

# DEPARTMENT OF ECONOMICS

## Working Paper

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The relevant antitrust market for salmon

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Working Paper No. 2005-05



ISSN 1396-2426

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Sequential versus simultaneous market  
delineation:  
The relevant antitrust market for salmon\*

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23. March 2005.

**Abstract**

Delineation of the relevant market forms a pivotal part of most antitrust cases. The standard approach is sequential. First the product market is delineated, then the geographical market is defined. Demand and supply substitution in both the product dimension and the geographical dimension will normally be stronger than substitution in either dimension. By ignoring this one might decide first to define products narrowly and then to define the geographical extent narrowly ignoring the possibility of a diagonal substitution. These reflections are important in the empirical delineation of product and geographical markets. Using a unique data set for prices of Norwegian and Scottish salmon, we propose a methodology for simultaneous market delineation and we demonstrate that compared to a sequential approach conclusions will be reversed.

JEL: C3, K21, L41, Q22

Keywords: Relevant market, econometric delineation, salmon.

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\*We thank Tobias Købke of Copenhagen Economics ApS for excellent research assistance and the Centre of Industrial Economics for financial support.

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# 1 Introduction

Delineation of the relevant market constitutes a pivotal part of most antitrust cases. The standard approach is sequential. First the product market is delineated, then the geographical market is defined. However, demand and supply substitution in both the product dimension and the geographical dimension will normally be stronger than substitution in either dimension at a time. By ignoring this, one might decide first to define products narrowly and then to define geographical extent narrowly ignoring the possibility of diagonal substitution.

Price tests are frequently used in market delineation because detailed production and sales data are inaccessible. Using a unique price data set, we demonstrate that the sequential approach can reverse conclusions compared with a more proper simultaneous approach to market definition. We use monthly export price data for farmed salmon produced in Norway and Scotland. Data has been acquired from Norwegian Kontali and Eurostat's Comext. All prices are converted to the same currency and unit of account (Euros per kilo). The sample runs from January 1995 through August 2003.

The excellent data for this market allow for the use of a number of different applications of modern time series econometrics that each corroborate the conclusions. As a powerful tool in the analysis of joint market delineation we suggest to employ the Johansen ML procedure for cointegrated systems which takes advantage of an extended information set compared to a sequential procedure using univariate unit root tests, e.g. Dickey-Fuller tests, that do not use co-variate information regarding other price series.

Our most important result is that contrary to what we find when using a sequential approach, the simultaneous analysis suggests that Norwegian and Scottish salmon should be considered belonging to the same product market as well as the same geographical market when looking at the sample period January 1995 through August 2002. The conclusion is that the sequential approach should not be carried out when a simultaneous approach is feasible.

We also find that when EU regulation of Norwegian salmon prices (anti-dumping duties or minimum prices) are binding as was the case in the twelve months after our primary sample period then the market delineation changes so that Norwegian and Scottish salmon belong to different product and different geographical markets. The economic interpretation is that the regulatory intervention removes the normal competitive pressure of Norwegian salmon on Scottish salmon so that divergent price paths are sustainable.

In the next section a review of the literature on market and product delineation is given. This is followed, in section 3, by a thorough description of the EU salmon industry with particular focus on farmed Norwegian and Scottish salmon and the competition environment for these products. Section 4 suggests an empirical methodology for simultaneous market delineation and the approach is applied to the salmon price data set.

## 2 Literature Review

Defining the relevant market is crucial in the application of competition policies concerning restrictive agreements, abuse of domination and merger control. The purpose of defining the relevant market is to identify all substitutes that exert a significant competitive constraint on the product or service under scrutiny. These may be substitutes in demand or in supply. Demand substitution is carried out by customers that seek alternatives; supply substitution is carried out by suppliers that seek profit opportunities by shifting their supply towards higher priced alternatives. Both types of substitution may have both a product dimension and a geographical dimension: Customers may look for a product with different characteristics or they may look for the same product but at a different location. Likewise, suppliers may start producing a product with alternative characteristics or they may start supplying their existing product at a different location. The competitive constraint is exerted by both demand and supply substitution in both the product dimension and the geographical dimension.

The most common method for delineating the relevant market is that of the ‘hypothetical monopolist’ also known as the SSNIP test.<sup>1</sup> The question posed by this test is if a hypothetical monopolist in control of the products or services that constitute a candidate market could profitably increase the price by some small amount, typically five or ten per cent. The relevant market is the smallest set of products or services that satisfy this condition. In principle, what the test is looking for is an estimate of the elasticity of the residual demand of the hypothetical monopolist. Landes and Posner (1981) demonstrate that in the case of a dominant firm with a competitive fringe producing a homogeneous good, the absolute value of this residual demand elasticity,  $\varepsilon_i^d$ , may be expressed as:

$$\varepsilon_i^d = \frac{\varepsilon_m^d}{S_i} + \frac{\varepsilon^s(1 - S_i)}{S_i} \quad (1)$$

where  $\varepsilon_m^d$  is the (absolute value of the) price elasticity of market demand,  $S_i$  is the market share of the (hypothetically) dominant firm  $i$  and  $\varepsilon^s$  is the price elasticity of supply. The hypothetically dominant firm would then find it optimal to exercise market power as expressed by the familiar Lerner index:

$$L_i = \frac{P_i - MC_i}{P_i} = \frac{1}{\varepsilon_i^d} \quad (2)$$

These two equations summarize that the market power or the pricing of the hypothetically dominant firm may be constrained by both customers’ availability of alternatives and alternative suppliers’ readiness to supply more if the price increases. There are many variations of these basic equations. Neven *et al.* (1993) for example contains similar expressions for a hypothetical monopolist operating in an oligopoly with differentiated products.

