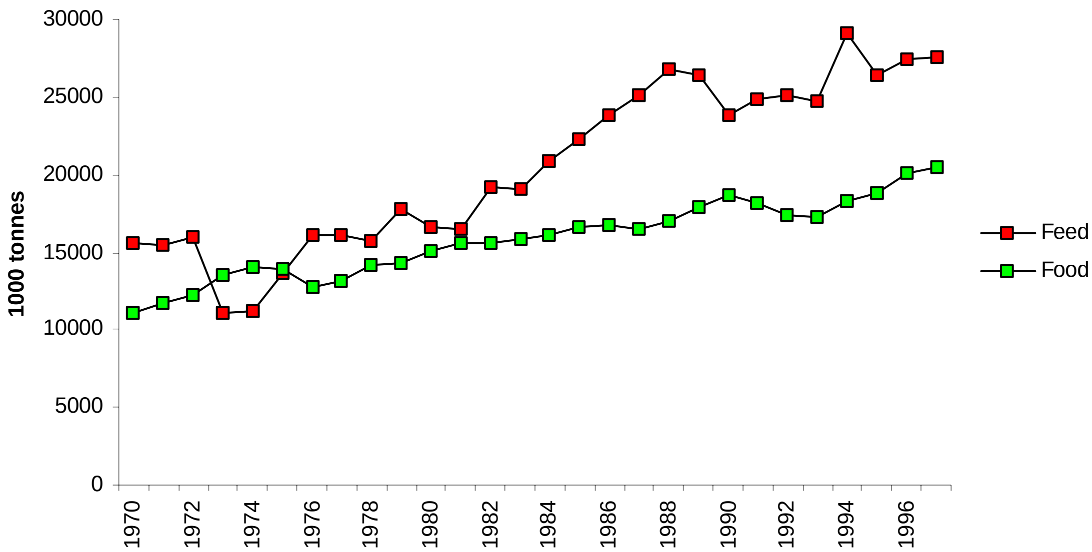

Figure 2.4 Pelagic species used for food and feed 1970-97 (FAO).

2.1.2 FISHMEAL AND OILMEAL DEMAND

Fishmeal is used almost solely as an ingredient in compound animal feed. It is attractive because of its high protein value, with approximately 65-70 %, and is together with oilseed meals the primary protein source in feeds. Another feature that makes fishmeal ideal for feeds is its content of essential amino acids that are important nutritional factors in feeds for domestic animals and aquatic species. Only soybean meal can compete with fishmeal regarding nutritional value, although fishmeal is richer in essential amino acids. Thus,

[4] This does not consider the possibility of a change in the relative prices of pelagics for consumption and pelagics for reduction.

fishmeal can substitute soybean meal and complement other oilseeds like rape seed and sunflower seed that have little amino acids, but are quite rich on protein.

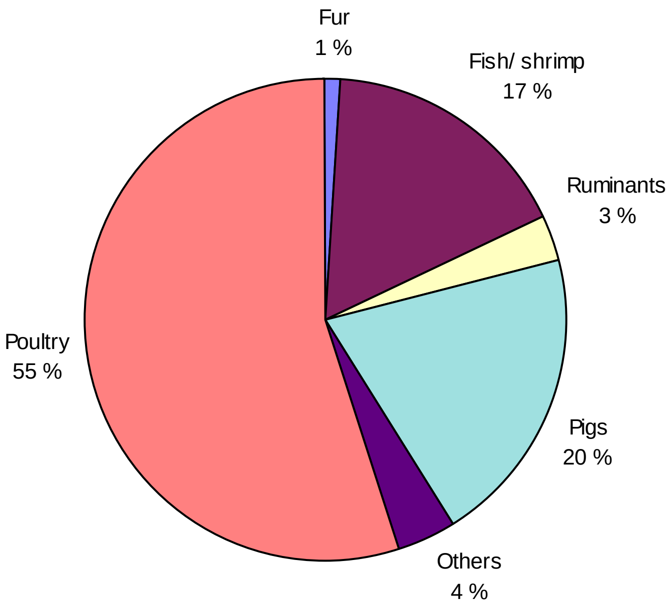

Figure 2.5 Estimated total use of fishmeal by farmed animals (Pike, 1996).

According to Figure 2.5 the feeds for aquaculture, pigs, poultry and ruminants utilise most of the fishmeal production. The majority of these species are bred in high intensity production systems that use tailor-made feeds rich on protein and energy. A limiting factor in fishmeal utilisation in animal feeds is palatability. Some animals will not eat feeds with large fishmeal inclusion. Relative prices are, of course, another important factor. Feed producers have developed least-cost formulas that consider relative prices, substitutability and complementability between different protein and nutritional sources like oilmeals and cereals. Some cereals, like wheat, have a low protein content, while barley on the other hand, is quite rich in protein. Thus there are a number of ways to combine different ingredients in compound feeds. Due to regional agriculture policies that distort the local prices there are regional patterns in the makeup of feeds (OECD, 1994). Feeds in USA are generally characterised by a high content of soybean meal and wheat. In EU, where subsidy schemes are larger than in USA, animal feed production is characterised by a higher use of other oilmeals and fishmeal than soybean meal relative to USA, and also a higher use of barley compared with USA.

More specifically substitution between fishmeal and different oilmeals is based on price differentials. Substitution is normally limited when relative price changes are small or are considered to be transitory. This is because protein sources in feed rations can be technologically difficult to switch. Some species do not respond well to sudden shifts in the makeup of feed rations. In the case of salmon feeds, fishmeal is a major ingredient, and cannot be wholly substituted by soybean meal. Soybean meal contains anti-nutrients that hinder fat digestion in salmon (Storebakken et al., 1999). However, there are highly processed soy products like soy protein concentrates and soy isolates that can almost fully substitute fishmeal, but currently they are too expensive to function as alternatives. On the other side, fishmeal only accounts for a small part in pig and poultry feeds, maybe 2-3% inclusion rate (FIN, 2000). Furthermore, it is not an indispensable ingredient as in salmon feeds thus enabling producers to more easily switch the makeup of the feed.

2.1.3 FISHMEAL AND OILMEAL PRICE FORMATION

The price formation process is another respect where fishmeal differs from vegetable oilmeals. While oilmeal markets are marked by transparency with well developed cash and futures markets, most details concerning fishmeal transactions are usually only known by the involved parties, and subsequently development of a cash and futures market for fishmeal remains difficult (Durand, 1994). The fishmeal transactions are carried through on a direct bilateral basis between the producers and a handful of traders working on behalf of the feed industry. The private character of the fishmeal market is probably induced by the variability of fishmeal supplies. While other agriculture commodities markets are well informed and are able to build up stocks for times with low supply, the raw material situation of fishmeal production brings a lot of uncertainty concerning future predictions of the supply. Fishmeal stocks have on average represented three months worth of production, which is not much compared to other commodities. A market with futures on fishmeal would therefore be highly speculative. But there are some fishmeal prices reported on a regular basis, and the Hamburg market has become the most important market reference for fishmeal prices. The Hamburg market is also the largest European CIF market for agricultural commodities.

Due largely to USA’s leading role in global oilseed market the Chicago Board of Trade (CBOT) has established itself as the most important price discovery mechanism for most oilseed commodity prices (OECD, 1994). CBOT provides daily prices for soybeans, soybean oil and soybean meal, and provides futures up to 9 months into the future. Large international agriculture firms carry out most of the oilseed trade and they are also heavily involved in the oilseed processing. In addition there are a large number of private national firms, which dominate national markets.

There is an understanding in some parts of the oilmeal market, especially among the feed producers, that there exists an equilibrium price ratio between fishmeal and soybean meal in the sense that there is a fixed relation between the two prices. Durand (op.cit.) noted that fishmeal agents operate with a ratio of 2 between the prices of fishmeal and soybean meal, although her own tests showed a long-term equilibrium price ratio closer to 3. A more recently quoted 'ideal' ratio is 2.60 (Hempel, op.cit.). The actual ratio has varied over the years rising as high as 4 at certain times, but there are obvious limits of how large the price ratio can be. As long as they are to some extent technical substitutes, feed producers will always choose the most inexpensive which should reduce price differentials.

In Figure 2.6 monthly price data for fishmeal and soybean meal is printed for the Hamburg market. These are the data used in this analysis. The fishmeal prices reported from Hamburg are CIF prices for standard quality meal,[5] which here implies a protein content of 64-65 %. The Hamburg soybean meal prices are FOB prices reported for soybean meal with a 44-45 % protein content. We can observe from the figure that the fishmeal and soybean meal prices have some common trends. Both have peaks in the end of the eighties and in the 1996-98 period. The price differential between the two products is not quite stable due to the volatility of the fishmeal price.

It was argued that the markets for the various vegetable oilmeals have more developed global markets than fishmeal, mainly due to a more stable raw material situation. In Figure 2.7 four prices for vegetable protein sources are reported. Although not all of the reported product prices represent fully processed meals, they show how integrated the global oilmeal markets are. The price differential can mainly be attributed to the relative protein content,

[5] Standard quality meal is also denoted as FAQ meal, which is an abbreviation for Fair & Average Quality meal.

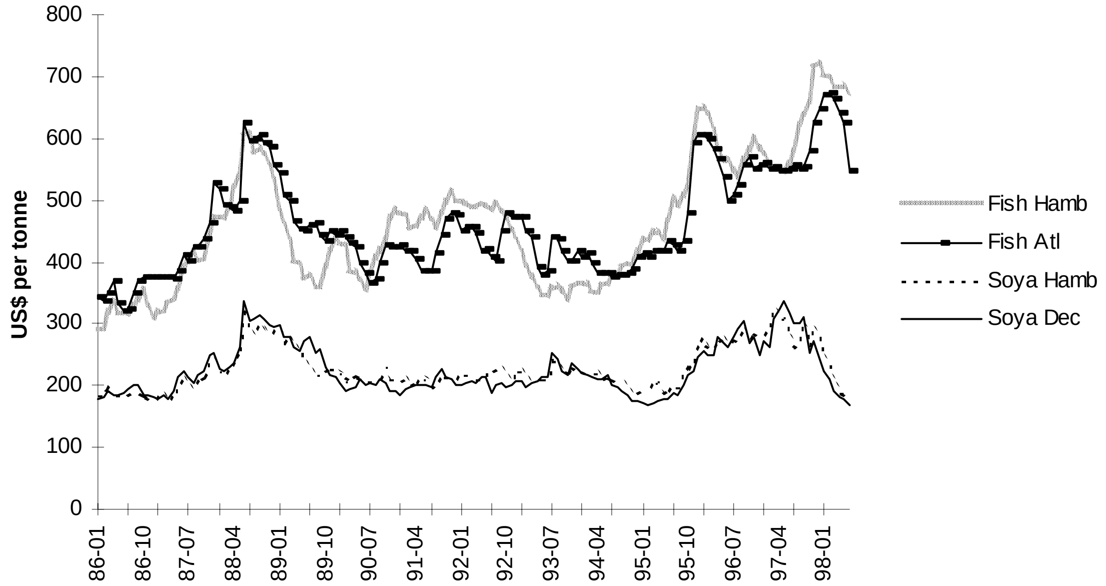

Figure 2.6 Monthly fishmeal and soybean meal price data from Hamburg (Hamb), Atlanta (Atl) and Decatur (Dec) in the period of 1986 to 1998 (OilWorld).

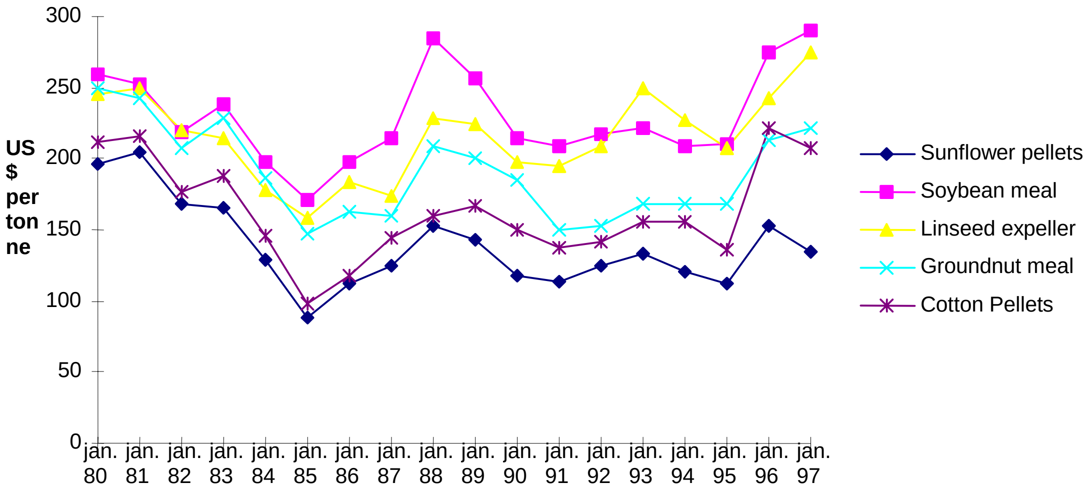

Figure 2.7 Yearly prices in the period of 1980-97 reported for Sunflower pellets (from Arg./Uru., 37/38% protein content; cif Rotterdam), Soybean meal (44/45% protein content, Hamburg, fob exmill.), Linseed expeller (from Arg. 36% protein content; cif Rotterdam), Groundnut meal (48/50% protein content; any origin, cif Rotterdam) and Cotton meal (expel., 43% protein content; orig. China. cif Denmark/UK).

although other attributes also contribute to the differentials. Linseed expeller, for instance, is an important oil source for industrial uses. Otherwise the price differential between soybean meal and the others have, except for linseed expeller, increased since the beginning of the eighties.

2.1.4 FISHMEAL TRADE

Chile and Peru account for over 60 % of the world fishmeal export in 1997 with respectively 0.93 mmt and 1.96 mmt (FEO). Nearly 60% of the fishmeal from Chile and Peru goes to Southeast Asia where the biggest importers are China (60%) and Japan (10%). The EC is also a big importer of fishmeal from South America (20%).

The Nordic countries export mainly to EU where Denmark and Iceland combined exported 0.29 mmt in 1997. Norway is at times net exporter and at other times net importer.

USA, which is a substantial producer, varies between net import and net export. From 1995 USA has been a modest net exporter. Most of its production is consumed at home.

The largest fishmeal importers are the EU with 1.18 mmt, China with 0.95 mmt, Japan with 0.44 mmt, Taiwan 0.37 mmt.

2.2 SOYBEAN MEAL

2.2.1 SOYBEAN MEAL PRODUCTION

Soybeans are the world's dominant oilseed. It is considered the premium oilmeal with a protein content of 40 to 50% while other oilseed meals range from 35 to 40%. In comparison, fishmeal has around 65% protein content and cereals have only 6 to 15% protein content.

Compared to other oilmeals the production of soybean meal is by far the largest globally. This is not only due to the high soybean production, but also the high meal content in the soybeans.

The meal content in soybeans is 80 % by volume and 60-70 % by value (OECD, 1994). Since soybean is mostly converted to meal the prices of soybean are more determined by the price of competing oilmeals than the prices of vegetable, animal and fish oil. A few major producing countries dominate the soybean production. The USA is the largest

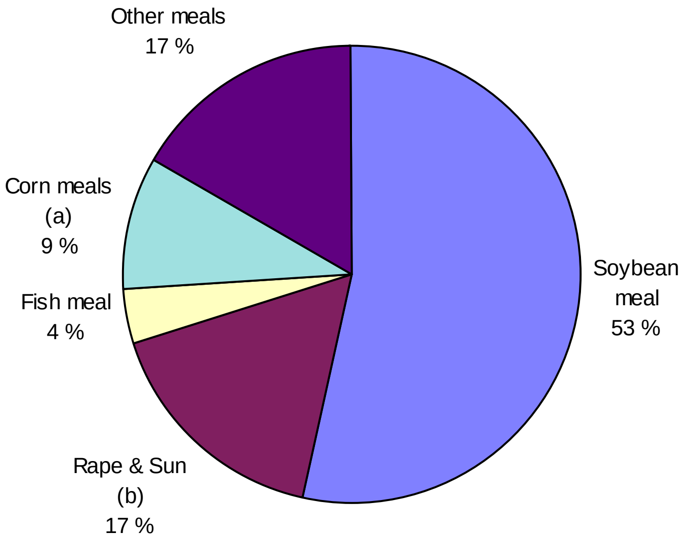

Figure 2.8 World production of meals 1996/97 (OW, 1999).
(a) Corngerm & cornglutenfeed. (b) Rapeseed meal & sunflower seed meal.

producer (50 %) followed by Brazil (18 %), Argentina (10 %) and China (10 %). The same countries are the largest producers of soybean meal. In 1997 they produced 31.88 mmt, 14.74 mmt, 8.43 mmt and 6.76 mmt soybean meal respectively, and the total world production was 91.53 mmt, 15 times bigger than global fishmeal production.

The agriculture based soybean meal production does not meet similar capacity constraints as the fish resource based fishmeal production. Soybean meal production is 4 times bigger today than in 1970. The growth does not show any sign of decline yet, as the soybean production is still rising.

2.2.2 SOYBEAN MEAL DEMAND

Like fishmeal almost all of the soybean meal is used in animal feeds. Together with some other oilmeals like sunflower seed meal, rapeseed meal and cottonseed meal, soybean meal is the primary vegetable protein source in feeds. It serves as a protein supplement for all classes of animals. The most important feeds in this respect are for poultry, pigs and dairy. However, aquaculture is becoming increasingly more important. The amounts of oilmeals used in the different feeds vary from region to region. Thus, it is difficult to provide a general statement on soybean meal usage in feeds.

2.2.3 SOYBEAN MEAL TRADE

Although the global soybean meal production is 15 times larger than the fishmeal production, the global trade is less than 10 times that of fishmeal. This is not due to significantly higher transportation costs. One important reason is that US meat production consumes a large part of its domestic production, but maybe the most important reason is that soybeans are not only processed to meal in the soybean producing countries. EU, which is the major soybean importer of unprocessed soybeans, processes the soybeans to meal themselves. Hence, the soybean meal trade is more than 10 times bigger when some of the trade of unprocessed soybeans is included. USA is the third most important soybean meal exporter with 7.00 mmt in 1997. The two top exporting countries were Brazil with 9.89 mmt and Argentina with 8.18 mmt soybean meal. India is also a major exporter with 2.26 mmt in 1997.

China has gone from being a major exporter of soybean meal to being the biggest importer in the latter half of the nineties, and imported 3.58 mmt in 1997. Seen by region the EU is the most important importer with 10.81 mmt in 1997. EU countries account for a third of the world imports. Southeast Asia also accounts for almost a third of the imports and is the second most important market for soybean meal. The trade patterns for fishmeal and soybean meal share some geographical similarities, with South America being the most important exporter and Southeast Asia and the EU being the most important importers.

2.3 SUMMARY

Fishmeal and soybean meal are the richest protein sources available for livestock and aquaculture feeds. They are also quantitatively the largest protein sources compared with other oilseed meals. Soybean meal, which accounts for more than 50 % of the global oilmeal production, is considered the market leader. The world market for oilseed meals seems to be characterised by competitive prices, although country-specific export taxes and subsidy schemes distort the international trade flows (OECD, 1994). The last decade's increasing demand for low fat meats like poultry, pork and fish have put an increased pressure the oilmeal markets. This has been met by an increasing oilseed production, which has prevented substantial price increases. The raw material situation for fishmeal is different from the oilseed meals. While the oilseed production can increase by expanding their farming areas, the fishmeal production is dependent on scarce fishery resources. In 1998 fishmeal prices increased radically due to exceptionally low supplies. This may be evidence of the special qualities of fishmeal since soybean meal was not able to fully substitute fishmeal, at least not in the short run. Besides its rich protein content, fishmeal has its particular amino acids and fatty acid profiles. Without these special qualities one should believe fishmeal prices would not have diverged so much from soybean meal prices when there are severe negative production shocks.

3 MARKET INTEGRATION THEORY

The purpose of this chapter is to give an overview over some elements of the market integration theory. The theory deals with the subject of how to define the extent of the market. Although market delineation is quite unproblematic in theory, it has proved to be an area that is not wholly unproblematic in applied work. The extent of a market is far from self-evident due to factors such as geographical distance, quality differences in products and the aspect of time which is also a factor that segregates markets.

In Section 3.1 the microeconomic foundations of the theory concerning market integration and delineation are sketched out. Following this discussion a simple demand and supply model is outlined in Section 3.2 illustrating the implications of market integration. In Section 3.3 Hotelling's model of products differentiation is visited. In Section 3.4 the relationship between market integration and product aggregation is reviewed, which is quite instructive for a better understanding of the concept of market integration and its implications in a micro economic perspective. Finally, in Section 3.5 the operationalisation of market integration hypotheses is reviewed.

3.1 THE EXTENT OF A MARKET

3.1.1 MARKET DELINEATION

The central meeting point for almost all market definitions has been, and still is, the theory of supply and demand. The demand and supply theory assumes that there exists a market place constituted by a certain commodity, or bundle of commodities. Interaction between the quantity supplied and the quantity demanded of the commodity, given that all other relevant variables are constant, leads to a price, which represents the market equilibrium, so that the asking price of the last unit supplied equals the last buyer's willingness to pay. A mismatch between demand and supply will induce a change in the quantity supplied to the market, and/or the price received, so that the latter condition is fulfilled.

One of the main aims of market definitions is to find some criteria of how to delineate markets. Because price data are readily available and also contain much information concerning markets, they have been the point of departure in many definitions concerning market delineation. Especially the observation that certain prices seem to move together has become a key point in this analysis. This phenomenon is known as the "law of one price" (*LOP*) in its strict sense. More generally, this feature carries important information concerning the underlying market structures. Stigler's definition of the market is probably the best known definition concerning the extent of the market. He characterised the market as

> "the area within which the price of a good tends to uniformity, allowance being made for transportation costs" (Stigler, 1969).

Hence, if two products reside in the same market their prices will be interrelated in the long-run, although they can differ in the short run. The reason why there can exist a long-run relationship between prices, is the assumption that agents substitute between different suppliers (or goods) if there are possibilities of arbitrage.[6] If enough sellers and buyers are present, his definition would imply perfect competition.

Cournot provided other definitions that preceded Stigler's

> "It is evident that an article capable of transportation must flow from the market where its value is less to the market where its value is greater, until difference in value, from one market to the other, represents no more than the cost of transportation" (Cournot, 1971),

and Marshall

> "The more nearly perfect a market is, the stronger the tendency for the same price to be paid for the same thing at the same time in all parts of the market: but of course if the market is large, allowance must be made for the expense of delivering the goods to different purchasers" (Marshall, 1947).

[6] Arbitrage refers to the exploitation of differences between the prices of a commodity within or between markets by buying at low prices and selling at high prices. An arbitrage opportunity is a guaranteed profitable enterprise and is assumed to equalise price differentials.

Cournot's and Marshall's definitions preceded Stigler's. The three definitions all refer to selling a homogenous product in a market place where the product meets different transportation costs depending on the distance to the market place. The definitions determine the spatial extent of the market, which here means the geographical area that the market encompasses.

One of the main problems with conditioning market delineation solely on homogenous goods is that its application in market integration testing is more restricted than what really is necessary. By the definitions above it is implied that there is proximity in the spatial dimensions, product and time. The combinations of these requirements which homogenous goods have to fulfil, together with geographical proximity, assure that they are perfect substitutes. If there in addition are enough agents present in the market, it would be perfectly competitive. In such markets all buyers and sellers will find each other on the basis of having full information. A very literate example could be a grocery market for vegetables where there are several suppliers of identical products. The buyers can choose freely which supplier they will use without having to consider transportation costs.[7] Hence, the spatial proximity of the suppliers in space and time together with the fact that they supply the same vegetables, fulfil the necessary conditions of creating a market with perfect substitutes. Arbitrage then takes care of the price equalisation for the identical goods within the market.

Instead of using perfect substitutes as criteria for market delineation, allowance for imperfect substitutability would make market integration tests more applicable. Markets are seldom organised in such a way as illustrated with the grocery market, where you have perfect or near-perfect substitutes. If the vegetables market is expanded to include the wholesale dealers, the element of transportation costs would be incorporated into the market as well. Moreover, homogenous goods in themselves are not sufficient to constitute a perfectly integrated market. The markets for homogenous goods can be segmented in many ways, by transportation costs, governmental regulations, trade barriers, and too few agents in the market, either buyers or sellers. Hence, homogenous goods are not a guarantee of integrated markets. But the presence of substitution is evident through all the commodity arbitrage, which takes place in global

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[7] Although there are no transportation costs there will be costs in seeking all the relevant information which is thought necessary for trading in the market. Therefore the market for foreign exchange currencies could be a better example due to lower cost in obtaining the relevant information.

markets. When Richardson (1978) tested for arbitrage in the trade between Canada and the US of 22 commodity groups, he found that the hypothesis of commodity arbitrage could not be rejected for 9 out of them. But the hypothesis of perfect commodity arbitrage was rejected for all of them. This illustrates some of the problems with applying too strict criteria for market integration testing.

The real interest, should be to unveil if markets interact with each other or not. The point to make here is that even though markets are not perfectly integrated there may exist strong causal links between them. As long as products are perceived as substitutes to some degree, their demand will be related. And the consumers may even perceive products that are qualitatively very different as substitutes. Asche, Salvanes and Steen (1997) found that product as different as salmon and crustaceans seem to reside in the same market using cointegration tests and demand analysis for the European market. If, on the other hand, market delineation should be solely based on homogenous goods, this kind of conclusion would not be possible. It is not possible to disregard the fact that even though goods are imperfect substitutes, their markets can be very strongly related. In fact, the relationship may be so strong that it is not possible to analyse one market without taking the other into consideration. Hence, it is more appropriate to treat them as one market instead of two. Stigler has also extended the market integration concept by including heterogeneous products in the discussion (Stigler & Sherwin, 1985).

3.1.2 A SIMPLE DEMAND AND SUPPLY MODEL

The arguments raised in the preceding section concerning the conditions for market integration are better illustrated in the framework of a demand and supply model, not at least the implications of market integration. When market integration is discussed one can get the feeling that it is really just a question of price relationships. But the price is only a signifier of the underlying structures of the market. The important questions in relation to market integration are the spatial differences between markets; how close are the markets located? How do the products from the markets differ? When are the products/services available in the markets? Hence the spatial proximity in time, geographical- and product- space are key factors in determining the level of integration. In this model it is assumed that there are two markets represented by two goods, *i* and *j*, in an economy. The demand and supply relations for the two goods can generally be formulated as

$$y_i^D = (a_i + b_i p_S + c_i I) + d_i p_O, \qquad \text{where } b_i \geq 0, c_i > 0, d_i < 0 \qquad (3.1)$$

$$y_i^S = (e_i + f_i w_i) + g_i p_O, \qquad \text{where } f_i < 0, g_i > 0. \qquad (3.2)$$

Equation (3.1), the demand of good *i* y_i^D, is given by an intercept a_i, the price of a substitute p_S, the price of its own good p_O, and finally the income *I*. The variables in the parentheses represent the exogenous variables. A change in one of these variables will induce a shift in the demand. The size of b_i and c_i give the cross-price effect and income effect respectively while d_i is the effect of its own price. Equation (3.2) represents the supply, and is given by an intercept e_i, the price of the input factor w_i, and the price of the good p_O. Labour is assumed to be the only input. f_i is the effect of the wage level and g_i is the effect of the product price on the supply. As with (3.1) the parameters in the parentheses are the exogenous variables. Substitutability between good *i* and *j* is measured with the cross-price elasticity which can generally be formulated as

$$\varepsilon_{ij} = \frac{\partial y_i^D(p_i, p_j, I)}{\partial p_j} \frac{p_j}{y_i^D} = b_i \frac{p_j}{y_i^D} \qquad (3.3)$$

where $y_i^D(p_i, p_j, I)$ is the demand function of good *i*. The cross-price elasticity measures the percentage change in the demand of good *i* in response to a 1 percent increase in the price of good *j*. If the cross-price elasticity is positive, good *i* and *j* are substitutes, if it is negative, the goods are complements, and if it is zero, their demand is unrelated. Since b_i is assumed to be zero or larger the case of *i* and *j* being complements is excluded here.

The possible relationships can easily be illustrated in a figure. Let us assume there are two goods, 1 and 2. The prices of good 1 and 2 are normalised, meaning that they are initially set equal for the two markets. Hence, factors such as transportation costs and quality differences are disregarded here. In the following section three cases will be reviewed; no substitution, perfect substitution and imperfect substitution. All the cases will be analysed in the framework of a positive shift in the supply of good 1.

I . The case of no cross-price effect.

If $\varepsilon_{ij} = 0$ there is no substitution between the markets. This case is illustrated in Figure 3.1. In the market for good 1, there is a positive shift in the supply. This could be initiated by e.g. a reduced input price. The increased supply to the market leads to a decrease in the price of good 1. If there had been any possibility of substitution between good 1 and 2, consumers would to a certain degree switch their demand from good 2 to good 1 because of the change in relative prices. But since there is no cross-price effect no substitution will take place. The market for good 2 is unresponsive to the change in market 1.

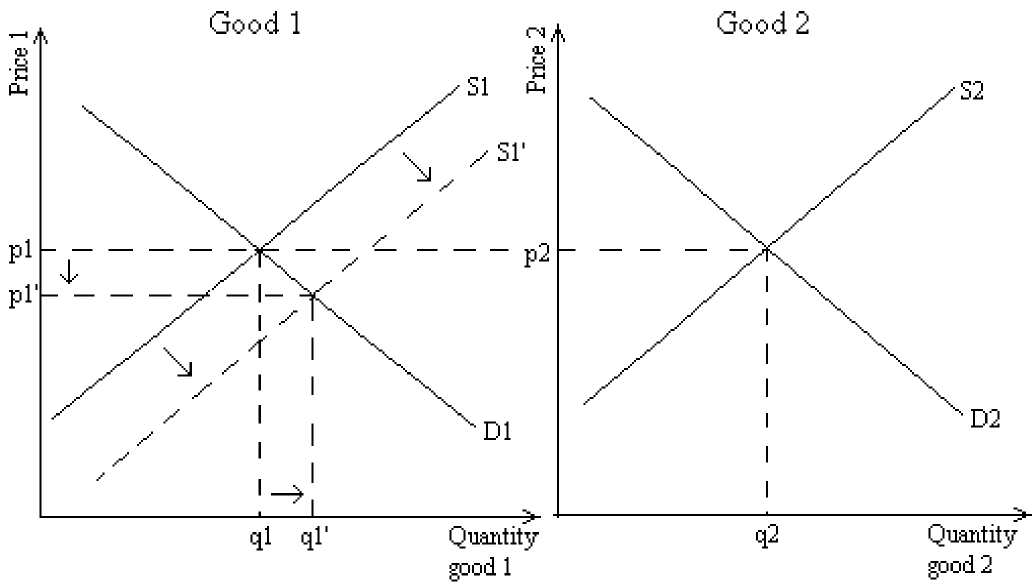

Figure 3.1 The market for two goods, good 1 and good 2. A positive shift in the supply curve of good 1 leads to a decrease in the price in the market for good 2. Due to the fact that the cross-price elasticity between the two markets are zero the market for good 2 is unaffected by the change in market i.

II. The case where good 1 and 2 are perfect substitutes.

The implications of good 1 and 2 being perfect substitutes are illustrated in Figure 3.2. Firstly there is a positive shift in the supply of good 1. The increased supply drives the prices in market 1 downwards. The consumers are indifferent between good 1 and good 2 and are therefore not willing to pay any more for good 2 than 1. Hence the demand for good 2 shifts negatively until the price for good 2 is exactly the same as the reduced price for good 1. Feedback mechanisms between the markets will drive the prices even further downwards than is illustrated in the figure, but the result concerning the relative price relationship is unaltered. Under these circumstances the *LOP* applies. Any shift in either of the markets that lead to a change in the price will lead to a response in the other market so that their prices are equalised, and they are as such perfectly integrated market.

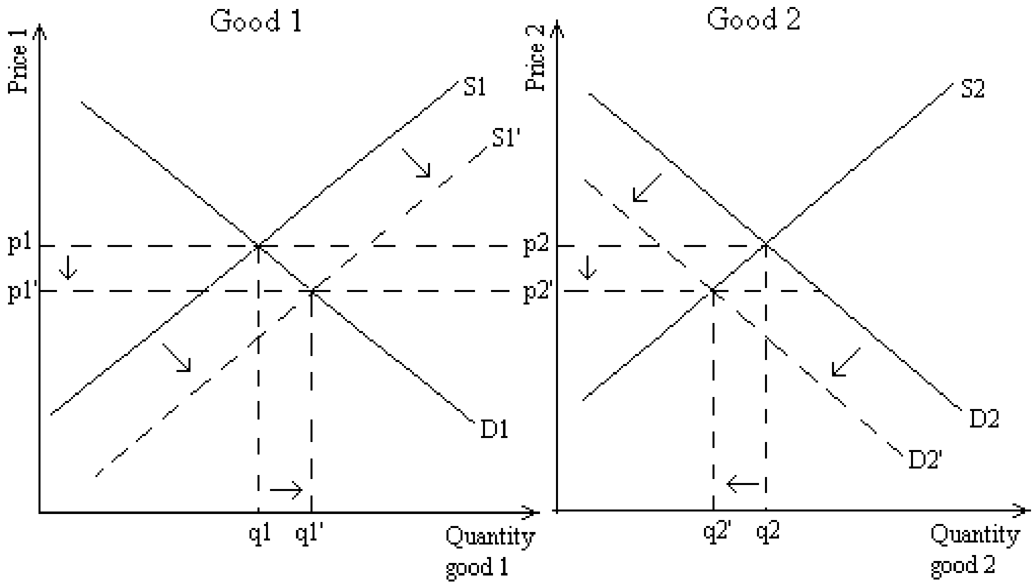

Figure 3.2 The market for two perfectly integrated goods, good 1 and good 2; A positive shift in the supply curve of good 1 leads to a decrease in the price in both markets due to a positive cross-price elasticity in the demand of good 2 in relation to the price of good 1.