In the EU, the European Commission seems to adopt a particular version of this methodology. In its Notice on market definition, the central definition of

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<sup>1</sup>SSNIP = Small but Significant Non-transitory Increase of Price.

the test is:

“The question to be answered is whether the parties’ customers would switch to readily available substitutes or to suppliers located elsewhere in response to an hypothetical small (in the range 5%-10%), permanent relative price increase in the products and areas being considered. If substitution would be enough to make the price increase unprofitable because of the resulting loss of sales, additional substitutes and areas are included in the relevant market. This would be done until the set of products and geographic areas is such that small, permanent increases in relative prices would be profitable.” (European Commission, 1997, paragraph 17)

The SSNIP test is also endorsed in other jurisdictions, e.g. in the United States (*Merger Guidelines*) and in the United Kingdom (Office of Fair Trading, 1999). However, this methodology is only very rarely used directly in practice. In a recent survey of EU merger cases between 1990 and 2001, Copenhagen Economics (2003) demonstrates that the SSNIP methodology is used *as a framework* in only eleven per cent of the product definitions and in only four per cent of the geographic delineations. The methodology is never applied directly in a quantitative analysis. Instead the European Commission typically relies on very simple indicators such as trade flows and differences in price levels as empirical documentation for their choice of market definition.

The reason why the SSNIP methodology is applied only rarely and unsystematically is probably that in order to estimate the components of (1) a lot of data is needed (time series of quantities, prices and background variables).<sup>2</sup> An alternative that has been used, particularly in merger analysis, is price correlation analysis, see Bishop and Walker (2002, ch. 11). The application of these tests may be attributed to a more limited data requirements as only price data series are needed. This methodology is based on Stigler and Sherwin (1985) who argued that the (relevant) market should consist of those suppliers and customers whose trading determine the price. They thus defined the market as “the area within which the price of a good tends to uniformity, allowance being made for transportation costs.”

Evidently, price correlations must be purged of common factors such as seasonality in demand or price movements of a common input that have nothing to do with competitive pressures.<sup>3</sup> Thus at the very least market definition based on price correlation analysis should be based on partial correlation coefficients. In addition, if the price series are not stationary, modern methods of co-integration and error-correction models are needed to deal with the analysis of co-variation of prices and the tendency for prices to revert to a stable relationship.<sup>4</sup>

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<sup>2</sup>See la Cour and Møllgaard (2002) for an application of a SSNIP-like approach to market delineation for cement.

<sup>3</sup>See Copenhagen Economics (2003) for a survey of these methods.

<sup>4</sup>See Wills (2002) for an example of a market delineation of salmon using stationarity tests

Typically, when such analysis is undertaken at all, it is based on pairwise comparisons of products or geographical locations. In the *Nestlé/Perrier* merger case<sup>5</sup> the European Commission needed to establish whether still bottled water, sparkling bottled water and other soft drinks would belong to the same relevant market. The delineation was resolved by examining a set of correlation coefficients that established high correlation between still and sparkling mineral water and low correlation between either of these and other soft drinks. The market was thus defined as mineral (source) water; see Bishop and Walker (2002, 11.12-14).

It is even more rare that more advanced methods, such as Granger causality tests and co-integration analysis, are employed in European competition cases.<sup>6</sup> However, Granger causality tests were used in the *Mannesmann/Vallourec/Iva* merger case<sup>7</sup> to establish whether the US, the EU and Eastern Europe belonged to the same geographical market for seamless stainless steel tubes, indicating that they were. Co-integration analysis has been used in e.g. the *Lonrho/Gencor*<sup>8</sup> and in the *CVC/Lenzing*<sup>9</sup> merger cases. In the former the absence of co-integrating relationships was taken as an indication that the five products (platinum, rhodium, palladium, gold and silver) belonged to separate product markets. In the latter, the European Commission used an Augmented Dickey-Fuller test to determine that since “relative prices do not revert to some long-run equilibrium [... the] two products do not belong to the same relevant markets.”

There is a sense in which the SSNIP methodology advocates sequentiality. The SSNIP thought experiment often runs as follows: The starting point is some good. You ask the question if that good is worth monopolizing. If the answer is negative,<sup>10</sup> you look at a neighbouring good (in the product dimension or in the geographical dimension) and extend the monopolizing requirement to that good. You continue in this way until the monopolizing requirement is satisfied.

Typically, however, there are several neighbouring goods along both dimensions. It is not obvious that a sequential or step-wise approach will give the same answer as one that uses the information that is given by the *system of competitive pressures*. Neven *et al.* (1993) argue that the European Commis-

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on the price of Scottish salmon relative to that of Norwegian salmon. See Haldrup (2003) for a survey of traditional and moderne econometric methods applicable to market delineation.

<sup>5</sup>Case IV/M190 [1993] 4 *Common Market Law Review* M17; [1992] *Official Journal of the European Communities* L356/1.

<sup>6</sup>See Bishop and Walker (2002) 15.10-11 for a survey on which the following is based.

<sup>7</sup>Case IV/M315 [1994] *Official Journal of the European Communities* L102/15.

<sup>8</sup>Case IV/M619 [1997] *Official Journal of the European Communities* L11/30.

<sup>9</sup>Case COMP/M2187 [2000].

<sup>10</sup>The answer may be negative simply because the good is already monopolized. This is known as the ‘cellophane fallacy’, see Stocking and Mueller (1955). The ‘hypothetical monopolist’ might in fact be a real monopolist and thus have set the monopolist price. It would then obviously not be profitable to raise the price by whatever small but significant non-transitory amount. Some argue (e.g. Posner, 2001, 150-152) that the test should not be based on actual prices but on the (counter-factual) competitive prices.

This is evidently not an operational approach. We find that the relevant question for market delineation is whether other products exert a competitive pressure at the actual price level.

sion uses a sequential approach by first defining product markets and then only later defining geographical markets. On theoretical grounds, they argue that demand substitution may be underestimated by this approach, since the SSNIP test may fail to be satisfied first in the product dimension and then in the geographical dimension. We will argue that this critique extends and generalizes.

First, it extends to supply substitution. Suppliers may often react more to e.g. geographical price differences than consumers, e.g. when the good represents low value to the consumer that hence would not find it profitable to overcome transportation costs while suppliers would find it profitable to ship the goods in large quantities.