III The case where good 1 and 2 are imperfect substitutes.

Initially there is a positive shift in the supply like the two preceding benchmark cases. Due to a positive cross-price elasticity the effects of the increased supply of good 1 on the market of good 2 will be similar to that of case II, only to a less degree. Since good 1 and 2 are substitutes, although imperfect, the demand will shift from good 2 to 1 to the point when the consumers are indifferent between the two goods. Hence, as long as there are arbitrage possibilities consumers will acquire good 1 instead of good 2. From Figure 3.3 it is shown that the demand for good 2 is reduced as a response to the price decrease for good 1, but not as much as good 1's. So contrary to Case II the relative price relationship does not stay constant after a shift in one of the prices.

These examples illustrate that the presence of integrated prices do not only signify an interrelation in the prices, but also through the quantity traded in each market. All of the above examples have utilised a positive shift in the supply as the point of exit in order to make the three cases more consistent. It could just as well have been a shift in the demand of one or the other kind. All of the variables in the parentheses of Equation (3.1) or (3.2) could have been used to illustrate the effect of integrated markets.

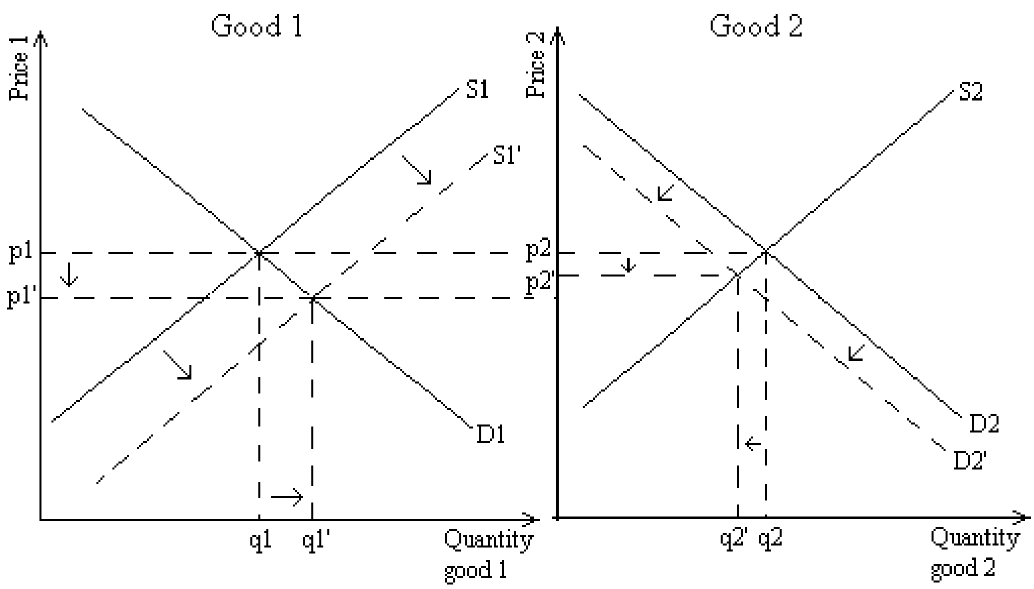

Figure 3.3 The market for two integrated goods, good 1 and good 2. A positive shift in the supply curve of good 1 leads to a decrease in the price in both markets due to a positive cross-price elasticity in the demand of good 2 in relation to the price of good 1, but the shift in market for good 2 is smaller due to imperfect substitutability.

It has been illustrated above that the significance of a long-run relationship between prices is that they are substitutes. Hence market integration implies that goods are either perfect or imperfect substitutes. If they are perfect substitutes the "law of one price" will hold. But in contrast to demand analysis, it is not possible to quantify the degree of substitutability, through the likes of the cross-price elasticity. Studying markets interrelationship through their prices is a study where one is only allowed to watch the price dimension in the Figures 3.1-3.3, and not the quantity axis. But underlying the price movements lies the mechanisms outlined by the theory of demand and supply, where an interrelation between markets open up for arbitrage possibilities.

Of course there is an inferential danger of wrongly concluding that there is market integration due to coincidental similarities in the price movements (Ravallion, 1986). For example, changes in income can generate similar price movements if the goods in question have similar income elasticities. But this is a methodological problem and not a theoretical one.

The discussion above is essential with respect to the analysis of the fishmeal and the soybean meal markets. In the introduction of this thesis it was suggested that fishmeal has special premium qualities that separate the fishmeal market from the soybean meal market.

Moreover, there were expressed fears of fishmeal scarcity in the future due to low supplies and increased demand. If fishmeal and soybean meal are found to be integrated it implies that they are substitutes. If so, then fishmeal is essentially demanded due to its protein content, and not for other qualities. Hence, fishmeal shortages in the future should only lead to temporarily high prices, since increased fishmeal prices will lead to a spillover in the demand towards soybean meal. Thus, the stronger they are integrated, the more important to the price development of fishmeal is the combined quantity supplied of fishmeal and soybean meal, and not their respective supply.

3.2 HOTELLING'S MODEL

The preceding model showed some of the implications of markets that were integrated. The purpose of Hotelling's model, which is presented here, is to show how differences in the dimensions of time, space and product quality can be perceived in a market integration framework. More specifically, it is the cases of when you have consumer transportation costs and product differentiation that are examined here. Hotelling's original model examined the effect of transportation costs, but has since often been used to analyse product differentiation. In Subsection 3.2.1 the basic model will be outlined, and in Subsection 3.2.2 there is a discussion on the significance of the model concerning market integration.

3.2.1 THE BASIC MODEL

The model looks at two identical firms, firm i and firm j, which sell an identical good at their respective shops, shop *i* and shop *j*. The shops are placed on a line where the consumers are uniformly distributed. The model examines how big market share the shops will achieve given their placement on the line. The only cost the consumer meet is the transportation cost, x to shop i and $(1-x)$ to shop j. x is also the location of the consumer. His utility can be described as

$$S - x - p_i, \qquad \text{if he buys at shop } i\text{, and} \tag{3.6}$$

$$S - (1-x) - p_j, \qquad \text{if he buys at shop } j \tag{3.7}$$

where *S* is his reservation price. If both shops operate with equal prices the consumer will buy at the shop located nearest themselves. The transportation costs are normalised to one, and since the shops are located at the ends of the line, shop 1 is placed at location *0* and shop 2 at location *1* (cf. Figure 3.4).

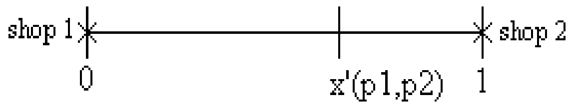

Figure 3.4 The indifferent consumer placed at x' between the two shops .

The indifferent consumer is placed at *x*'. All consumers to the left of him will buy at shop 1 while the consumers to the right will buy at shop 2. The placement of the indifferent consumer, *x*', is dependent on the prices, p_1 and p_2. *x*' will also represent the consumer which divides the market between the firms. Generally the indifferent consumer's location can be formulated as

$$x'(p_i, p_j) = \frac{1 - p_i + p_j}{2} \tag{3.8}$$

This is a Cournot equilibrium, which implies that competitiveness in the market will increase with the number of firms. From (3.8) it is clear that the two firms will divide the market 50/50 with equal prices. This is illustrated in Figure 3.5. The stapled lines draw up the market that each shop has. The location of the indifferent consumer is still marked as *x*'. Initially the shops are placed at each end of the line, at address *0* for shop 1 and address *1* for shop 2.

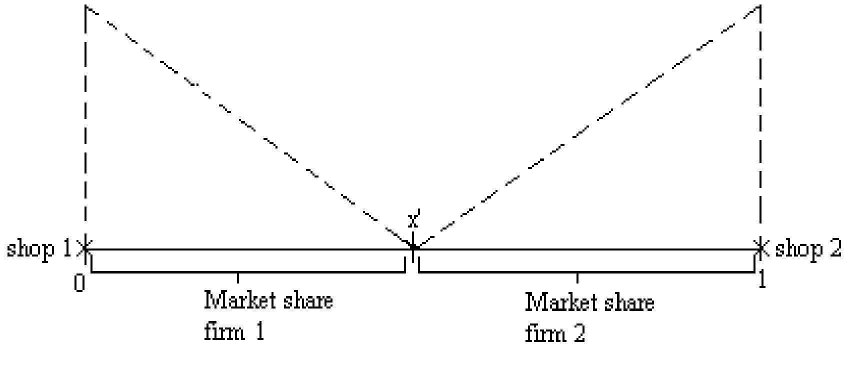

Figure 3.5 The market solution of two identical firms placed at each end of the line. With transportation costs the market is segmented in the middle, so that the firms take half of the market each.

The market is divided in the middle, under the assumption that both firms charge the same price for their product. This placement is not a Nash equilibrium since each firm can gain market shares by changing their position. This is illustrated in Figure 3.6. If shop 1 is initially located at *0* and then moves to the location marked in the figure, it will get a larger market share than it had initially. The reason is that many consumers now find that the transportation costs to shop 1 is reduced to the point where it is more inexpensive to travel to shop 1 rather than shop 2. If shop 1 is located even closer to shop 2 it will acquire an even larger share of the market. What is usually predicted in a situation where both shops have the possibility of relocating from their initial point, is that they both will end up at location 0.5, in the middle of the market as illustrated in Figure 3.7. At this point they will get 50 per cent of the market each, as they had initially, but since this is a Nash equilibrium none of the firms can gain by changing their position. This is known as Hotelling's law. The law is used to explain why competition can lead to reduced diversity in the sense that firms "mimic" each other in order to increase their market shares.

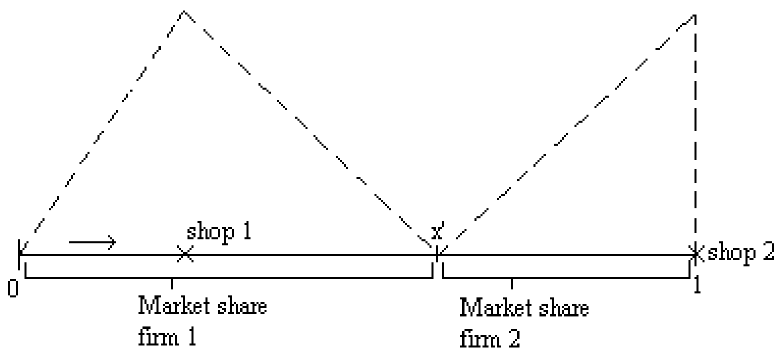

Figure 3.6 Shop 1 moves closer to shop 2 and thereby acquires a larger segment of the market.

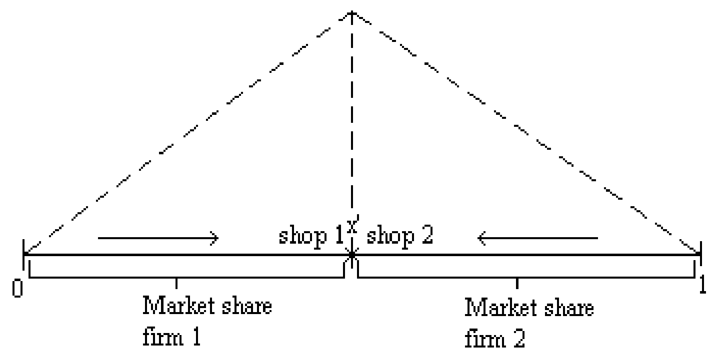

Figure 3.7 After initially being located at *0* and *1*, shop 1 and 2 are now located in the middle of the market in a Nash equilibrium. They have the same market share as they had initially, but have no incentives to change their positions since this would lead to a reduced market share.

3.2.2 MARKET INTEGRATION IN THE FRAMEWORK OF THE HOTELLING MODEL

In the basic model sketched above, the market is segmented between the firms due to transportation costs facing the consumers. Assume that the transportation costs in the market are reduced substantially after an initial segmentation as in Figure 3.6. The results are illustrated in Figure 3.8.[8] The lower transportation costs are represented with the lower stapled lines. Under the new regime both firms have a potential of capturing a larger segment of the market. Whether they finally capture this newborn potential is dependent on several factors. The transportation costs the consumers face are the same in the grey area in Figure 3.8, irrespective if they use shop 1 or 2. Thus, a marginal lower price from either of the two shops would lead to a capture of this whole segment. This can be interpreted as an imperfect market integration since the firms are perfectly integrated in the grey area while they are also being segmented by this area, having each a segment on either side of the grey area.

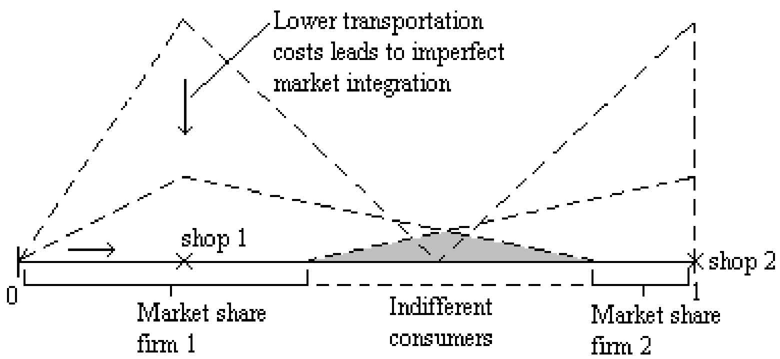

Figure 3.8 The transportation costs are reduced which is illustrated by the stapled lines which are "pressed" downwards. The shops have a larger potential clientele, but are dependent on the choice of the indifferent consumers' decisions.

If the transportation costs disappeared altogether, the stapled lines will "collapse" together with the horizontal line in Figure 3.8. In this situation the only aspect which interests the consumers is which shop can provide the lower price. The placements of the shops are irrelevant. So the market has in a sense gone from Cournot competition to Bertrand competition. This means that the firm, which is able to set the lowest price, will capture all of

[8] The locations of the shops are not essential in this discussion.

the market. As long as both firms are able to stay in the market it is implied that $p_1 = p_2$. Hence the market is perfectly integrated with the "law of one price" prevailing.

Hotelling's model can also be applied to product differentiation in this respect. If the line, instead of representing the distance between the two shops, represents horizontal differencing between the products from the two firms, then the consumers' placement on the line will represent their preferences for either product, instead of their distance to the shops. Market integration in this respect means that the consumers' preferences for either product are quite alike, implying that the products are substitutes. The purpose of product differentiation is not to integrate markets, but to segregate them. Firms try to differ their product in order to segment a share of the market from their competitors.

Fishmeal and soybean meal, on the other hand, are really more like different products than differentiated products. But in this context the important aspect is how the consumers perceive the products. If the consumers buy these products for the same reasons, then their markets will be integrated. The level of integration depends on the consumers' preferences. The more fishmeal and soybean meal are considered fulfilling the same needs, the more indifferent the buyers will be between these products. This is analogous to the collapse of the stapled line Figure 3.8.

3.3 OPERATIONALISATION OF MARKET INTEGRATION HYPOTHESES

After having reviewed some of the theoretical background concerning market integration, the next step is to see how market integration hypothesis can be implemented empirically. Since integration implies that the goods' prices in a market influence each other, econometric testing of market integration usually refers to testing for relationship between prices. A common way to formulate a hypothesis of market integration is through the equation

$$P_{1t} = \alpha P_{2t}^{\beta} . \qquad (3.9)$$

The subscript *t* of the prices indicates the relevant period. The size of β marks the degree of integration, where the closer it is 1 the closer they are integrated, and if it is 0 there is no integration at all. α accounts for the price differential by functioning as a scaling parameter. Hence if the price of good 1 P_{1t} is considered twice as large as P_{2t} in a long-term relationship α would be equal to 2. Such a price differential could be generated by transportation costs or quality differences among others. By taking the logarithms of the prices in (3.9) the model can be reformulated as a linear relationship

$$p_{1t} = \alpha_0 + \beta p_{2t} \tag{3.10}$$

where $p_{1t} = ln\, P_{1t}$, $p_{2t} = ln\, P_{2t}$ and $\alpha_0 = ln\, \alpha$. Market integration requires that $\beta \neq 0$ and, furthermore, the *LOP* hypothesis implies that $\beta = 1$. Although α_0 do not have interpretation as a scaling parameter anymore, it is still used to account for any price differential. Hence, the role of the parameter is to allow other than homogenous goods to be integrated by allowing for a price differential to enter the relationship. Equation (3.10) is a very strict formulation of the market integration hypothesis since it requires instantaneous adjustment. If the price of good 2 p_2 changes it is required that the price of good 1 p_1 adjusts in the same period. Slade (1986) proposed a method, which incorporates the fact that there may be some time lag before an actual adjustment takes place by including dynamic elements in the specification.

$$p_{1t} = a + \sum_{j=1}^{m} b_j p_{1t-j} + \sum_{i=0}^{n} c_i p_{2t-i} \; . \tag{3.11}$$

Here p_{1t} is dependent on lagged values of its own price, p_{1t-j}, and the present and lagged values of another price, p_{2t-i}. Causality is tested by testing a restriction laid on the c_i's so that null hypothesis is

$$H_0 : c_1 = c_2 = \ldots = c_N = 0 \; . \tag{3.12}$$

If this restriction is not rejected then the hypothesis of p_2 causing p_1 is not accepted. If, on the other hand, the null hypothesis is rejected, p_2 will have a significant influence on p_1.

Furthermore, the *LOP* hypothesis can be tested in this framework. In a dynamic sense the *LOP* hypothesis implies that $\sum b_j + \sum c_i = 1$.[9] By imposing the restrictions that all $b_j = 0$ and all $c_i = 0$ except for c_0 which is set equal to 1 it can be seen that equation (3.10) is just a special case of the more general equation (3.11). This test can be run both ways. If p_2 is set as the dependent variable instead of p_1 the effects of p_1 on p_2 can be tested.

Testing for causal relationships between markets is not analogous with testing for market integration. A causal relationship implies that one market influences the other, but not the other way round. In contrast, integrated markets are characterised by simultaneous determination of market prices typical of competitive markets.[10] But causal relationships do not exclude the possibility that the LOP hypothesis is fulfilled since causality can lead to very similar price movements between markets. The similarity arises from the fact that the market leader to some degree determines the price(s) of the other market(s).

A market that is a price leader does not necessarily have market power. Market power generally arises from the lack of substitutes. Thus allowing producers to the set the price and/or quantity independent of its competitors. More generally it is often required that a firm which has market power is able to set a price higher than its marginal cost. One way in which single producers can obtain this position is by product differencing, thereby segmenting its market from the “standard” product of the others. The size and location of markets can also limit substitution possibilities. With a spatial market structure consisting of a central market connected to several local markets, the central market typically functions as a price leader of the local ones due to its size and location. But the central market in itself may be well integrated and competitive, and as such does not have any market power.

The fishmeal and soybean meal markets may separately be perfectly competitive, but that does not hinder one of them having influence on the other. Soybean meal is maybe the most

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[9] Consider the form Equation (3.11) takes when $p_{1t} = p_1^*$ and $p_{2t} = p_2^*$; then (3.11) can be reformulated as $p_1^* = \frac{a + \sum c_i p_2^*}{1 - \sum b_j}$, and if $\sum b_j + \sum c_i = 1$, then $p_1^* = a + p_2^*$.

[10] Market integration is by no means sufficient for the Pareto optimality of a competitive equilibrium (Newberry and Stiglitz, 1984). If there were many suppliers in the market one could always assume a competitive equilibrium, but acceptance of the market integration hypothesis does not itself prove that there is perfect competition in the market.

likely candidate as a price leader of the two. With a trade 10 times the size of fishmeal it certainly has a potential of being dominant.

3.4 MARKET INTEGRATION AND PRODUCT AGGREGATION

A concept that can shed more light on market integration and the *LOP* is product aggregation. The interesting question regarding product aggregation is: When is it possible to study the demand of some goods as a group without worrying about how the demand is divided between them? This question is the basis for the concept of Hicksian separability. Hicksian separability relates to the composite commodity theorem developed by Hicks and Leontief and sets criteria of how to aggregate products. The idea behind the concept is to find a method of handling a group of goods as one good by creating a price, in reality a price index, which represents all of them. It uses a deterministic relationship between the prices of goods as condition for grouping. If two goods are used, as described by Deaton and Muellbauer (1980), the following relationship can be set up

$$P_{1t} = \theta_t P_{10} \text{ and } P_{2t} = \theta_t P_{20} \tag{3.13}$$

where θ_t varies with time. The relationship that θ_t describes between the two prices is strictly deterministic. It sets the prices by scaling them at the same rate such that the relation between P_1 and P_2 stays exactly the same, namely at P_{10}/P_{20} where the zero refers to any arbitrarily chosen base period. Any deviation from this relationship would lead to rejection of the composite commodity theorem as set by Hicks and Leontief. If one of the equations in (3.13) is solved for θ_t, (3.13) can be rewritten as

$$P_{1t} = \left(\frac{P_{2t}}{P_{20}}\right) P_{10} . \tag{3.14}$$

By defining $b = P_{10}/P_{20}$, this can be written as

$$P_{1t} = bP_{2t} . \tag{3.15}$$

From (3.15) it can be seen that the prices move proportionally over time. If you take the logarithm to (3.15) it can be formulated as:

$$\ln P_{1t} = \ln b + \ln P_{2t} \tag{3.16}$$

If there were put a restriction on (3.10) that $\beta = 1$, then (3.10) and (3.16) would be identical. Thus, the composite commodity theorem is a special case (3.10). More precisely, the composite commodity applies when the *LOP* applies in its strictest sense, i.e. when there is an exact relationship between the prices. An alternative formulation was put forward by Lewbel, since the original theorem was not really applicable in empirical testing (Lewbel, 1996). Lewbel showed that appliance of the composite commodity theorem would always lead to rejection of aggregation due to its strictly deterministic formulation. He has modified the original theorem and come up with a more general formulation. His formulation is applicable in all but welfare economics.

4 TIME SERIES ANALYSIS

This chapter presents some basic elements of time series analysis together with the Johansen Maximum Likelihood (*ML*) cointegration test. These are the statistical tools used in this thesis to analyse the relationship between fishmeal and soybean meal prices. In Chapter 1 it was pointed out that the varying nature of time series variables make the choice of estimation methods a non-trivial question, since the choice of an inappropriate test procedure can give misleading inferences. There has been a shift in econometric modelling, especially during the last decade, due to an increased awareness of the presence of unit roots in many time series variables. Unit roots leads to non-stationary variables that invalidates classical estimation methods like the *OLS*. The *OLS* estimation procedures cannot handle time series containing unit roots since they do not fulfil the classical properties of the residual, which are

i) $E[u_t] = 0$

ii) $E[(u_t)^2] = \sigma^2$

iii) $E[u_t u_s] = 0$

These three properties are sufficient and necessary to ensure a white noise residual. Non-stationary time series break with the first two properties, i.e. a zero mean and a constant variation. Conventional tests of hypothesis will be seriously biased towards rejecting the null hypothesis of no relationship between the dependent and independent variables. Hence the t- and F-tests based on normal distribution are no longer applicable. Therefore it is necessary to choose one of the more recently developed methods which can handle non-stationary variables.

In Section 4.1 some concepts which describe each time series variable are discussed. The first concept is *stochastic process*, which is a concept that is used to simulate the data generating process (*DGP*) behind time series variables. Furthermore the concepts *stationary, non-stationary* and *integrated series* are described. A *unit root* test is a test to uncover if a time series is integrated or not. In Section 4.2 there is a discussion of the Dickey Fuller (*DF*) unit root test and the augmented version of the *DF* test. In Section 4.3 the concept of cointegration is briefly discussed, and finally in Section 4.4 the Johansen *ML* procedure is described.

4.1 STATIONARY AND NON-STATIONARY TIME SERIES VARIABLES

A stochastic process is characterised by random data generation. It is a collection of random variables, which in this case are ordered in time. Formally this sequence of random variables, Y_t, can be characterised by its first and second moments:

Mean $\mu_t = E(Y_t)$ (4.1)

Variance $\sigma_t^2 = var(Y_t)$ (4.2)

Autocovariance $\gamma_{t_1,t_2} = cov(Y_{t_1}, Y_{t_2})$ (4.3)

The sample space is here represented with two realisations, Y_{t_1} and Y_{t_2}, where variation over t will describe a stochastic process. Note that the value of Y_t is dependent on the point in time it is drawn. From the second property it can be seen that the stochastic process is heterogeneous with respect to time, i.e. the variance is not constant over time. The third property suggests that the process is characterised by having a memory, implying that the value of the variable in this period depends on the variable's value in the preceding time period.

A stochastic time series variable can either be stationary or non-stationary. A stationary time series variable has, as opposed to a non-stationary variable, a restriction on the stochastic process. The restriction relates to the variance of the process, which is now assumed time invariant, i.e. constant over time. A stationary stochastic process $\{Y_t, t \in T\}$ can now be described as

$$E(Y_t) = E(Y_{t+\tau}) = \mu \quad (4.4)$$

$$E(Y_t^2) = E(Y_{t+\tau}^2) = \sigma^2 \quad (4.5)$$

$$cov(Y_{t_1}, Y_{t_2}) = cov(Y_{t_1+\tau}, Y_{t_2+\tau}) = \gamma_{t_1,t_2} = \gamma_\tau \quad (4.6)$$

where μ, σ^2 and $\gamma_\tau < \infty$, and $t_1 - t_2 = \tau$. For all $t = 1,\dots,T$ the stationary process has a constant mean, a constant variance and a covariance that only depend on the lag or interval $\tau = t_1 - t_2$, not on t_1 and t_2.

Non-stationary variables can be divided into two groups, *difference-stationary processes* (*DSP*) and *trend-stationary processes*[11] (*TSP*). A *TSP* process can be formulated as

$$y_t = \mu + \beta t + u_t , \tag{4.7}$$

where the residual, u_t, has the properties of white noise. The *t* variable is a time variable. By removing βt successively from each realisation of y_t, the *TSP* is detrended. The remains of y_t are then a stationary process around the intercept μ. Equation (4.8) below is on the other hand a *DSP*. In the rest of this thesis the concepts non-stationary process (or variable) and *DSP* are used interchangeably. A non-stationary series is integrated of a higher order than zero. A series is said to be integrated of order *d* if it has to be differenced d times to become stationary, thereof the name difference stationary process. To take the first difference of a time series you subtract the value of the previous period from this period, i.e. $y_t - y_{t-1} = \Delta y_t$, while the second difference is formulated as $\Delta y_t - \Delta y_{t-1} = \Delta^2 y_t$. Integrated series are denoted by *I[D]*. An example of an integrated series is

$$y_t = y_{t-1} + u_t \tag{4.8}$$

where u_t have the properties of white noise. Equation (4.8) is a random walk which is integrated of order one, *I[D]*. With only one explanatory variable besides the stochastic error term, u_t , it is the simplest projection of a non-stationary series. A random walk is a special case of an autoregressive process[12] of first order (*AR[1]*). An *AR[1]* is formulated as $y_t = \rho y_{t-1} + u_t$ where ρ is set to one in the case of a random walk. If ρ is on the other hand set between -1 and 1, the *AR[1]* process is stationary. It was mentioned earlier that integrated series have memory. Memory implies that the innovations that come from stochastic shocks remain in the process. This can be illustrated more instructively if (4.8) is reformulated. Firstly, the preceding period is written as

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[11] A trend-stationary process can be described as $z_t = \alpha + \delta t + u_t$. The series can be said to be stationary around the trend t, i.e. if the trend is removed the series will be stationary.

[12] An autoregressive process of order *p* can be formulated as $y_t = \psi_1 y_{t-1} + \psi_2 y_{t-2} + ... + \psi_p y_{t-p} + u_t$ where $u_t \sim IID(0, \sigma^2)$.

$$y_{t-1} = y_{t-2} + u_{t-1} \tag{4.9}$$

When (4.9) is substituted into (4.8) the result is

$$y_t = y_{t-2} + u_{t-1} + u_t \tag{4.10}$$

If this exercise is repeated iteratively all the way back to the base period of the series, the process behind the sample series can be written as

$$y_t = y_0 + \sum_{i=0}^{T} u_{t-i} \tag{4.11}$$

The intercept y_0 is the initial value in the base period. The last realisation of the process, y_t, is the sum of stochastic shocks from all the previous periods. The shock in one period is brought over to the next period. This is what is meant by memory. A stationary series will only bring a portion of the effect over to the next period, and as the time dimension increases the effects of the previous periods will die out. Formulating a stationary process equivalently to the non-stationary in Equation (4.11) shows this more easily.

$$y_t = y_0 + \sum_{i=0}^{T} \rho^i u_{t-i} \tag{4.12}$$

where $|\rho| < 1$. Since ρ is smaller than unity, the elements in the summation bracket will become smaller and smaller the larger *i* gets. In the end the effect of the previous periods on this period will be infinitely small as the number of time periods separating them increases.

4.2 UNIT ROOTS TEST

A unit root test is a univariate test used to determine if a time series variable is stationary or not. The name unit root refers to the root of the *characteristic equation.* There may be more than one unit root present in a time series variable, which means that the variable is integrated of a higher order than one. The order of integration of the variable is equal to the number of unit roots present in the characteristic equation. To find the characteristic equation of an *AR[1]* process it is useful to rewrite the process using *lag operators*. A lag operator L is defined as having the characteristics $Ly_t = y_{t-1}$ and $L^2 y_t = y_{t-2}$. If we substitute y_{t-1} in an *AR[1]* with a lag operator we can rewrite it as

$$(1 - \rho L)y_t = u_t \tag{4.13}$$

where the characteristic equation is $(1 - \rho L) = 0$. There can only be one unit root in this case, $L = 1/\rho$. If $\rho = 1$ then y_t is an *I[1]* series and if $\rho < 1$ it is an *I[0]* series, which means that it is stationary. In more complex processes there may be more than one unit root.

There are several ways to test for unit roots, and the method which maybe has proved most popular is the Dickey-Fuller (*DF*) test (Dickey and Fuller, 1979). The restrictions on the *DGP* imposed on y_t in the *DF* test is that $y_t = \rho y_{t-1} + u_t$, where the null and alternative hypotheses are

$$\begin{aligned} H_o &: \rho = 1 \\ H_1 &: \rho < 1 \end{aligned} \tag{4.14}$$

Another way to formulate the *DF* test is to look at the first difference of y_t. It can be formulated as $\Delta y_t = (\rho - 1)y_{t-1} + u_t$. The null and alternative hypotheses are then

$$\begin{aligned} H_0 &: \rho^* = 0 \\ H_1 &: \rho^* < 0 \end{aligned} \tag{4.15}$$

where $\rho^* = \rho - 1$.

A problem with non-stationary series is that they do not conform to the regular t-distribution. Two-thirds of the sample is skewed to the left of the true value, which means the null hypothesis will be over-rejected using critical values from the t-distribution. Dickey and Fuller developed new critical values based on Monte Carlo computations of equation (4.8). Thus, the critical values of the *DF* test are therefore based on the outcomes of a random walk process. But the true *DGP* is not necessarily best described with (4.8). There may be deterministic components in the process, like an intercept, a trend or dummies. The *DF* test can be expanded to include deterministic components like an intercept and a trend. Visual inspection of time series can give a good indication of the presence of an intercept (non-zero mean) and trend. Deterministic components included in the model require new *DF* critical values. Dickey and Fuller have calculated these as well (Dickey and Fuller, 1981). With a constant, μ, and a trend, *t*, included the equation can be written on a first difference form as

$$\Delta y_t = \mu + \gamma\, t + (\rho - 1) y_t + u_t \qquad (4.16)$$

It has been argued that one should begin with a richly specified regression model, because if there are less deterministic components in the model than in the *DGP* the null and alternative hypothesis will not be nested. A procedure suggested by Perron (1988) is to start with a richly specified regression and then move to more restricted regressions until the null is rejected (Perron, 1988). Another specification problem usually encountered with the *DF* approach is autocorrelation. Instead of being an *AR[1]* process, which the *DF*-test presume, it might be an *AR[p]* process. Autocorrelation occurs because the residuals compensate for the mis-specification. A modified version of the *DF*-test has been developed to deal with this problem, namely the Augmented Dickey Fuller (*ADF*) test. With a trend and intercept included the *ADF* test can be written as

$$\Delta y_t = \rho y_{t-1} + \sum_{i=1}^{p-1} \beta_i \Delta y_{t-i} + \mu + \gamma t + u_t \qquad (4.17)$$

The size of *p* determines the order of the *AR* process. The differences of the earlier periods, Δy_{t-i}, account for the autocorrelation which were present in the *DF* test. The *ADF* test is also valid if there is a moving average[13] term (*MA[q]*) present in the process, which makes the process an *ARMA[p,q]*[14], as long as the lag length *k* increases at a suitable rate with the size of the sample (Said and Dickey, 1984). Generally, it is not easy to choose the correct lag length. Several approaches have been suggested in determining the number of lags to be included. Schwert (1989) suggested a rule based on the sample size *T* formulated like

[13] A moving average process of order *q* can be formulated as $y_t = u_t + \theta_1 u_{t-1} + \ldots + \theta_q u_{t-q}$ where $u_t \sim IID(0, \sigma^2)$.