Second, the critique generalizes to *any dimension* of the market delineation. Even if the market delination exercise is done only in one dimension, e.g. the product dimension, we may end up with erroneous results if part of the information set is ignored. This is because competitive pressures that operate in the other dimensions, e.g. the geographic dimension or (if the good may be stored) in the time dimension, are ignored so that the partial model is misspecified.

### 3 The market for salmon in the EU

This section describes the product and the market for (farmed) salmon in the EU. In addition, a recent merger case in the UK highlights the fairly advanced methods already applied for delineating the relevant market for salmon.

#### 3.1 The product and the industry

Salmon may be farmed or caught in the wild. Farmed salmon is a relatively recent phenomenon, dating back about a quarter of a century. Before 1975, fresh salmon was only caught from wild stocks and considered a luxury product. Today, wild salmon accounts for a negligible fraction of EU consumption and will be ignored in the following exposition that focuses entirely on the market for farmed salmon in the EU.

The major producers of Atlantic salmon are Norway (54% of production volume), Scotland (17%), Chile (13%), Canada (8%), Faroe Islands (5%) and Ireland (3%). During the decade from 1990 to 2000, Atlantic salmon production more than tripled. All producing countries increased production, however the production of Scotland, Chile and Canada grew more than that of Norway.

In recent years the farmed salmon industry has shown signs of concentration: major producers have taken advantage of economies of scale and increased capacity utilisation. The salmon industry includes several vertical elements of a supply chain:

1. breeding of the salmon,
2. primary processing (slaughtering and gutting),
3. secondary processing (e.g. filleting and smoking), and
4. retailing or exporting.



The main battle fields of Norwegian and Scottish producers of farmed salmon are England, France, The Netherlands, Germany and Spain. Norway exports a lot to Denmark as well: Denmark serves as a hub for further distribution and processing of Norwegian salmon, in the same way as England serves as a hub for Irish and Scottish farmed salmon.

### **3.2 Barriers to competition**

In the markets for farmed salmon, barriers to competition might include advertising, possibly contracts with retailers, transportation costs and regulatory barriers in the form of antidumping duties. All in all, however, these barriers seem low relative to the fast growth of the markets.

Processors, wholesalers and retailers are relatively big and purportedly willing to buy salmon from both countries. Advertising is used by producers: Norwegian salmon is advertised as a healthy product. Scottish salmon is generally marketed as a superior quality product and has e.g. been awarded the Label Rouge in France. Thus Scottish producers attempt to differentiate their product vertically above Norwegian salmon. Retailers sell some salmon products as own brands.

Contracts are not widely used: Most trade is handled informally. However, retailers seem to drive a movement towards increased use of longer-term contracts but at present the market seems very flexible for all players.

Transportation is complicated but not overly expensive. Salmon requires specialized treatment throughout the distribution chain, involving iced containers and refrigerated storage facilities. Transportation costs amount to about four per cent of total costs to farmers and six per cent to processors.

In terms of regulatory barriers, the EU Commission found Norwegian producers guilty of dumping in 1996. Price floors and export volume caps were established for Norwegian producers. A punitive anti-dumping tax of three per cent was applied to all Norwegian exports. However, this tax may be used to finance marketing projects. Although Norwegian salmon is restricted by these regulations, their impact have been minimal due to the overall market development with increased volumes and prices. Prices have generally remained over the floor. Very recently the market price of farmed salmon has dropped significantly making the price floor binding.

### **3.3 A merger case in the salmon industry**

The UK Competition Commission has recently (2000) investigated and reported on the proposed acquisition by Nutreco Holding NV of Hydro Seafood GSP Ltd from Norsk Hydro. Nutreco has substantial interest in fish feed and in salmon production in Scotland, Chile and Canada but not in Norway or Ireland. Norsk Hydro is Norway's largest industrial group originating in oil and energy production. Norsk Hydro did not regard its salmon farming businesses, Hydro Seafood, as belonging to its core competencies.

Nutreco's Marine Harvest (Scotland; MH) and Hydro Seafood GSP (Norway; GSP) are the two largest farmers and suppliers of farmed salmon in the UK. They have seawater farms and gutting/packing facilities on the west coast of Scotland and in the western isles and Shetland. GSP and MH also both have freshwater facilities in Scotland for rearing smolts (juvenile salmon). Nutreco's Trow is UK's largest manufacturer of feeds for salmon and trout.

The UK Competition Commission found that the relevant market for salmon is that for gutted farmed Atlantic salmon extending across all of the EEA: Farmed salmon is imported from other European countries, mainly Norway, competes with Scottish farmed salmon and is considered a substitute for Scottish salmon by many secondary processors, wholesalers and retailers. Nutreco's post-merger share would be above 15 per cent of this broadly defined market. The Competition Commission argued, however, that Scottish salmon due to vertical product differentiation can command a modest premium in the UK and some export markets and thus ended up defining the market as "a small market segment for which Scottish salmon is a differentiated premium product within the single, wider EEA market for farmed gutted salmon." In this narrowly defined market Nutreco's share of the UK market for Scottish salmon would be around 46 per cent.

The Competition Commission recommended prohibition of the merger because of the expected direct effects on the feed market and its indirect effect on the salmon market: Nutreco's share of the UK market for salmon feed would increase substantially. The supply of salmon feed is concentrated with a three-firm concentration ratio above 90 per cent. Nutreco's Trow is one of the three large suppliers of feed. Since the merged company was stipulated to buy mainly from Trow, the Competition Commission expected the other two big feed suppliers to face increased unit costs following reduced capacity utilizations. This would lead to an even further increase of Trow's position and make it the only competitive feed producer. Other salmon farmers would thus face increased costs and "[a]s the costs of independent salmon farmers and smolt producers increase, some will either become more dependent on Nutreco or go out of business, thereby further consolidating Nutreco's position." (UK Competition Commission, 2000, p. 4).