$k = INT\{12(T/100)^{1/4}\}$. The problem with this rule is that it is not optional for all *p* and *q* in the *ARMA[p,q]*. Hall (1994) discussed two sequential rules, specific to general and general to specific. The specific to general rule suggests that one starts with a small *k* and increase successively until a non-significant lag is encountered. The general to specific rule, on the other hand, suggests that one starts with a large *k* and reduces the number until a significant lag is encountered. Hall, amongst others, has argued that the general to specific approach is to be preferred because of problems with asymptotic validity of the specific to general approach. One of the problems with the *ADF* test is the choice of lag length. There is a trade-off between size and power; the unit root test has high probability of rejecting the null of non-stationarity falsely, and low power of keeping the alternative when true (Blough, 1992, p. 299). The reason why this problem arises, is the difficulty in dividing between a near stationary series and real one. It should be noted that if more than one parameter is included in the model, the critical values of MacKinnon (1991) are used.[15]

4.2.1 SEASONAL VARIATION

Seasonal variation is present in many data series that are reported more than once a year. When non-annual time series data are presented, they sometimes come as seasonally adjusted. The methods used for adjusting the data tend to be quite ad hoc and can cause distortion and loss of information in the data. Therefore seasonally unadjusted data are usually preferred. In particular, seasonally adjusted data tend to be biased toward rejecting the null of non-stationarity too seldom with the *DF* test (Harris, 1995, p 42). Another problem is that seasonal adjustment may build autocorrelation in the residuals where none was earlier (Greene, 1992, p 412). A common way to account for seasonal variation, instead of seasonally adjusting the data, is by using seasonal dummies. If monthly data are used, as the case is here, then 11 dummies are included. The estimates of the dummies will then account for a part of the value of the endogenous time series variable each month. This is a deterministic way of estimating seasonal variation that will not be able to account for stochastic changes in the seasonal pattern.

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[14] Autoregressive moving average process where *p* is the number of lags in the AR process and *q* is the number of lags in the MA process.

Alternatively, seasonal processes may be non-stationary if the seasonal pattern is changing over time. In such case it would be necessary to seasonally difference the variable to capture the seasonal variation. If the variable is reported on a quarterly basis, there may be up to four different unit roots in a seasonal process. This problem may be formulated as $\Delta_4 y_t = (1-L^4)y_t = y_t - y_{t-4}$. If the characteristic equation, $(1-L^4)=0$, is factored, we get the following equation

$$(1-L^4)=(1-L)(1+L)(1-iL)(1+iL)=0. \tag{4.18}$$

From this equation it can be seen that there may be four unit roots, with two of them consisting of complex numbers, *iL*. With data on a monthly basis, which is the case in this thesis, there can be up to twelve unit roots. This route will not be followed here due to its complexity. This approach is not usually applied since the finding of seasonal unit roots has proved difficult.

There are other ways to account for seasonal variation. A method is to try to model the seasonal variation as an *ARIMA*[16] process. If the autocorrelation function is visually inspected, patterns in the peaks from year to year may give an indication of the seasonal variation. Modelling an *ARIMA* process on this basis is not easy, since the picture is seldom clear cut. An *ARIMA* process included in the model would make it overly complex. In this thesis I will limit the method of seasonal adjustment to the use of seasonal dummies.

4.2.2 STRUCTURAL BREAKS

Another problem with unit root tests is structural breaks. A structural break can be interpreted as a shift in the *DGP* of some kind. If there is a shift in the mean or the variance of the sample of a stationary series, failure to account for this may lead to wrongly accepting the null hypothesis, i.e. problem with low power of the test (Perron, 1989). Structural breaks occur for several reasons: permanent shifts in the series, ad hoc shocks like the oil crisis, wars etc. The problem with structural breaks is that they are seldom known *a priori*. It is therefore

[15] The critical values of MacKinnon have replaced the *DF* critical values in PcGive 9.0, which is the software that is used here.
[16] An *ARIMA* process is an *ARMA* process which is integrated of a higher order than zero.

necessary to conduct tests for structural shifts. Structural shifts and parameter instability are closely related concepts. If there are any structural shifts present in the data series, model estimation can produce estimators that are unstable over the sample. Recursive estimation can produce Chow tests that give good indications of parameter instability. The Chow tests are F-distributed and rely on normally distributed errors from the estimations. Hence, the tests have to be interpreted with some care if the errors do not fulfil this property.

Outliers are another concept that is closely related to structural breaks, and are often described as a particular kind of structural breaks. An outlier is an irregular observation in the sample that may lead to distortions in the estimators if not taken into account. Visual inspection of the residuals from the estimated equations will reveal potential outliers, and will appear as irregular high or low value in the residuals. Dummy variables will remove outliers if necessary. Dummy variables are also a mean of removing structural breaks.

4.3 COINTEGRATION

Cointegration is a method to examine the relationship between integrated time series variables. The general observation, which motivates cointegration estimation, is that some variables seem to move together over time. If the variables are cointegrated they are restricted in such a way that they cannot wander to "far away" from each other. This fits with the discussion of the *LOP* hypothesis in Chapter 3 regarding the price movements of integrated markets. Cointegrated variables can be interpreted as having long-term steady state equilibrium in an economic framework. Furthermore, the short run dynamics can be studied in the Johansen framework (Johansen, 1988, 1991), which was not possible with earlier methods.

The Johansen multivariate test is one of two cointegration procedures that are usually used for market integration testing, the other being the Engle and Granger (*E-G*) bivariate test (Engle & Granger, 1987). The Johansen test has a couple of advantages over the *E-G* test besides being able to handle multivariate systems. In the bivariate *E-G* test one has to normalise on one of the prices, i.e. one of the price variables has to be chosen as the dependent variable while the other price functions as an explanatory variable. The problem is that the *E-G* procedure does not give any suggestions to which of the two prices should be chosen as the dependent variable. Economic theory can only suggest which variable to treat as the dependent, but in the end one has to rely on *a priori* beliefs on the interrelation between two prices. In practical application testing both price variables as dependent variables often solves this problem. Often such a procedure will reveal conflicting results, although the results of the tests are asymptotically identical. This makes interpretations of the results difficult. Another problem with the *E-G* procedure is that hypothesis testing on the cointegration test results is not valid. It is not sufficient to establish that there exists a long-run relationship between the prices of the two products. The market integration hypothesis has to be tested by imposing certain restriction on results from the cointegration tests. The nature of these restrictions will be returned to later. These problems are not prevalent in the Johansen procedure.

The Johansen procedure will be used here in order to determine if there exists a single market for fishmeal and soybean meal, since they are both technical substitutes in animal feed. Finally, it is worth noting that tests used in time series analysis generally do not represent any exhaustive descriptions of the time series. The underlying data generation process may be so complicated that it is really not possible to model it satisfactory. Thus, it is vital to evaluate all information available, and not only confer to the test results.

4.4 THE JOHANSEN PROCEDURE

As mentioned earlier, the motivation for using other methods than *OLS* estimation is the possibility of spurious regressions (Yule, 1926), i.e. regressions which paint a false picture of the world. The Johansen procedure is capable of handling a multivariate system of non-stationary variables in a way that produces statistical valid test results (Johansen, 1988). It also has a couple of advantages over the *E-G* procedure besides the advantage of handling multivariate series. Firstly, hypothesis testing is valid in the Johansen framework, but not with Engle-Granger. Secondly, in the two-variable case there is not the problem of deciding which variable to normalise upon since both variables are endogenous in the system.

To start with we have a vector autoregressive (*VAR*) system:

$$
\begin{aligned}
y_{1t} &= \sum_{i=1}^{n} \pi_{11i} y_{it-1} + \sum_{i=1}^{n} \pi_{12i} y_{it-2} + \ldots + \sum_{i=1}^{n} \pi_{1ki} y_{it-k} + \sum_{i=1}^{n} u_{1it} \\
y_{2t} &= \sum_{i=1}^{n} \pi_{21i} y_{it-1} + \sum_{i=1}^{n} \pi_{22i} y_{it-2} + \ldots + \sum_{i=1}^{n} \pi_{2ki} y_{it-k} + \sum_{i=1}^{n} u_{2it} \\
&\ldots \\
y_{nt} &= \sum_{i=1}^{n} \pi_{n1i} y_{it-1} + \sum_{i=1}^{n} \pi_{n2} y_{it-2} + \ldots + \sum_{i=1}^{n} \pi_{nki} y_{it-k} + \sum_{i=1}^{n} u_{nit}
\end{aligned}
\tag{4.19}
$$

where there are *n* endogenous variables included in the matrix. The *VAR* system can be written in a more compact form as:

$$Y_t = \Pi_1 Y_{t-1} + \ldots + \Pi_k Y_{t-k} + \mu + u_t , \qquad u_t \sim IN(0,\sigma) \tag{4.20}$$

where Y_t are the *nx1* potentially endogenous variables, the Π_i's are *nxn* matrix of parameters, μ is an intercept vector, and u_t is the residual matrix. This is a system with jointly endogenous variables without any strong *a priori* restrictions. (4.20) can be rewritten as first differences. Unless the error process is also differenced, it is implied that there is a loss of information in the data (Johansen & Juselius,1990). (4.20) is rearranged by taking the first differences of the endogenous variables, except the Y_{t-k} variable, giving

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \ldots + \Gamma_k \Delta Y_{t-k+1} + \Pi Y_{t-k} + u_t . \tag{4.21}$$

The new parameter Γ_i and Π are combinations of the matrixes Π_i, and can be formulated as $\Gamma_i = -I + \Pi_1 + ... + \Pi_i , \quad i = 1,\ldots,k-1$ and $\Pi = -I + \Pi_1 + ... + \Pi_k$. The advantage of the formulation in (4.21) is that the long-run relationship can be identified. The Π matrix contains the long-run parameters which can be interpreted as the mechanism that brings the system back to a steady state equilibrium. The Γ_i matrixes are the effects of the variables in previous periods. Assuming that all the variables, Y_t, used in the *VAR* system are *I[1]*, then all the terms involved in ΔY_t must be *I[0]* since first differences of *I[1]* variables produce *I[0]* variables. What remains in Equation (4.21) is ΠY_{t-k}, the long-run equation in the system. ΠY_{t-k} must be *I[0]* if the residuals, u_t, are to be white noise. In other words, there has to exist a matrix Π that make Y_{t-k} stationary when multiplied. We can examine the long-run matrix Π more closely by splitting it up into two matrixes, $\alpha\beta'$. α can be interpreted as the speed of adjustment to equilibrium, and β as the matrix of long-run coefficients. Thus, the $\alpha\beta'$ are the parameters that bring back the system to the long-run steady state equilibrium. This leads $\beta' Y_{t-k}$ to represent up to *n-1* potential cointegration vectors. The existence of cointegration vectors are necessary if the multivariate model is to converge to a long term equilibrium, but it is not a necessary criterion for the u_t to be white noise. There are three instances where the residual u_t is white noise:

i) The rank of the matrix Π is zero. There are no cointegration vectors and consequently there do not exist any linear combination of Y_t that are *I[0]*. In this case all the *nxn* elements of Π are zero, which is a trivial solution.

ii) Π has a full rank. This is equivalent as stating that there are *n* stationary variables in the model. As with 1) this is an uninteresting solution, since when no interrelationships between the variables are uncovered, the *I[0]* variables form 'cointegration relationships' themselves.

iii) The rank of Π is $r \leq (n-1)$. In other words there exits *r* cointegration vectors in β that make *r* linearly independent combinations of Y_{t-k}. The *r* columns in β form stationary long term relationships between the variables in Y_t. It is also implied by the rank *r* of Π that all the elements in the columns of α corresponding to the cointegration rows in β', are significant.

Earlier it was assumed that all the variables in Y_t were *I[1]*. Generally it is not necessary that the variables are integrated of the same order. A combination of *I[0]*, *I[1]* and *I[2]* variables can be integrated, except in the bivariate case. But when testing for market integration where the Law of One Price is the fundament it is more or less required that the price variables are integrated of the same order since the same underlying data generation process is presupposed.

4.4.1 TESTS FOR COINTEGRATION VECTORS

There are two tests that are used for examining the number of cointegration vectors. Both are Likelihood Ratio tests (Johansen and Juselius, 1992). The first is the maximum (*max*) eigenvalue test (λ_{max}) and the other is the *trace* test (λ_{trace}). The null hypothesis of the first test is whether there are not more than *r* cointegration vectors, against the alternative that there are more than *r* cointegration vectors. The null of the trace test is equal to that of the *max* test, but the alternative is that there is $r+1$ cointegration vectors. The *trace* shows more robustness against skewness and excess kurtosis in the residuals than the *max* test (Cheung and Lai, 1993), and should be assigned more weight if problems with the distribution of this kind are encountered.

4.4.2 MIS-SPECIFICATION TESTS

The are several mis-specification tests reported in the PcFiml 9.0. The Portmanteau statistic is a goodness-of-fit test based on the *ARMA* model. It is a lagrange multipler (*LM*) test which is only valid in single equations with no exogenous variables, which is the case in *VAR*-estimation. The null hypothesis is that the Ljung-Box statistic is asymptotically distributed as $\chi^2(s-k)$ where *k* is the lag length in the *AR* model. There is a *LM* test of no autocorrelation in the residuals. This test is performed through the auxiliary regressions of the residuals on the original variables and lagged residuals. The null hypothesis is no autocorrelation, which would be rejected if the test statistic gets too high. The *ARCH* test (AutoRegressive Conditional Heteroscedasticity) is a *LM* test that tests the joint significance of lagged square residuals in the regression of squared residuals on a constant and lagged square residuals. The null hypothesis is no autocorrelated squared errors which is reported as χ^2 and F-statistic. A test for normality as proposed by Doornik and Hansen (1994) amounts to test whether skewness and kurtosis of the residuals corresponds to that of normal distribution. The null hypothesis is that of no skewness and kurtosis. A test for heteroskedasticity based on White (1980) involves an auxiliary regression of the squared residuals on the original regressors and all their squares. The null is unconditional homoscedasticity. The output comprises TR^2, the F-test equivalent, and the coefficients of the auxiliary regressions plus their individual t-statistics to help highlight problem variables. In addition there are versions of each of these tests in vector form, except of the *ARCH* test, to test the system specification as a whole.

4.4.3 WEAK EXOGENEITY

A variable Δy_{it} is defined as weakly exogenous in the system if there is no loss of information by not modelling the determinants of Δy_{it} (Harris, 1994, p 98). Hence, Δy_{it} is sufficient as a right hand side variable in the system. To determine if a variable is weakly exogenous in a system amounts to testing if all the elements of the row in the α matrix corresponding to the variable Δy_{it} are not significantly different from zero. These elements in α are the speed of adjustment parameters that decide at which rate the other variables influence Δy_{it}. When the elements are zero, the other variables have no influence on Δy_{it}. This is a Likelihood Ratio test.

The economic interpretations of exogenous price variables are that they function as price leaders. The interrelation between geographical markets is often such that you have a central market which is connected together with many local markets (Ravallion, 1986). In such cases the central market will often function as a price leader that influences or even sets the price in the local markets. Price leaders can also be interpreted in a context of product space. Here, for instance, the soybean meal price could be candidate as a weakly exogenous variable since the trade of soybean meal is ten times bigger than fishmeal, and the production even bigger.[17]

4.4.4 MARKET INTEGRATION AND LOP HYPOTHESIS TESTING

Market integration within a *VAR* system of n price variables implies $n-1$ cointegration vectors. This is the same as stating that all the variables are pairwise cointegrated (Asche, Bremnes and Wessels, 1998). This point can be more easily seen in a geometric perspective. If there are three endogenous variables in a system they will span R^3. If the variables are non-stationary, and there is a common trend the system converges to a long-run equilibrium represented by a line, determined by the intersection of the planes defined by the two, $n-1$,

[17] Cf. Section 3.3 for a discussion of price leaders in an econometric context.

cointegration vectors, in R^3. This is a stationary equilibrium in the sense that the variance about this line is finite (Dickey, Jansen & Thornton, 1994). The variables can only be scaled equally up or down along this line, thereof they all have the same stochastic trend. Hence, testing of market integration with all pairs of price variables, is identical with testing the whole system of price variables for $n-1$ cointegration vectors, at least theoretically. Generally, hypothesis can be tested in the Johansen framework by imposing restrictions on the cointegrating vectors. Bivariate tests of the *LOP* hypothesis involve testing the restriction

$$y_{1t} = -\beta y_{2t} , \qquad (4.22)$$

where y_{1t} and y_{2t} are the price variables. This restriction implies that the relative relationship between the prices is constant. A multivariate specification corresponds to the bivariate, where one of the prices in the system will be normalised upon.