Lexecon analysed the market definition for gutted salmon in this merger case. Based on weekly data from July 1997 through June 2000 relative prices were analyzed using stationarity tests. Lexecon relied on a sequential procedure according to which they first decided that Scottish salmon was part of the same product market as Norwegian salmon (in the UK) and then decided that Scottish salmon sold in the UK was part of a market including France and the rest of Europe. Apparently this analysis was accepted by the Competition Commission (Wills, 2000). Below we will argue that this sequential procedure may lead to wrong conclusions.

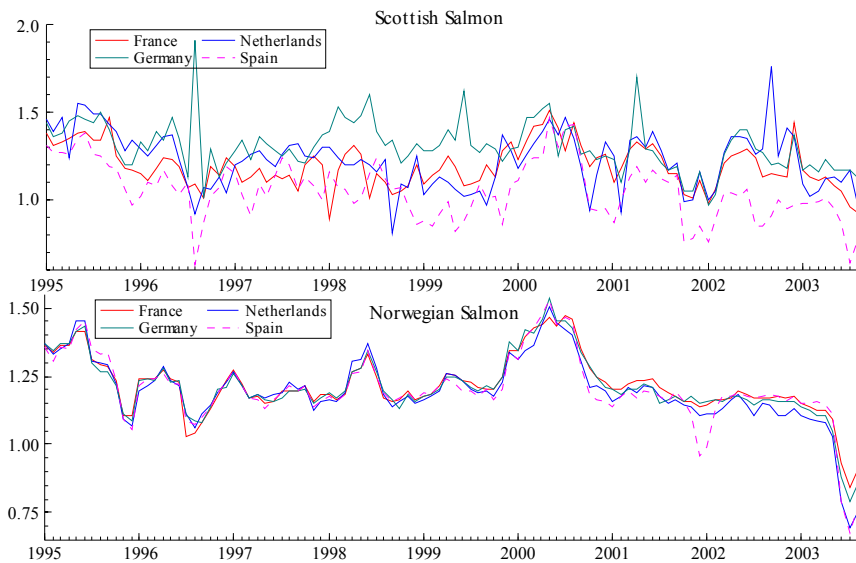


Figure 1: Log export prices of Norwegian and Scottish Salmon 1995:1-2003:8.

## 4 Econometric market delineation

### 4.1 Description of the data and some motivation for the simultaneous analysis

The price data used for the analysis of the Salmon case are export prices (FOB) for Norwegian and Scottish Salmon (Source: Norwegian Kontali, and Eurostat's Comext). For Norway data is available for most of the EU countries whilst the Scottish prices only are available for a subgroup of countries. Due to these limitations the present analysis includes the export prices for Germany, The Netherlands, France and Spain for the period 1995:1 - 2003:8. However, because there are indications in the data set that the market conditions have changed recently, see the discussion in section 3.2, much of the analysis will be for the reduced sample period 1995:1-2002:8. All prices have been converted to the same currency and unit of account (Euros per kilo). In the statistical analyses the log-transformed price series are examined.

Before any formal statistical analysis it is worthwhile considering some descriptive and graphical measures of the available data. In figure 1 the (log) export prices (henceforth: export prices) are displayed separately for Scottish and Norwegian salmon to emphasize the product dimension. Visual inspection of the figure seems to indicate different time series properties. The Scottish prices do seem to co-move to some extent, as is strongly the case for the Norwegian prices. However, as compared to the Norwegian prices the Scottish prices

tend to be somewhat more volatile. From a visual analysis one might argue that the Scottish prices are stationary,  $I(0)$ , whereas the Norwegian prices are non-stationary  $I(1)$ . If this conjecture is correct, i.e. the integration orders for prices across the two products differ, the market for Norwegian and Scottish salmon are separate. Also, because the Norwegian prices seem to exhibit the same stochastic price trend for all of the four countries, i.e. the prices seem to cointegrate, see Engle and Granger (1987) and Johansen (1991), the geographical market for Norwegian salmon includes all four countries. Even though the Scottish Salmon prices seem to co-vary in the four countries it is harder from eye-balling to say how the relevant geographical market for Scottish salmon should be delineated.

The above arguing relies on a sequential market delineation strategy. Statistical analyses of the integration orders of the individual price series do in fact show that the above conjecture about the price behaviour is correct<sup>11</sup>. However, we will demonstrate that the sequential approach can contain pitfalls which may invalidate the conclusions. At least the statistical tools that are available to do a powerful simultaneous analysis of the price series for both Norwegian *and* Scottish salmon will provide a rather different conclusion. Lets try to put forth some explanations why this can occur.

First of all, the basic reasoning why the Scottish Salmon and Norwegian Salmon, based on price tests, are to be regarded as different products is that the integration order of the price series are different. If this finding is correct the products cannot belong to the same market. It is a general time series property that an  $I(1)$  series plus an  $I(0)$  series will always be  $I(1)$ . However, for a finite sample size it can be hard to discriminate between these cases because the variance of the  $I(0)$  component can be arbitrarily big, see Franses and Haldrup (1994). When this is the case any test will have difficulties detecting the true (asymptotic) order of integration of the series and relates to the poor power of unit root tests in many cases. In relation to the above data example our argument is that even though the Scottish prices are more volatile than the Norwegian prices the general *level* of the prices seem to co-vary, perhaps except for the last year of observations. This could indicate that the Scottish and Norwegian prices could share a common price trend. Some graphs will emphasize this argument. In figure 2 the pairs of Norwegian and Scottish export prices to the single countries are displayed after the series have been filtered using the Hodrick-Prescott filter, see e.g. Hodrick and Prescott (1997). The idea is to decompose the price series  $p_t$  into the sum of a trend component  $\tau_t$  and an irregular component  $c_t = p_t - \tau_t$  where the trend is found by solving the problem

$$\min_{\tau_t} \sum_{t=1}^T ((p_t - \tau_t)^2 + \lambda((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}))^2)$$

where  $\lambda$  is a smoothing parameter.