5 EMPIRICAL RESULTS

In this chapter the results from the market integration tests are presented. The price data used is presented in Section 5.1 with descriptive data and graphical representation. In addition the Dickey-Fuller unit roots tests are applied to the series for examination of their underlying data generation process. In Section 5.2 the market integration hypothesis is tested using the Johansen procedure.

5.1 THE FISHMEAL AND SOYBEAN MEAL PRICES

5.1.1 THE DATA

The data used are four monthly price series, two of which are fishmeal price series and the other two being soybean meal price series. The prices are reported from January 1986 to June 1998. Thus, there are 150 observations for each price series. The fishmeal prices are reported for Hamburg and Atlanta. The Hamburg prices are reported for fishmeal with 64/65 percent protein content while the Atlanta prices are reported for fishmeal with 60 percent protein content. The fishmeal prices are reported for Standard Steam Dried quality, which is mainly used in the poultry market. Fishmeal used in aquaculture and pig farming is of a higher quality and fetches a premium that varies relatively to the Standard meal. During the El Niño when the prices were very high, the price differential was very small; now that prices are low again the price differential is wide (Pike, I. H., personal correspondence). In Figures 5.1 and 5.2 the fishmeal price series are plotted, where the variables are denoted Fish_Ham and Fish_Atl respectively. The other two series are soybean meal prices which are reported from Hamburg[18] and Decatur, Illinois. The Decatur prices are reported at the Chicago Board of Trade (CBOT), which is the most important commodity exchange for oilseeds in the US. The Hamburg soybean meal prices are reported for meal with 44/45 percent protein content and the Decatur prices are reported for soybean meal with 48 percent protein content. The soybean meal price variables are denoted as Soya_Ham, and Soya_Dec and are plotted in Figures 5.3

[18] Before February 1990 the prices for this series were reported from Rotterdam, but due to non-availability Hamburg prices were reported afterwards.

and 5.4. The price series were provided by IFOMA which have obtained the data from OilWorld (OW, Hamburg), Agricultural Supply Industry (ASI, London) and Feedstuffs (Minneapolis, Minnesota 55405, USA). All the prices are reported in US dollars.

There are three observations missing distributed in two of the price series. This is probably due to lack of transactions in these months. At most there are two adjacent months with no reported prices. I used the mean of the last observation preceding the missing value and the first observation after the missing value to calculate a value for the non-reported prices.

From the values obtained from the standard deviations reported in Table 5.1 it can be observed that there are large variations in the fishmeal prices relative to the soybean meal prices. The mean of the fishmeal prices and soybean meal prices gives some evidence that a long-run ratio of 2:1 exists between the prices.

Table 5.1 Descriptive statistics of the four price series in the period of January 1986 to June 1998.

Variable	*Observations*	*Mean*	*Std .Dev.*	*Min*	*Max*
Fish_Ham	150	464.05	104.93	292	721
Fish_Atl	150	461.99	85.01	242	673
Soya_Ham	150	227.83	35.54	174	325
Soya_Dec	150	225.07	41.21	168	338

The data plotted in Figure 5.1 and 5.2 show the large variations in the fishmeal prices. From lows of approximately $300 per tonne to tops of $700 per tonne. From the beginning of 1986 to the middle of 1988 the prices nearly doubled, but dropped drastically in the beginning of the nineties. Their peak was in 1998 under the El Niño, but have since dropped radically. It can readily be observed from the figures that the peaks in the graphs are essentially the same for the two price series (cf. Figure 2.6 for better comparison). Judging by the similarities of the graphs, the US and European fishmeal markets seem integrated.

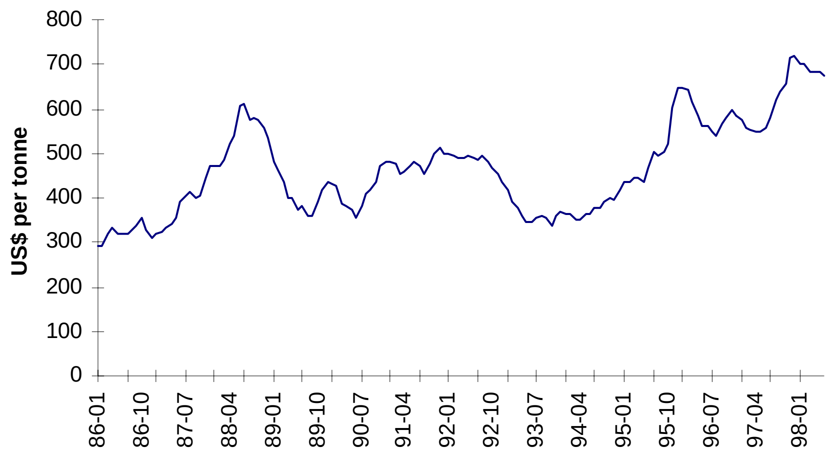

Figure 5.1 Fishmeal from any origin, cif Hamburg.

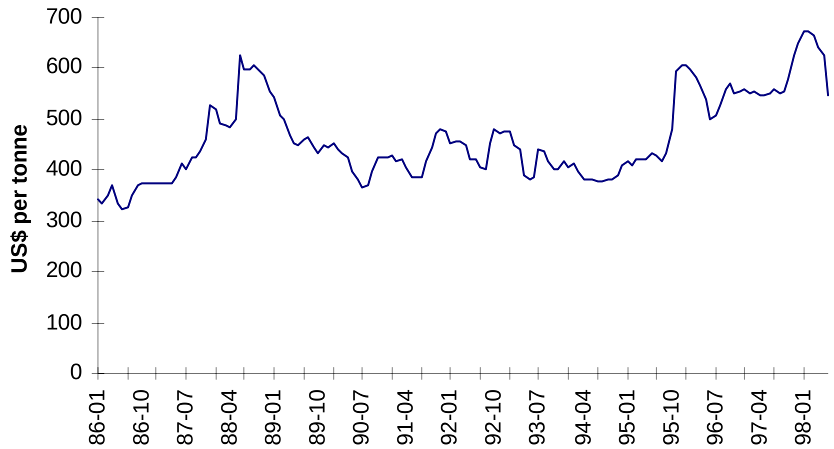

Figure 5.2 Fishmeal, Menhaden 60% protein content, Atlanta.

The soybean meal prices plotted in Figures 5.3 and 5.4 are more stable, although they have a couple of extreme periods. In the end of the 1980s and from 1995 to the end of 1997 the soybean meal producers enjoyed very high prices, approximately 100 dollars over their "normal" 200 dollars per tonne. From Figure 2.6 it can be seen that soybean meal prices show evidence of even stronger market integration than the fishmeal prices, being almost identical. Also notice that the fishmeal fetches considerably higher prices than the soybean meal.

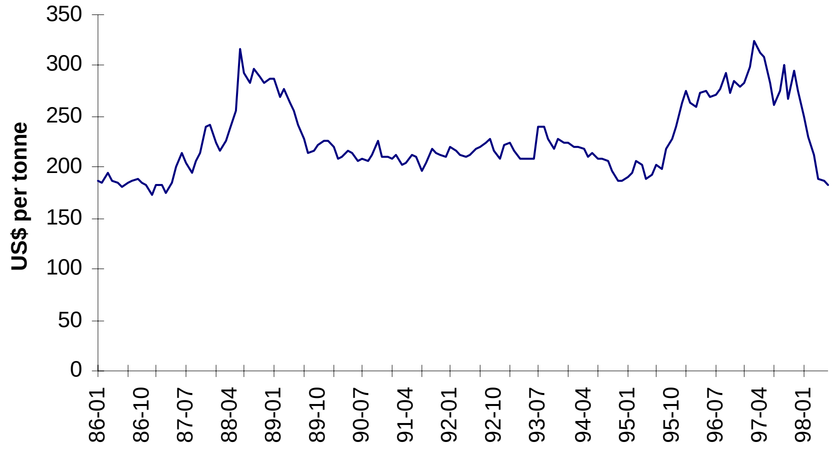

Figure 5.3 Soybean meal, 44/45% protein content, Hamburg fob ex-mill.

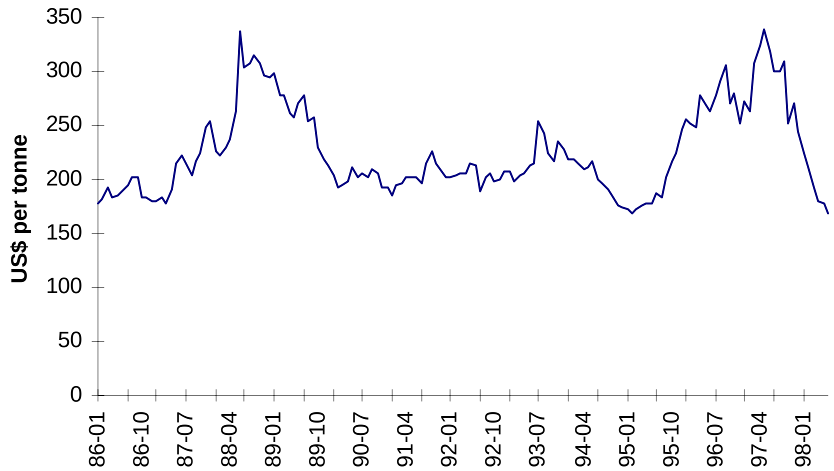

Figure 5.4 Soybean meal, 48% protein content, Decatur.

A non-stationary series is characterised by a long memory. Correlograms show correlation of the value in this period to values of earlier periods and can function as a measurement of the memory of the series. Inspection of correlograms is therefore a useful first step in examining the underlying DGPs of the variables. In Figure 5.5 the correlograms show that the fishmeal prices have slightly longer memory than the soybean meal prices. The fishmeal prices seem to be non-stationary because of the slowly dying memory. The soybean meal prices are more ambiguous and need further testing. The variables are all formally tested in the next subsection, 5.1.2.

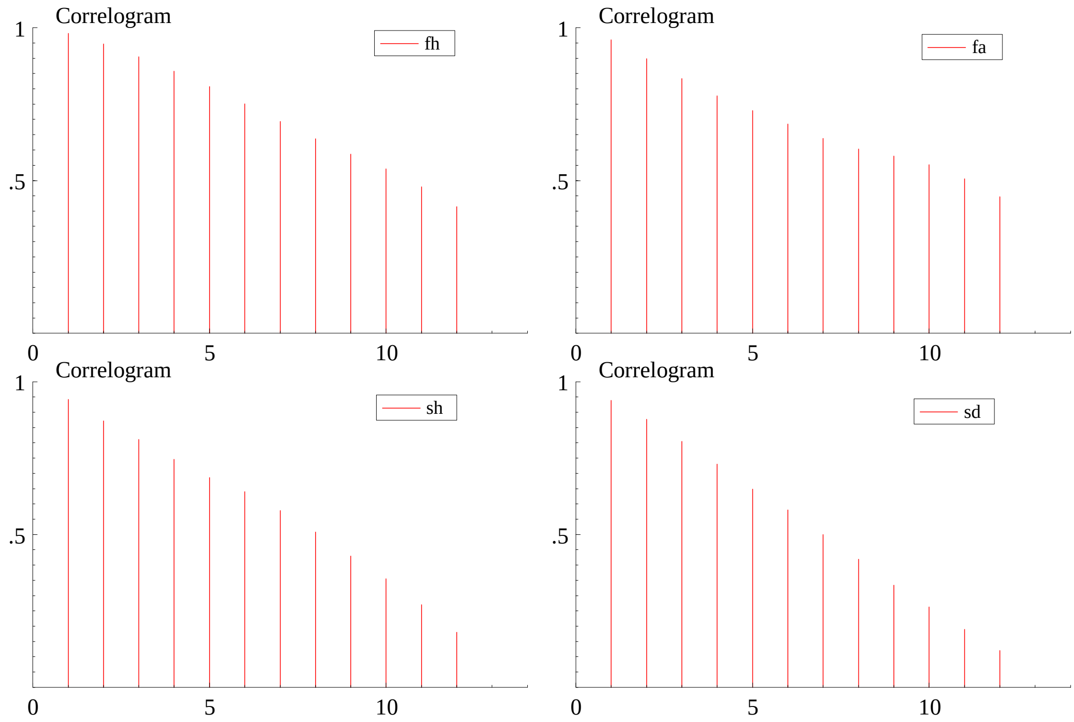

Figure 5.5 Correlograms of the fishmeal and soybean meal price series using 12 lags.

In Figure 5.6 the histograms are plotted for the series. They show that the distribution of the Hamburg fishmeal price series are skewed to the right while the other series are skewed leftwards, including the Atlanta fishmeal prices. The reasons for the differences in the distribution of the prices is mainly the raw material situation in the beginning of the nineties in addition to the El Niño in the late nineties (cf. Figures 2.6 for comparison of price movements in this period). In the early nineties there was a rise in the fishmeal prices both in absolute terms and relative to soybean meal. The Atlanta fishmeal prices did not experience the same boom. One likely reason why the Atlanta fishmeal prices did not follow the Hamburg prices is that Atlanta prices are reported for Menhaden meal, which is of poorer quality than the one reported in Hamburg. It contains only 60 percent protein and therefore loses some of its edge towards soybean meal.

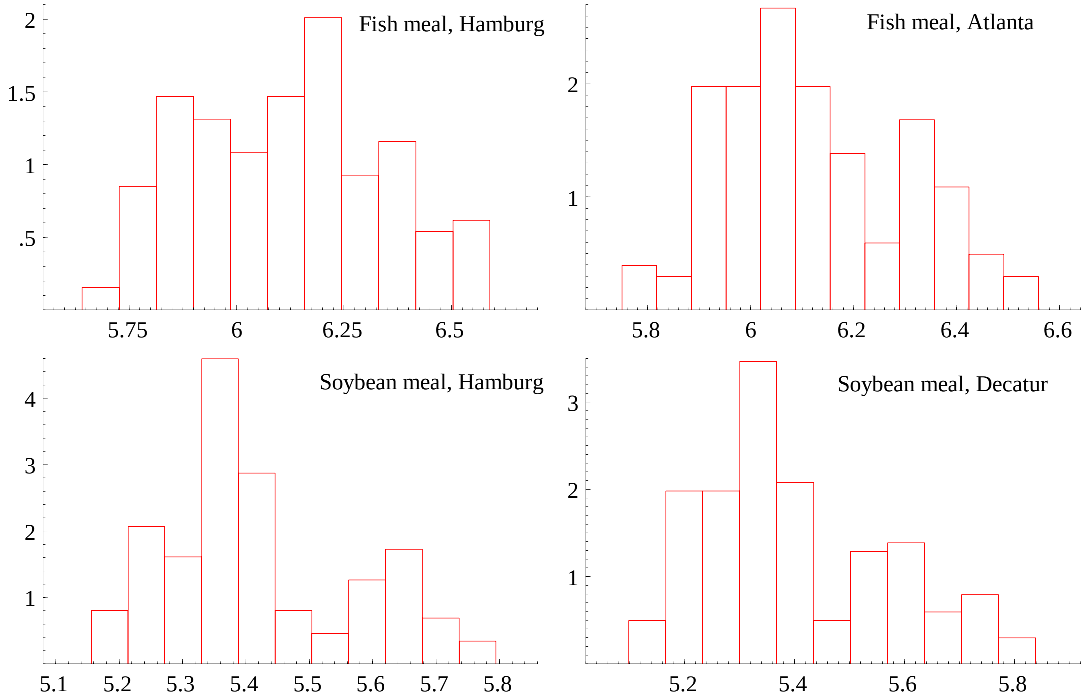

Figure 5.6 Histograms plotted for the logarithms of the fishmeal and soybean meal price series.

5.1.2 DICKEY FULLER TEST FOR UNIT ROOTS IN THE DATA

The unit root tests are conducted by starting with a richly specified test using constant, trend and seasonal dummies and then moving onto more restrictive formulations. The number of lags is chosen on the basis of Hall's General to Specific rule. The procedure is first to test the variables at levels. If the null hypothesis of unit root is not rejected at levels, the next step is to test the series as first differences. If the null of unit root is rejected at this point it will indicate that the series are *I[1]*, and if not, it is possible that there are more than one unit root present. The purpose of all the different specifications of the test is to exhaust the possibilities of how the underlying *DGP*s of the series really are. The results of the *ADF* tests of fishmeal and soybean meal price series are reported in Table 5.2 and 5.3.

Table 5.2: Unit root test on fishmeal prices using Hall's general to specific method, starting with 13 lags.

Variable	*ADF: C, S &T*	*ADF: C & S*	*ADF: C & T*	*ADF: C*	*ADF: No C*
LnFish_Ham	-2,2753 (9)	-1,7079 (1)	-2,2076 (9)	-1,9926 (1)	0,95230 (1)
LnFish_At	-2,8151 (10)	-2,5682 (10)	-2,8980 (13)	-1,2426 (0)	0,83520 (7)
ΔlnFish_Ha	-7,7725** (0)	7,8010** (0)	-7,8239** (0)	-7,8497** (0)	-7,7814** (0)
ΔlnFish_At	-8,8762** (0)	-8,9098** (0)	-5,4860** (6)	-5,5177** (6)	-5,4657** (6)

* indicates test statistic at 5 percent significance level, while ** indicates test statistic on 1 percent significance level.