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<sup>11</sup>Both augmented Dickey-Fuller tests, see e.g. Fuller (1976) and Dickey and Fuller (1979), and KPSS tests, see Kwiatkowski *et al.* (1992) were conducted. For space limitations these tests are not reported but can be obtained from the authors upon request.

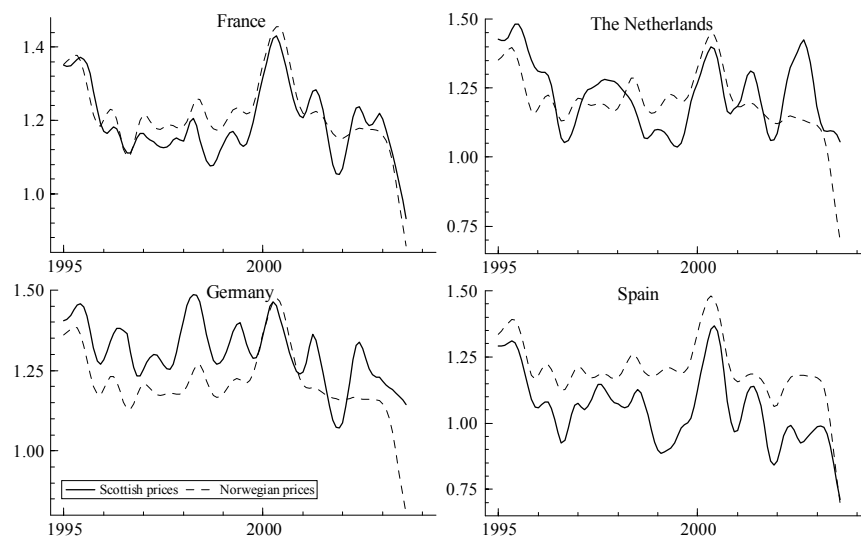


Figure 2: Hodrick-Prescott filtered (log) price trend for Scottish and Norwegian salmon exported to France, The Netherlands, Germany, and Spain.

Figure 2 displays the trend component after filtration with  $\lambda = 5$ . Even though the price trends of the Norwegian salmon are almost identical, it is of interest to observe that for each of the countries the variation of the price trends for Scottish and Norwegian salmon to each of the regions tend to co-vary, especially for the 1995:1-2002:8 period. This co-variation is hard to observe using the raw data due to the strong short-run fluctuations. So when attempting to extract the price trends across the different price series there does in fact seem to exist a common price trend element although we realize that the above analysis should be considered illustratory.

This result is interesting because it allows for the possibility that the entire system of 8 prices (2 salmon products to 4 countries) is governed by a single price trend, and when this is the case the product and geographical market is common for Norwegian and Scottish salmon. However, such an analysis necessarily requires that the 8 price series are considered jointly. The testable implications are thus to see whether the 8 price series are restricted by 7 cointegrating restrictions which implies that a single common stochastic price trend drives the entire system of prices. A particularly interesting testable implication of a joint product and geographical market is that the cointegrating relations appear in pairs whereby the relative prices (up to a scale) are stationary across products and across regions. According to Granger's representation theorem, see Engle and Granger (1987), cointegration amongst the series will imply that an error correction mechanism exists implying Granger causality in at least one direc-

tion which underscores the interaction of price behaviour. This is the property that links together the common price pattern of the price series in the present example. In the following section we will analyze these hypotheses by formal testing.

## 4.2 Simultaneous delineation of the relevant product and geographical markets

The starting point for the system analysis is a vector autoregressive model of order  $k$ , VAR( $k$ ), for the *levels* of the price series:

$$\mathbf{P}_t = \mathbf{m} + \mathbf{A}_1\mathbf{P}_{t-1} + \mathbf{A}_2\mathbf{P}_{t-2} + \dots + \mathbf{A}_k\mathbf{P}_{t-k} + \boldsymbol{\varepsilon}_t$$

where  $\mathbf{P}_t = (p_{1t}, p_{2t}, \dots, p_{qt})'$  is the vector of price series and  $\mathbf{A}_i$  are  $q \times q$  matrices with the parameters associated with each lag of the price series, and  $\mathbf{m}$  is a vector with the intercept terms of each equation. It is assumed that the error term in the VAR model is normally distributed with a covariance matrix  $\boldsymbol{\Sigma}$ :

$$\boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma})$$

The model can also be written on error correction model form, see Johansen (1991), as

$$\Delta\mathbf{P}_t = \mathbf{m} + \boldsymbol{\Pi}\mathbf{P}_{t-1} + \sum_{j=1}^{k-1} \boldsymbol{\Gamma}_j \Delta\mathbf{P}_{t-j} + \boldsymbol{\varepsilon}_t \quad (3)$$

The cointegration properties of the data are given by conditions concerning the matrix  $\boldsymbol{\Pi}$ . Technically we have to address (and estimate) the rank of that matrix. The following possibilities arise:

Rank  $\boldsymbol{\Pi} = q$  (full rank)  $\Rightarrow \mathbf{P}_t$  is stationary,  $I(0)$ .

Rank  $\boldsymbol{\Pi} = 0$  (zero rank)  $\Rightarrow \Delta\mathbf{P}_t$  is stationary,  $I(0)$ , (or equivalently,  $\mathbf{P}_t$  is  $I(1)$ ).

Rank  $\boldsymbol{\Pi} = r < q$  (reduced rank)  $\Rightarrow \boldsymbol{\Pi}\mathbf{P}_{t-1}$  is stationary  $I(0)$ .

In the third case there are  $r$  cointegrating relations and thus  $q - r$  separate price trends. This case is obviously most interesting because this is the situation where "attractor relations" exist between the price levels and hence affect market delineation. The empirical problem is thus initially to determine  $r$ . Assume now, that the rank of  $\boldsymbol{\Pi}$  equals  $r$  ( $0 < r < q$ ). In this case

$$\boldsymbol{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$$

where  $\boldsymbol{\alpha}, \boldsymbol{\beta}$  are both  $q \times r$ .

This yields the error correction model formulation of the model in the case of cointegration

$$\Delta\mathbf{P}_t = \mathbf{m} + \boldsymbol{\alpha}\boldsymbol{\beta}'\mathbf{P}_{t-1} + \sum_{j=1}^{k-1} \boldsymbol{\Gamma}_j \Delta\mathbf{P}_{t-j} + \boldsymbol{\varepsilon}_t. \quad (4)$$

It is important to observe that the number of cointegration relations measures the number of *stationary* relationships. In principle, this implies that the order of integration of the single series can be tested within the cointegrated VAR model, i.e. if the matrix  $\beta$  contains a column of zeros and a single cell with a non-zero entry, then the associated variable is stationary I(0). This has testable implications as we shall see.

With respect to the present application it is of interest to look at the further requirements for market delineation along the product and geographical dimensions, respectively. Let us look at the most interesting cases.

#### 4.2.1 Case 1. Norwegian and Scottish salmon are considered separate products and for each product there exist a geographical market delineated by the number of countries under scrutiny.

Write the 8 dimensional price vector

$$\mathbf{P}_t = (p_{1St}, p_{2St}, p_{3St}, p_{4St}, p_{1Nt}, p_{2Nt}, p_{3Nt}, p_{4Nt})' \quad (5)$$

with  $i = 1, 2, 3, 4$  indicating the country to which export takes place, and  $j = N, S$  signifies Norwegian and Scottish salmon, respectively. If we assume that the single price series are all I(1), then the cointegration rank is  $r = 6$  in the present case whereby the 8 price series are driven by 2 separate price trends: one for each product. To further identify these trends the  $\beta$  matrix should take the form

$$\beta = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ * & 1 & 0 & 0 & 0 & 0 \\ 0 & * & 1 & 0 & 0 & 0 \\ 0 & 0 & * & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & * & 1 & 0 \\ 0 & 0 & 0 & 0 & * & 1 \\ 0 & 0 & 0 & 0 & 0 & * \end{pmatrix} \quad (6)$$

where "\*" indicates an arbitrary number. If it occurs that the freely varying parameters equal minus one, then the relative prices across the different countries will be stationary which can be tested. In this case we have

$$\beta' \mathbf{P}_t = \begin{pmatrix} p_{1St} - p_{2St} \\ p_{2St} - p_{3St} \\ p_{3St} - p_{4St} \\ p_{1Nt} - p_{2Nt} \\ p_{2Nt} - p_{3Nt} \\ p_{3Nt} - p_{4Nt} \end{pmatrix} \quad (7)$$

i.e. the vector of stationary relative prices<sup>12</sup>.

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<sup>12</sup>Observe that stationarity of the relative prices is not necessary for the associated products to belong to the same market. It is sufficient that the pair of price series cointegrate

Note how the block structure in (6) indicates that Norwegian and Scottish salmon are considered separate products, i.e. only the pairs of prices for each of the goods are stationary.

The two goods can also be considered separate (in terms of product delineation) when the integration orders of prices differ. Assume the Scottish prices are all I(0) and that Norwegian prices are all I(1). Also assume that the geographical market for Norwegian salmon is the "the group of four"-countries considered in the study. In this situation the cointegration rank is  $r = 7$  and the single price trend drives the market for Norwegian salmon. Hence, the  $\beta$  matrix takes the form

$$\beta = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & * & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & * & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & * \end{pmatrix} \quad (8)$$

Whether this is a valid restriction of the cointegration matrix is again testable of course. Note that in the present case the geographical market for Norwegian salmon consists of the 4 countries. To analyze the geographical dimension for Scottish salmon requires further testing relevant for stationary variables.

#### 4.2.2 Case 2. Norwegian and Scottish salmon belong to the same product and geographical market.

In this second case the cointegration rank is  $r = 7$  and a single price trend drives all 8 prices series, i.e. this price trend is common to all prices. The  $\beta$ -matrix can for instance take the form

$$\beta = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ * & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & * & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & * & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & * \\ 0 & 0 & 0 & * & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & * & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & * & 0 \end{pmatrix} \quad (9)$$

Compared to (6) the extra column implies that the block structure vanishes and makes all prices across products pairwise cointegrated. For instance, using

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whereby the error correction mechanism following from the cointegration property will ensure co-movement of the prices. If relative prices are stationary it is just a further restriction of the model, but this will not have different implications concerning marketdelineation.



the normalization chosen in (9) the price pair  $(p_{1St}, p_{1Nt})$  cointegrates. In fact, proper rearrangement will show that all pairs  $(p_{iSt}, p_{iNt})$  for the countries  $i = 1, 2, 3, 4$  cointegrate in this case and because there are no over-identifying restrictions in this structure it is not possible to do any testing. An alternative way of specifying an exactly identified structure is

$$\beta = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ * & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & * & 0 & 0 & * & 1 & 0 \\ 0 & 0 & * & 0 & 0 & * & 1 \\ 0 & 0 & 0 & * & 0 & 0 & * \end{pmatrix} \quad (10)$$

In this case the cointegrating relations are arranged such that the price pairs for Norwegian and Scottish salmon to a particular region will cointegrate. Also the price pairs of e.g. Norwegian salmon to the various regions cointegrate. In fact, due to the exact identification several ways of arranging the pairwise prices exist.

As it can be seen, product and geographical market delineation has testable implications when the full system of price series is analyzed jointly. In the following section we will adopt the Johansen ML-procedure to test the possibilities using the present data set.

### 4.3 Testing market delineation

For the price vector  $\mathbf{P}_t$  given in (5) a VAR(2) model on the error correction model form (3) was estimated for the period 1995:1-2002:8. A constant which could be restricted to lie in the cointegration space was included which means that no linear trends were allowed to exist in the data. This is what we would also expect from visual inspection of the graphs in figure 1. The estimated VAR model was generally found to be statistically well-specified although there were some problems with the normality assumption associated with the export prices to France of Norwegian Salmon, see Table 1. However, it is well known from e.g. Gonzalo (1994) that cointegration analysis is robust to discrepancies from the normality assumption.