The *ADF* for the fishmeal prices all seem to be *I[1]*. The null hypothesis of a unit root in the series is not rejected in the levels of the variables, in any of the tests, but is rejected for all at first differences of the variables. The numbers in parenthesis are the number of lags used.

Table 5.3: Unit root test on soybean meal prices using Hall's general to specific method, starting with 13 lags.

Variable	*ADF: C, S &T*	*ADF: C & S*	*ADF: C & T*	*ADF: C*	*ADF: No C*
LnSoya_Ham	-2,3667 (6)	-2,6252 (6)	-2,4717 (6)	-2,7576 (6)	-0,242267 (6)
LnSoya_Dec	-3,1148 (7)	-3,2697* (7)	-2,5949 (6)	-2,7345 (6)	-0,14250 (0)
ΔlnSoya_Ha	-3,1296 (5)	-3,0162* (5)	-3,4140 (5)	-3,2866* (5)	-3,3171** (5)
ΔlnSoya_De	-2,0834 (6)	-1,9909 (6)	-12,069** (0)	-12,003** (0)	-12,044** (0)

* indicates test statistic at 5 percent significance level, while ** indicates test statistic on 1 percent significance level.

The *ADF* tests for the two soybean meal prices are more ambiguous than the ones for the fishmeal prices. Generally, if 13 lags are applied to the test, then the series appear to be stationary at levels. On the other hand, if 4 lags or less are applied, the null of a unit root is not rejected for either of them. The ambiguous results seem to stem from the fact that there is evidence of parameter instability. Unreported Chow tests based on recursive estimation of the soybean meal price series gives such evidence. As a result the *ADF* tests may get overly sensitive to the chosen lag length. The most feasible way to mend such a problem would probably be by including dummies that could account for the breaks or outliers. The Johansen procedure can also function as a test of stationarity (cf. Section 4.4). Therefore the series will be treated as *I(1)* variables until otherwise proven.

5.2 TEST FOR MARKET INTEGRATION BETWEEN FISHMEAL AND SOYBEAN MEAL

First the variables are pairwise tested for cointegration using the Johansen procedure. In Subsection 4.4.4 it is argued that if all the price variables are found to be bivariately cointegrated, then this is equal to finding $n-1$ cointegration vectors in a multivariate system featuring all the price variables. Due to sensitivity towards the underlying distribution the test may show transitivity problems. Hence, both bivariate and multivariate tests are provided. The bivariate and multivariate systems are specified with a restricted intercept and monthly, 11 non-centred seasonal dummies. The intercept is restricted to only enter the long-run equations of the system, and will as such represent the long-term price differential between integrated markets. Unreported tests show that a trend parameter is not significant in the specification. Two lags are used, which is sufficient to get rid of autocorrelation in most of the systems, but the series for the soybean meal prices seem to need more than two lags. This may be evidence of parameter instability of the series. Most of the tests do not have problems with autocorrelation when two lags are used, but in some of the tests three lags are included. There are also some problems with deviations from the normal distribution of the errors in the tests. The Johansen procedure is quite sensitive to deviations from independent normal errors. There is a greater risk that the null of no cointegration will be rejected with deviations from such errors (Huang and Yang, 1996). This problem is even more evident when the *VAR* system is richly specified, where it suffers under the curse of dimensionality. This will lead to less probability of obtaining independent normal errors, due to the loss in degrees of freedom. This has to be considered when evaluating the test results.

It has been pointed out before that the 1997/98 El Niño was very extreme regarding its impact on the raw material situation for the fishmeal production. Since the data used here do not include the price movements after the El Niño, when the raw material situation as normalised again, it could be argued that the observations from June 1997 to June 1998 should be excluded from the sample in the cointegration tests. This is due to the fact that the fishmeal prices would not have been able to return to a long-run equilibrium with the soybean meal prices during this period. Soybean meal and fishmeal are not homogenous goods in a technical sense. One result from this fact is that there is sluggishness in the substitution between fishmeal and soybean meal. In Subsection 2.1.2 it was pointed out that some animals do not adjust well to sudden shifts in the makeup of feeds. Time is therefore a factor before substitution can be taken into full effect. Another aspect is that complete substitution is difficult, to say at least. In theory full substitution of fishmeal is technically possible, but the side effects make it undesirable in many cases. In particular aquaculture will have problems in replacing fishmeal completely in the feeds. In addition to having effects on the growth of the fish, a higher inclusion rate of vegetable meals in the feed can have impact on the flavour and taste of the fish, although this is a very controversial topic. Hence, the period of June 1997 to June 1998 is excluded from the sample. However, tests with the full sample have been done and will be commented upon.

5.2.1 DISCUSSION OF THE COINTEGRATION AND LOP TEST RESULTS

In table 5.4 the results from the pairwise cointegration tests are reported. The complementing misspecification tests are found in the appendix, Tables A1-A6. The first reported test is the bivariate test between the fishmeal prices of Hamburg and Atlanta. The *max* test produces no cointegration vector, but the *trace* test rejects the null of no cointegration vector at 5% significance. Hence they can be accepted as cointegrated. The *trace* test is also considered more robust regarding errors deviating from an underlying normal distribution, and should therefore be attached more weight (cf. Table A1 for normality tests).

The null of one cointegration vector is, in fact, not rejected for any of the pairwise tests. Thus, giving evidence to the assertion that the fishmeal market and soybean meal market are integrated. This implies that fishmeal and soybean meal are substitutes, as was illustrated in Subsection 3.1.2.

It is evident from Table 5.4 that the fishmeal prices from Atlanta are more strongly cointegrated with the soybean meal prices than the Hamburg prices are. This probably relates to the quality of the product, but most importantly, to the structure of the market. The US domestic feed market differs from the European feed market in several ways. Firstly, the US market is dominated by soybean meal as the most important protein source for animal feeds. Secondly, the feed formulation for US broiler production seems to be less sophisticated than the European (Pike, I. H., personal communication). If the price ratio of 1.8-2 is exceeded, fishmeal is dropped for the benefit of soybean meal in the diets. The European market seems to be more complex in the way that more sophisticated methods are used to calculate feed diets, in addition to a more complex demand structure, particularly due to the presence of the salmonid aquaculture industry.

The *LOP* hypothesis is not rejected for any, but the US fishmeal and soybean meal prices, and here it is only rejected at a 5% level. The tests are conducted by imposing the restriction reported in Equation (4.22). Following the discussion above of the US feed market one should believe that US prices of fishmeal and soybean meal are strongly integrated. That is also the case shown by the *max* and *trace* test, therefore the rejection of the *LOP* is a contradicting result. The explanation probably lies in the underlying distribution of the series. Table A5 in the appendix show that there are some problems both with normality and with autocorrelation of the errors. This will have an impact on the tests. In the *ADF* tests it was also displayed an ambiguity concerning the underlying *DGP* of the soybean meal price variables, being non-stationary or not. This ambiguity is confirmed by further testing. There is some evidence of a couple of outliers in the test between Atlanta fishmeal price and Decatur soybean meal price. By applying a dummy to account for an outlier, the cointegration test reports the presence of two cointegration vectors, indicating that the variables are stationary. Hence, the tests should be interpreted with some care.

Some other results that are somewhat contradicting are the *LOP* tests for the fishmeal prices and soybean meal prices separately. These tests should provide the strongest acceptance of the *LOP* hypothesis. But as can be seen from the first and last tests reported in Table 5.4 this is not the case. But overall the qualitative results from the tests point quite unambiguously towards a strongly integrated market.

The results from the multivariate test are provided in Table 5.5. A dummy was included to account for an outlier in June, 1993. The test does not reject that there are three ($n-1$) cointegration vectors. Hence the market integration is accepted for the four price series. If the dummy is left out, the test only finds two cointegration vectors. In Subsection 4.4.4 it was argued that a multivariate test is really superfluous if the bivariate tests have been conducted.

Table 5.4. Bivariate Johansen tests with 2 lags except ⁎ where 3 lags are included.

Variable 1	*Variable 2*	*Max test p==0*	*Max test p<=1*	*Trace test p==0*	*Trace test p<=1*	*LOP*
Fish_Ham	Fish_Atl	14.99	6.949	21.94*	6.949	3.8093
Fish_Ham⁎	Soya_Ham⁎	13.77	8.831	22.61*	8.831	0.1331
Fish_Ham⁎	Soya_Dec⁎	12.14	7.868	20.01*	7.868	0.12388
Fish_Atl	Soya_Ham	26.31**	6.867	33.18**	6.867	0.01344
Fish_Atl	Soya_Dec	20.73**	6.821	27.55**	6.821	6.2011*
Soya_Ham⁎	Soya_Dec⁎	18.19*	2.64	20.83*	2.64	3.5974

The critical values at 95% confidence is 15.7 for H_0:p==0 and 9.2 H_0:p<=1 for the *Max* test and 20.0 for H_o:p==0 and 9.2 H_0:p<=0 for the *Trace* test. * indicates test statistic at 5 percent significance level, while ** indicates test statistic on 1 percent significance level.

Table 5.5 Multivariate Johansen test with 2 lags.

H_0*: Rank=p*	*Max test*	*Critical value 5%*	*Trace test*	*Critical value 5%*
p==0	46.19**	28.1	116**	53.1
p<=1	36.72**	22.0	69.85**	34.9
p<=2	24.75**	15.7	33.13**	20.0
p<=3	8.377	9.2	8.377	9.2

* indicates test statistic at 5 percent significance level, while ** indicates test statistic on 1 percent significance level. The system specification includes 1 dummy which account for an outlier.

But due to transitivity problems it can be worth conducting both kinds of tests. The results from the *LOP* test of the multivariate system rejects the *LOP* hypothesis at 1% significance with a $\chi^2_{(3)}$ value of 14.78. The corresponding critical value is 11.34. So there is a problem with transitivity. Since *LOP* test for one of the bivariate tests was rejected it could maybe be expected. There is still evidence of strong integration between the markets.

The cointegration test including the price data from the El Niño, i.e. the observations ranging from July 1997 to June 1998, also showed evidence of cointegration. But they show larger problems with transitivity in the results from the estimations. The transitivity problems arise from conflicting results between the *LOP* hypothesis tests and the corresponding tests for the number of cointegration vectors.

5.2.2 DISCUSSION OF THE WEAK EXOGENEITY TEST RESULTS

The bivariate weak exogeneity tests are reported in Table 5.6. The results of these tests in relation to the global fishmeal market gives quite strong evidence to the importance of the Hamburg market. The Hamburg fishmeal prices appear to be weakly exogenous to all of the other markets in the bivariate tests. Hence, movements in the fishmeal price reported from Hamburg have influence on the movements on the other prices, but not vice versa. This is noteworthy since the soybean meal trade is ten times the size to that of fishmeal, and as such should be believed to be the more important. Durand (1994) comes to similar conclusions in her studies using Granger causality[19] as criteria. She studied the long-term relationship between fishmeal and soybean meal price series from the Hamburg market with a sample of the prices from January 1977 to June 1993. She finds a long-run relationship between fishmeal and soybean meal prices using Engle and Granger bivariate cointegration test. Furthermore, using Granger causality as a criterion, she found that fishmeal prices partly determine the soybean meal prices, while the soybean meal prices only exert short run causality on the fishmeal prices. Finally, it should be noted that the test between the Hamburg fishmeal and Decatur soybean meal prices accepts that both variables are weakly exogenous. This is a contradiction and witness to the sensitivity of the tests. The same problem occurs with the Atlanta fishmeal prices against the Decatur soybean meal prices.

Furthermore, the Atlanta fishmeal price is not rejected as weakly exogenous towards the Hamburg soybean meal price. Of the soybean meal markets it is the Hamburg market which is not rejected as weakly exogenous.

The above mentioned inconsistencies can be solved in a multivariate system. In table 5.7 the exogeneity tests for the full system are reported. The results of the test on the four price variables show that the Hamburg fishmeal price is the only variable where the null of weak

[19] Granger causality is absent when $f(x_t|x_{t-1}, y_{t-1})$ equals $f(x_t|x_{t-1},)$. The definition states that in conditional distribution, lagged values of y_t add no information to explanation of movements in x_t beyond that provided by lagged values of x_t, itself (Green, 1993, p 714).

exogeneity is not rejected. This could be expected from the bivariate tests and confirm the importance of this market. All of the others are rejected as weakly exogenous to the system.

Table 5.6 Exogeneity test of the variables which are pairwise cointegrated.

Variable 1 : Var. 2	*Test statistic:* H_0*: Var. 1 exogenous*	*p-value*	*Test statistic:* H_0*: Var. 2 exogenous*	*p-value*
Fish_Ham : Fish_At	1.2024	0.2728	8.0292	0.0046**
Fish_Ham : Soya_Ham	0.10487	0.7461	4.5653	0.0326*
Fish_Ham: Soya_Dec	0.097795	0.7545	3.525	0.0604
Fish_At : Soya_Ha	1.546	0.2137	9.817	0.0017**
Fish_At : Soya_Dec	3.299	0.0693	3.12	0.0773
Soya_Ha : Soya_Dec	0.2396	0.6245	4.7383	0.0295*

5% and 1% critical values from the chi-square distribution are respectively 3.84 and 6.63. * indicates test statistic at 5 percent significance level, while ** indicates test statistic on 1 percent significance level.

Table 5.7 Exogeneity test of the variables in the multivariate system.

Variables	*Test-statistic*	*p-values*
Fish_Ham	7.0765	0.0695
Fish_Atl	33.735	0.0000**
Soya_Ham	27.464	0.0000**
Soya_Dec	16.643	0.0008**

5 % and 1 % critical values for the chi-square distribution are respectively 9.49 and 13.28. * indicates test statistic at 5 percent significance level, while ** indicates test statistic on 1 percent significance level.

6 SUMMARY AND CONCLUSIONS

The motivation behind this report was concerns in the salmon farming industry for insufficient supplies and increasing prices of fishmeal. Fishmeal is considered very important in the diets of both farmed shrimp and salmon due to its high protein content and essential amino and fatty acids. Thus, low supplies of fishmeal could strangle further growth of these industries. The cause of these concerns has been the volatile and generally insecure fishmeal supply. Especially the 1997-98 El Niño triggered concerns due to minimal supplies as a consequence of the collapse in the industrial fisheries in Peru and Chile (Cf. Chapter 2).

Aquaculture is not the only consumer of fishmeal. Both the pork and poultry production sectors use fishmeal in their diets (cf. Ch. 2). Their combined consumption of fishmeal accounts for over 50 percent of the global fishmeal supply. In the production of these animals there is generally a high inclusion rate of soybean meal (OECD, 1994). However, in Europe the usage of local produced oil meals like sunflower and rapeseed meal has increased somewhat in the last decade, at the expense of soybean meal (IFOMA, 1997). These soybean meal replacements do not provide animals with essential amino acids as effectively as soybean meal. Fishmeal, which is rich on these amino acids, effectively complements the soybean meal replacers in such feeds.

If the concerns of fishmeal scarcity are justified, this could mean a major limitation for further growth of the salmon industry. Scarcity would imply restrictively high prices of fishmeal. The pork and poultry production sectors, which more easily can substitute with soybean meal, do not face these problems to the same degree.

In Chapter 3 it was argued that if the markets for fishmeal and soybean meal are well integrated these concerns are to some degree unfounded. The implication of integrated markets is that fishmeal and soybean meal are substitutes, not necessarily perfect substitutes, but nevertheless close substitutes. Since there are no serious shortages of soybean meal in the global market, temporary shortages in the supply of fishmeal should not have any serious consequences. In those cases it should be offset by substitution of fishmeal with soybean meal, especially in pork and poultry production that can more easily switch between these inputs. Moreover, the more the markets are integrated the more perfect fishmeal and soybean meal function as substitutes. Hence, scarcity should not be a prevailing problem.

This report applies the Johansen Procedure to empirically test the degree of market integration between fishmeal and soybean meal (Johansen, 1988). Four monthly price series are used; fishmeal prices from Hamburg and Atlanta and soybean meal price series from Hamburg and Decatur, Illinois. Thus, the European and US fishmeal and soybean meal markets are covered. The price series stretches from January 1986 to June 1997. They were tested for unit roots with the Augmented Dickey Fuller-test and most of the series were found to be non-stationary *I(1)* series, although some of the test showed ambiguous results (Dickey & Fuller, 1981).[20]

The Johansen *ML* cointegration test is applied to fishmeal prices and soybean meal prices. The results from these tests, as they were presented in Chapter 5, give strong evidence of market integration between fishmeal and soybean meal. All the price series are pairwise cointegrated as well as being cointegrated in multivariate system with 3, $(n-1)$, cointegration vectors. Moreover, the *LOP* hypothesis is generally accepted in the bivariate tests, indicating that fishmeal and soybean meal are near perfect substitutes.[21] But the *LOP* hypothesis is rejected in the multivariate test.[22] Still the tests point in the direction of strong, if not perfect, market integration.

It is clear from visual inspections of the data that there is some stickiness in the adjustments to a long-run equilibrium. This has to be explained by the technical difficulties in shifting from one protein source to another protein source in the feeds during a very short time. It is still quite clear that fishmeal and soybean meal are strong substitutes. Hence, the concerns of scarcity may seem somewhat unfounded.

Furthermore, the results from this report may give some evidence that the fishmeal market has a leading role relative to soybean meal, especially the Hamburg fishmeal market, thus functioning as a price leader. Considering the size of the soybean meal market this is a dubious explanation. A more likely explanation could be that the volatile supply and the lack of stocking options give the fishmeal price a seemingly "price leader" quality, when in reality

[20] Confer Table 5.2 and 5.3 for results.
[21] Confer Table 5.4.
[22] Confer Section 5.2.

the price is just behaving responsively due to insecurity in the market. But this question is beyond the scope of this report.

APPENDIX

Table A1 Mis-specification tests for the Johansen bivariate cointegration test between Fish_Ham and Fish_Atl.

```
fh      :Portmanteau 12 lags=   13.179
fa      :Portmanteau 12 lags=   19.259
fh      :AR 1- 7 F( 7,113) =    0.57054 [0.7785]
fa      :AR 1- 7 F( 7,113) =     1.1483 [0.3384]
fh      :Normality Chi^2(2)=     5.8815 [0.0528]
fa      :Normality Chi^2(2)=     33.804 [0.0000] **
fh      :ARCH 7  F( 7,106) =    0.13382 [0.9955]
fa      :ARCH 7  F( 7,106) =    0.38254 [0.9108]
fh      :Xi^2    F( 8,111) =    0.56855 [0.8017]
fa      :Xi^2    F( 8,111) =     1.1707 [0.3232]
fh      :Xi*Xj   F(14,105) =    0.78252 [0.6857]
fa      :Xi*Xj   F(14,105) =    0.97472 [0.4840]
Vector portmanteau 12 lags=   43.936
Vector AR 1-7  F(28,210) =     1.1819 [0.2512]
Vector normality Chi^2( 4)=    34.308 [0.0000] **
Vector  Xi^2   F(24,316) =    0.78018 [0.7617]
Vector  Xi*Xj  F(42,306) =    0.85159 [0.7310]
```

Table A2 Mis-specification tests for the Johansen bivariate cointegration test between Fish_Ham and Soya_Ham.

```
fh      :Portmanteau 12 lags=   10.158
sh      :Portmanteau 12 lags=   12.963
fh      :AR 1- 7 F( 7,110) =      1.032 [0.4131]
sh      :AR 1- 7 F( 7,110) =       1.51 [0.1712]
fh      :Normality Chi^2(2)=     4.0923 [0.1292]
sh      :Normality Chi^2(2)=     24.324 [0.0000] **
fh      :ARCH 7  F( 7,103) =   0.088139 [0.9988]
sh      :ARCH 7  F( 7,103) =    0.58199 [0.7692]
fh      :Xi^2    F(12,104) =    0.71219 [0.7366]
sh      :Xi^2    F(12,104) =     0.8067 [0.6429]
fh      :Xi*Xj   F(27, 89) =    0.74935 [0.8008]
sh      :Xi*Xj   F(27, 89) =    0.60108 [0.9330]
Vector portmanteau 12 lags=   45.509
Vector AR 1-7  F(28,204) =     1.0861 [0.3579]
Vector normality Chi^2( 4)=    28.687 [0.0000] **
Vector  Xi^2   F(36,302) =    0.77195 [0.8252]
Vector  Xi*Xj  F(81,261) =     0.5695 [0.9983]
```

Table A3 Mis-specification tests for the Johansen bivariate cointegration test between Fish_Ham and Soya_Dec.

```
fh      :Portmanteau 12 lags=   10.704
sd      :Portmanteau 12 lags=   18.403
fh      :AR 1- 7 F( 7,110) =    0.75349 [0.6273]
sd      :AR 1- 7 F( 7,110) =     2.2259 [0.0373] *
fh      :Normality Chi^2(2)=     1.5983 [0.4497]
sd      :Normality Chi^2(2)=     20.292 [0.0000] **
fh      :ARCH 7  F( 7,103) =    0.10545 [0.9979]
sd      :ARCH 7  F( 7,103) =    0.22771 [0.9779]
fh      :Xi^2    F(12,104) =    0.79268 [0.6570]
sd      :Xi^2    F(12,104) =    0.94944 [0.5016]
fh      :Xi*Xj   F(27, 89) =    0.99394 [0.4856]
sd      :Xi*Xj   F(27, 89) =     0.7997 [0.7408]
Vector portmanteau 12 lags=   42.292
Vector AR 1-7  F(28,204) =      1.037 [0.4208]
Vector normality Chi^2( 4)=    20.187 [0.0005] **
Vector  Xi^2   F(36,302) =    0.85932 [0.7016]
Vector  Xi*Xj  F(81,261) =    0.93667 [0.6291]
```

Table A4 Mis-specification tests for the Johansen bivariate cointegration test between Fish_Atl and Soya_Ham.

```
Fa       :Portmanteau 12 lags=   13.919
sh       :Portmanteau 12 lags=    15.27
fa       :AR 1- 7 F( 7,113) =     1.048 [0.4020]
sh       :AR 1- 7 F( 7,113) =    1.8626 [0.0823]
fa       :Normality Chi^2(2)=    30.484 [0.0000] **
sh       :Normality Chi^2(2)=    21.296 [0.0000] **
fa       :ARCH 7  F( 7,106) =   0.60822 [0.7480]
sh       :ARCH 7  F( 7,106) =   0.47873 [0.8482]
fa       :Xi^2    F( 8,111) =    1.6223 [0.1264]
sh       :Xi^2    F( 8,111) =   0.92767 [0.4967]
fa       :Xi*Xj   F(14,105) =    1.1649 [0.3131]
sh       :Xi*Xj   F(14,105) =   0.72014 [0.7499]
Vector portmanteau 12 lags=   48.832
Vector AR 1-7  F(28,210) =     1.282 [0.1658]
Vector normality Chi^2( 4)=    31.361 [0.0000] **
Vector  Xi^2   F(24,316) =   0.98389 [0.4872]
Vector  Xi*Xj  F(42,306) =   0.76156 [0.8575]
```

Table A5 Mis-specification tests for the Johansen bivariate cointegration test between Fish_Atl and Soya_Dec.

```
Fa       :Portmanteau 12 lags=   14.543
sd       :Portmanteau 12 lags=   19.618
fa       :AR 1- 7 F( 7,113) =   0.79247 [0.5951]
sd       :AR 1- 7 F( 7,113) =    2.4356 [0.0231] *
fa       :Normality Chi^2(2)=    30.994 [0.0000] **
sd       :Normality Chi^2(2)=    18.398 [0.0001] **
fa       :ARCH 7  F( 7,106) =   0.77401 [0.6104]
sd       :ARCH 7  F( 7,106) =   0.31146 [0.9474]
fa       :Xi^2    F( 8,111) =     1.715 [0.1026]
sd       :Xi^2    F( 8,111) =     1.094 [0.3728]
fa       :Xi*Xj   F(14,105) =    1.4474 [0.1447]
sd       :Xi*Xj   F(14,105) =    0.8412 [0.6234]
Vector portmanteau 12 lags=   52.341
Vector AR 1-7  F(28,210) =    1.2603 [0.1822]
Vector normality Chi^2( 4)=    31.413 [0.0000] **
Vector  Xi^2   F(24,316) =   0.92993 [0.5610]
Vector  Xi*Xj  F(42,306) =   0.94093 [0.5793]
```

Table A6 Misspecification tests for the Johansen bivariate cointegration test between Soya_Ham and Soya_Dec.

```
sh       :Portmanteau 12 lags=   12.786
sd       :Portmanteau 12 lags=   21.093
sh       :AR 1- 7 F( 7,110) =    1.9734 [0.0651]
sd       :AR 1- 7 F( 7,110) =    3.0156 [0.0062] **
sh       :Normality Chi^2(2)=    21.738 [0.0000] **
sd       :Normality Chi^2(2)=    19.256 [0.0001] **
sh       :ARCH 7  F( 7,103) =     0.637 [0.7243]
sd       :ARCH 7  F( 7,103) =   0.39136 [0.9055]
sh       :Xi^2    F(12,104) =   0.84275 [0.6066]
sd       :Xi^2    F(12,104) =    1.0061 [0.4488]
sh       :Xi*Xj   F(27, 89) =   0.50164 [0.9780]
sd       :Xi*Xj   F(27, 89) =   0.57947 [0.9457]
Vector portmanteau 12 lags=   35.663
Vector AR 1-7  F(28,204) =    1.1926 [0.2414]
Vector normality Chi^2( 4)=      16.5 [0.0024] **
Vector  Xi^2   F(36,302) =    1.0193 [0.4435]
Vector  Xi*Xj  F(81,261) =   0.78858 [0.8959]
```

Table A7 Mis-specification tests for the Johansen multivariate cointegration test between Fish_Ham, Fish_Atl, Soya_Ham and Soya_Dec.

```
fh      :Portmanteau 12 lags=   12.395
fa      :Portmanteau 12 lags=   11.802
sh      :Portmanteau 12 lags=   11.727
sd      :Portmanteau 12 lags=   17.872
fh      :AR 1- 7 F( 7,106) =    0.63927 [0.7225]
fa      :AR 1- 7 F( 7,106) =    0.99649 [0.4380]
sh      :AR 1- 7 F( 7,106) =    0.95993 [0.4644]
sd      :AR 1- 7 F( 7,106) =     2.0415 [0.0565]
fh      :Normality Chi^2(2)=      6.352 [0.0418] *
fa      :Normality Chi^2(2)=     34.931 [0.0000] **
sh      :Normality Chi^2(2)=      20.13 [0.0000] **
sd      :Normality Chi^2(2)=     15.868 [0.0004] **
fh      :ARCH 7  F( 7, 99) =    0.20968 [0.9825]
fa      :ARCH 7  F( 7, 99) =    0.46736 [0.8560]
sh      :ARCH 7  F( 7, 99) =    0.62583 [0.7335]
sd      :ARCH 7  F( 7, 99) =    0.72017 [0.6551]
fh      :Xi^2    F(19, 93) =    0.61078 [0.8895]
fa      :Xi^2    F(19, 93) =    0.85139 [0.6415]
sh      :Xi^2    F(19, 93) =    0.63814 [0.8674]
sd      :Xi^2    F(19, 93) =     1.0323 [0.4334]
fh      :Xi*Xj   F(48, 64) =    0.56393 [0.9802]
fa      :Xi*Xj   F(48, 64) =    0.91928 [0.6167]
sh      :Xi*Xj   F(48, 64) =    0.54627 [0.9850]
sd      :Xi*Xj   F(48, 64) =    0.68866 [0.9109]
Vector portmanteau 12 lags=   164.23
Vector AR 1-7  F(112,328) =    0.99656 [0.4988]
Vector normality Chi^2( 8)=    40.693 [0.0000] **
Vector  Xi^2   F(190,769) =    0.64299 [0.9999]
Vector  Xi*Xj  F(480,569) =    0.67065 [1.0000]
```

Table A8. USD per tonne: Fishmeal 64/65% any origin cif Hamburg (Fish_Hamb); Fishmeal Menhaden 60% Atlanta (Fish_Atl); Soybean meal 44/45% Hamburg fob ex-mill (Soya_Hamb); Soybean meal 48% Decatur (Soya_Dec).

	Fish_ Hamb	Fish_ Atl	Soya_ Hamb	Soya_ Dec		Fish_ Hamb	Fish_ Atl	Soya_ Hamb	Soya_ Dec
jan.86	292	343	186	178	**apr.92**	489	447	210	205
feb.86	292	336	185	181	**mai.92**	495	419	212	215
mar.86	321	350	194	192	**jun.92**	491	422	218	213
apr.86	333	368	187	183	**jul.92**	485	407	220	188
mai.86	317	335	184	186	**aug.92**	493	402	224	201
jun.86	317	321	180	189	**sep.92**	481	451	229	205
jul.86	319	325	184	194	**okt.92**	469	480	216	199
aug.86	326	350	187	201	**nov.92**	455	472	208	200
sep.86	339	368	189	202	**des.92**	438	474	222	208
okt.86	353	375	185	183	**jan.93**	418	474	224	207
nov.86	328	375	182	183	**feb.93**	391	449	216	199
des.86	310	375	174	180	**mar.93**	377	441	208	203
jan.87	317	375	182	179	**apr.93**	361	391	209	206
feb.87	322	375	183	183	**mai.93**	348	380	209	213
mar.87	332	375	175	178	**jun.93**	348	387	209	214
apr.87	341	373	185	191	**jul.93**	356	441	239	253
mai.87	355	387	201	214	**aug.93**	361	438	239	243
jun.87	393	411	214	223	**sep.93**	353	418	228	224
jul.87	403	400	204	214	**okt.93**	339	401	219	216
aug.87	413	424	194	204	**nov.93**	358	402	229	236
sep.87	400	242	207	217	**des.93**	367	418	225	228
okt.87	406	436	214	224	**jan.94**	366	407	225	219
nov.87	445	462	239	249	**feb.94**	364	413	220	218
des.87	474	528	241	254	**mar.94**	352	399	221	215
jan.88	473	518	225	226	**apr.94**	351	382	219	209
feb.88	473	493	216	223	**mai.94**	362	383	210	211
mar.88	487	488	227	229	**jun.94**	365	383	214	217
apr.88	520	484	237	237	**jul.94**	376	376	209	200
mai.88	541	499	255	263	**aug.94**	378	378	208	197
jun.88	606	624	317	337	**sep.94**	392	380	206	191
jul.88	609	597	293	304	**okt.94**	398	382	196	185
aug.88	577	598	283	307	**nov.94**	394	390	187	176
sep.88	582	605	297	315	**des.94**	418	408	187	175
okt.88	575	593	290	307	**jan.95**	435	416	191	172
nov.88	556	586	283	297	**feb.95**	437	408	195	168
des.88	534	556	287	294	**mar.95**	447	419	206	172
jan.89	481	543	288	299	**apr.95**	447	419	203	176
feb.89	464	507	270	278	**mai.95**	436	419	189	177
mar.89	437	498	277	277	**jun.95**	467	434	192	177
apr.89	400	467	264	262	**jul.95**	502	428	202	187
mai.89	399	453	256	257	**aug.95**	493	418	198	184
jun.89	371	449		271	**sep.95**	505	434	219	201
jul.89	380	460		278	**okt.95**	522	479	228	216
aug.89	359	463	214	254	**nov.95**	602	594	240	224

sep.89	360	443	216	258	**des.95**	647	606	264	246
okt.89	393	433	222	230	**jan.96**	649	606	275	256
nov.89	419	450	226	218	**feb.96**	641	598	264	251
des.89	438	444	226	213	**mar.96**	616	582	260	249
jan.90	430	451	221	203	**apr.96**	583	568	273	277
feb.90	426	441	208	192	**mai.96**	564	538	276	269
mar.90	385	431	211	194	**jun.96**	563	498	269	263
apr.90	381	424	217	199	**jul.96**	547	507	271	278
mai.90	374	399	215	211	**aug.96**	539	526	278	291
jun.90	354	383	206	201	**sep.96**	566	558	292	306
jul.90	383	365	208	205	**okt.96**	581	569	274	270
aug.90	407	371	207	202	**nov.96**	600	551	285	280
sep.90	417	397	212	209	**des.96**	583		279	251
okt.90	435	426	227	205	**jan.97**	576	560	283	273
nov.90	473	424	210	192	**feb.97**	558	551	298	263
des.90	481	424	211	192	**mar.97**	554	553	325	308
jan.91	480	429	208	185	**apr.97**	547	547	312	324
feb.91	476	418	212	194	**mai.97**	548	546	308	338
mar.91	455	419	202	196	**jun.97**	558	549	284	318
apr.91	459	405	204	201	**jul.97**	581	557	261	300
mai.91	471	386	213	202	**aug.97**	621	551	276	300
jun.91	482	385	211	202	**sep.97**	637	553	301	310
jul.91	471	387	197	196	**okt.97**	658	579	267	252
aug.91	452	416	204	215	**nov.97**	716	626	294	271
sep.91	478	445	218	226	**des.97**	721	649	276	244
okt.91	498	471	215	215	**jan.98**	703	671	249	224
nov.91	512	480	212	210	**feb.98**	699	673	230	211
des.91	500	476	210	202	**mar.98**	682	663	212	192
jan.92	500	451	221	202	**apr.98**	684	642	188	180
feb.92	494	458	216	204	**mai.98**	685	626	187	178
mar.92	488	458	213	206	**jun.98**	675	547	182	168

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