In Table 2 the results of Johansen's cointegrated VAR analysis are reported. Using a conservative 10% level (which is reasonable given that the asymptotic distributions may be poor in finite samples) there is clear sign of the presence of  $r = 7$  cointegration vectors which further implies that only a single common price trend drives the data. According to the discussion in section 4.2 this is a *necessary requirement* for Norwegian and Scottish salmon to belong to the same product and geographical market. In figure 3 the "cointegrating relations" are displayed and visual inspection of these reveal evidence that 7 relations are very stationary whilst the 8th relation seems much more non-stationary.

However, we need to impose further restrictions to conclude on market delineation because different possibilities exist.

Table 1. Specification testing of the VAR(2) model. The tests reported are LM tests for ARCH, heteroscedasticity, and autocorrelation. The JB test is the Jarque-Bera test for Normality.

	AR(1-6) LM-test	JB- $\chi^2$ test	ARCH-LM test	White-LM test
<b>Scottish Salmon</b>				
France	.73	9.20**	.52	.18
The Netherlands	.74	3.50	.30	1.17
Germany	.98	8.19**	.56	1.25
Spain	.95	4.93	.62	.70
<b>Norwegian Salmon</b>				
France	1.00	27.08***	.46	.23
The Netherlands	.58	1.14	.83	.73
Germany	1.37	4.69	.66	.64
Spain	.77	2.26	.25	.57

Note: "\*\*", "\*\*\*", and "\*\*\*\*" indicate significance at 10, 5 and 1% level, respectively.

Table 2. Johansen trace test for cointegration rank. The sample period is 1995:1-2002:8.

rank $r$	eigenvalue	log-likelihood	Trace-test: $H_0 : rank \leq$
0		1144.99	244.76 [0.000]***
1	.5165	1177.69	179.36 [0.000]***
2	.4210	1202.28	130.18 [0.000]***
3	.3862	1224.24	86.26 [0.007]***
4	.2861	1239.41	55.92 [0.032]**
5	.2190	1250.53	33.67 [0.071]*
6	.1542	1258.07	18.60 [0.083]*
7	.1305	1264.37	6.01 [0.197]
8	.0646	1267.37	

First we consider the possibility of all Scottish prices being stationary. This was the outcome when conducting univariate ADF and KPSS test of the single price series. We imposed the restriction

$$\beta = \begin{pmatrix} 1 & 0 & 0 & 0 & * & * & * \\ 0 & 1 & 0 & 0 & * & * & * \\ 0 & 0 & 1 & 0 & * & * & * \\ 0 & 0 & 0 & 1 & * & * & * \\ 0 & 0 & 0 & 0 & * & * & * \\ 0 & 0 & 0 & 0 & * & * & * \\ 0 & 0 & 0 & 0 & * & * & * \\ 0 & 0 & 0 & 0 & * & * & * \end{pmatrix}$$

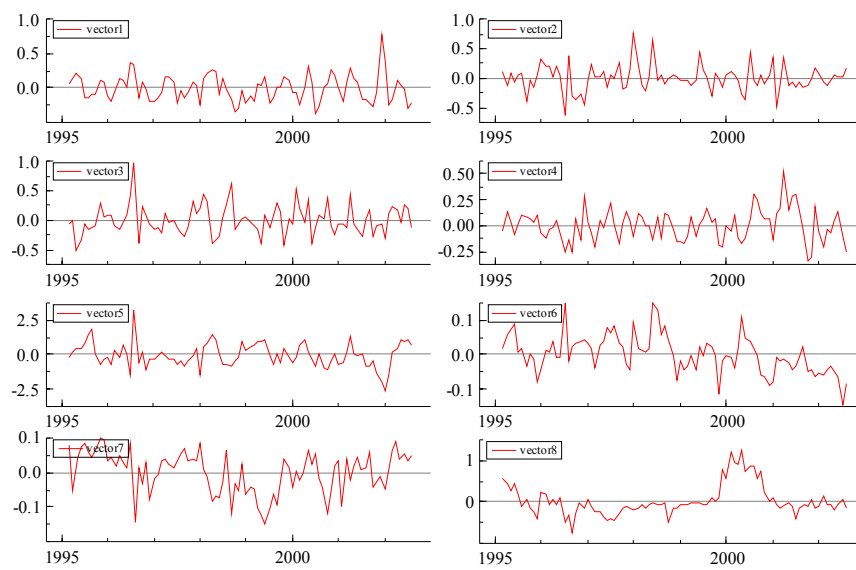


Figure 3: The cointegrating vectors. According to the Johansen ML trace test the first 7 vectors are stationary whereas the 8th is non-stationary. Note the different scales.

which is a joint test of all Scottish price series being stationary whilst leaving the remaining stationary relations unaffected. This test gives 4 over-identifying restrictions and the LR test is thus distributed as  $\chi^2(4)$  yielding a p-value of 0.002. Hence the hypothesis is rejected, thus reversing the conclusion drawn from univariate (sequential) testing. One explanation behind this result is the fact that an increased information set is used compared to the univariate tests which increases test power.

Next, in order to see how much structure we can impose on the co-integrating relations, we have considered whether the price series cointegrate in pairs. This would correspond to the  $\beta$  matrix (9) where no overidentifying restrictions are imposed. Any testing requires further restrictions. A test of whether all the relative prices are pairwise stationary implies one over-identifying restriction on each of the  $\beta$ -vectors; the LR test is thus distributed as  $\chi^2(7)$  with a p-value of 0.008 which leads to rejection. However, loosening the restrictions yields the following structure which could not be rejected:

$$\beta = \begin{pmatrix} 1 & 1 & 1 & 0 & 0 & 0 & 1 \\ * & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & -1 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 \end{pmatrix}$$

The  $\chi^2(6)$  test yields a p-value of 0.112. This means that all but one relative price tends to be stationary; the remaining relation is also stationary but it is not given as a (1, -1) relation. However, it is important to stress that while these restrictions give rise to easier intuition, they are not important for the market delineation as such. It is sufficient that we have found that the price series do in fact cointegrate in pairs whereby the error correction model representation will ensure the price dynamics to be such that the prices tend to co-move which is sufficient for the goods to belong to the same market.

The major strength of the simultaneous analysis is that the interaction of prices across Norwegian and Scottish prices can be examined. To further emphasize the interaction of prices for these products we have rearranged the above system to focus on the relative price pairs for the products. To do so the  $\beta$  matrix has been formulated such that the elements of  $\beta' \mathbf{P}_t$  reads

$$\beta' \mathbf{P}_t = \begin{pmatrix} p_{1St} - p_{1Nt} \\ p_{2St} - p_{2Nt} \\ p_{3St} - p_{3Nt} \\ p_{4Nt} - p_{4Nt} \\ * \\ * \\ * \end{pmatrix} \quad (11)$$

where we only want to focus on the first four cells for illustration. Note that these price pairs in (11) measure respectively the relative prices of Norwegian and Scottish salmon to each of the countries ( $i = 1, 2, 3, 4$ ) France, The Netherlands, Germany, and Spain. The loading matrix of these relative prices can be written as follows according to the error correction model (4) (where the remaining dynamics has been abstracted from):

$$\begin{pmatrix} \Delta p_{1St} \\ \Delta p_{2St} \\ \Delta p_{3St} \\ \Delta p_{4Nt} \\ \Delta p_{1Nt} \\ \Delta p_{2Nt} \\ \Delta p_{3Nt} \\ \Delta p_{4Nt} \end{pmatrix} = \begin{pmatrix} -.74^{***} & 0 & 0 & 0 \\ 0 & -.46^{***} & 0 & 0 \\ 0 & 0 & -.56^{***} & 0 \\ 0 & 0 & 0 & -.52^{***} \\ .06^{**} & 0 & 0 & 0 \\ 0 & .04^{***} & 0 & 0 \\ 0 & 0 & .02 & 0 \\ 0 & 0 & 0 & .01 \end{pmatrix} \begin{pmatrix} p_{1St-1} - p_{1Nt-1} \\ p_{2St-1} - p_{2Nt-1} \\ p_{3St-1} - p_{3Nt-1} \\ p_{4Nt-1} - p_{4Nt-1} \\ * \\ * \\ * \end{pmatrix}.$$

It is apparent from the price dynamics that very strong adjustment of prices takes place across the different salmon products. For instance, when a unit price difference exists between Norwegian and Scottish Salmon export to France, then 74% of this discrepancy is eliminated in the following period with respect to the Scottish salmon prices. The adjustment in Norwegian salmon prices is somewhat weaker, i.e. only 6% of the discrepancy is subsequently corrected for. In general, the Norwegian salmon prices seem to adjust somewhat less to the Scottish salmon prices than opposite. But the conclusion is that as a result of common price trends causal effects exist across products and hence advocating for a *common* product in market delineation.

#### 4.4 On the robustness of the empirical results to the full sample period

In the above empirical analysis we have limited the analysis to the data period 1995:1-2002:8. If we extend the sample to include the following twelve months for which we know that the antidumping regulation of Norwegian salmon prices has been binding, we find that our empirical market delineation results are *not* robust to such an extension. From figure 1 it is apparent that the price behaviour changes by the end of the sample period as discussed in section 3.2. Asche and Steen (2003) show how these antidumping measures affected Norwegian salmon pricing behaviour that was detached from EU salmon producers' behaviour.

A formal test of cointegration using the above techniques to the full sample period yields the results reported in table 3

Table 3. Johansen trace test for cointegration rank. The sample period is 1995:1-2003:8.

rank $r$	eigenvalue	log-likelihood	Trace-test: $H_0 : rank \leq$
0		1277.70	225.79 [0.000]***
1	.4629	1309.39	162.40 [0.000]***
2	.3715	1333.08	115.02 [0.007]***
3	.3044	1351.60	77.99 [0.040]**
4	.2353	1365.27	50.64 [0.097]*
5	.1981	1376.53	28.12 [0.239]
6	.1411	1384.30	12.59 [0.406]
7	.0755	1388.30	4.59 [0.343]
8	.0440	1390.59	

The underlying model is based upon a VAR(2) and all but the normality tests appear satisfactory. In fact, the normality tests deteriorate compared to the reduced sample which is likely to be caused by outliers in the extended observation period. For the eight price series the cointegration rank is found to be 5 using a 10 % significance level. This is a rather low value and indicates that Norwegian and Scottish salmon cannot be considered belonging to the same product and geographical market. A test of whether the Norwegian salmon prices cointegrate in pairs can also be rejected using a  $\chi^2(6)$  test which points to a much more scattered picture with respect to market delineation given the most recent price developments.

This shows that market delineation must take regulatory intervention in the pricing decisions of firms very seriously. Empirical market delineation can be sensitive to temporary, government-imposed deviations from the market conditions that would otherwise exist. Unfettered market behaviour for a given period is needed to support conclusions regarding the relevant geographical and product delineation. In other words, regulation such as antidumping duties or minimum prices may remove the competitive pressure from a certain product or geographical location thus possibly reducing the extent of the relevant market.

## 5 Conclusions

A simultaneous strategy for product and geographical market delineation has been proposed and it was demonstrated how results may differ from sequential delineation, indicating that the sequential method may lead to spuriously narrow markets. A sequential market delineation strategy where the product market is delineated prior to geographical market delineation will typically be based on a limited information set as compared to a joint market delineation. The sequential strategy suggests that for the sample period 1995:1-2002:8 Norwegian and Scottish salmon are separate products and for each product France, Spain and Holland belong to the same geographical market. The simultaneous delineation suggests that Norwegian and Scottish salmon are to be considered belonging to the same product market as well as the same geographical market.

In addition, we showed that regulatory intervention in a part of the relevant market may reduce the extent of the market since it reduces or eliminates a part of the competitive pressure.

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