“Management, markets and politics: statistical screening for historical footprints in Arctic coal mining”

SECTION 4. Practitioner's corner

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Abstract

The paper looks at the economic performance of the main (coal mining) company operating in Svalbard based on time series data from 1922 to 2006 and uses statistical techniques to detect structural breaks in economic indicators decomposed into components that the company control or influence and components that are exogenous. The analysis suggests distinctive historical periods and illustrates that statistical time series analysis may be used as a screening device to discriminate between noise and real change.

Keywords: management, coal mining, time series analysis, Svalbard.
JEL Classification: C22, F5, L72, M11, M21, N54.

Introduction

The business enterprise we study is located in Svalbard, the archipelago in the Arctic Sea between the 74th and the 81st parallel, half way between the northern mainland of Norway and the North Pole. Svalbard consists of 4 main islands (around 150 islands in total) and covers an area of about 1.5 times the size of the Netherlands or about the same as the area of West Virginia. The place name "Svalbard" is known from Icelandic chronicles dating back to 1197, but it has not been possible to verify Norse presence before Dutch explorers arrived in 1596. Svalbard has been under Norwegian rule since the world order after the First World War was settled at the Versailles conference (the Svalbard treaty was not accepted by the former Soviet Union until 1928).

Coal findings were reported as early as 1610, but commercial explorations are more recent. Operations, set up in 1906 by an American company (*Arctic Coal Company*), and taken over a decade later by *Store Norske Spitsbergen Kulkompani* (Great Norwegian Spitsbergen Coal Company in translation – hereafter SNSK) are still running a century later and is by far the major economic enterprise in Svalbard. Today the Norwegian State owns 99.9 percent of the company's shares.

Although the history of arctic coal mining is fascinating in itself, the purpose of this inquiry is to take advantage of the long records for the company in order to statistically detect historical footprints (data from 1922 to 2006)[1]. The use of statistical analysis coupled with economic theory in the study of business performance over the long haul has increased during the last decades, and the importance of such an approach is advocated by Harvey (1989). We will argue that the time series methodology we apply have potentially a general interest as a screening device in order to discriminate between more or less important events when long time series are available[2].

To identify significant changes in the development of the company, we employ statistical techniques to test for breaks in the time series, in particular with respect to turnover and productivity. We believe that the structural break methodology may serve as a screening device in time series analysis of firm performance, and point to periods of time where richer descriptions and analysis are of particular importance. Hence, we do not argue that statistical techniques offer a panacea for substantial analysis. After all, sampling precision as measured by statistical significance is not a substitute for practical significance, as forcefully argued by McCloskey and Ziliak (1996). Moreover, univariate time series analysis is basically *atheoretical* in the sense that it describes the behavior of a variable in terms of past values without the benefit of a well-developed substantial theory (Greene, 2000, p. 748). What we do argue is that the statistical approach is a potential useful tool that may inform subsequent research about points in time that deserves particularly careful attention.

The main aim of the present paper is to demonstrate how the statistical approach can be applied by shedding light on how the company has fared in terms of commercial performance, to what extent the performance is due to good management as opposed to good fortune, and to what extent the right to manage based on commercial interests has been hindered by political concerns. To answer these questions we should look for data that may discriminate internal from external effects.

External market effects are arguably best represented by product prices. SNSK is a price taker by

[1] A detailed historical account of coal mining in Svalbard until 1965 is given by Hoel (1966). Literature specifically on SNSK include Arlov (1991), Westby (2003), Martinussen (2005), and Kvello (2006a; 2006b). In English, Arlov (1989) offers a very brief introduction to the history of Svalbard (including mining) with suggestions for further reading, and very recent, Avango et al. (2011) offers a more international perspective.

[2] Hansen (2001). See also the editorial introduction by C. Harvey (1989).

assumption as a small player, but there may be some element of endogeneity in average prices obtained through the choice of product mix and hence traces of internal effects and in periods also bargaining with the authorities. We should therefore be aware that price taking is an approximation.

Quantity of coal mined and shipped should in principle be choice variables for the company, but there are numerous constraints that could limit the feasible alternatives. Ice conditions could, e.g., reduce shipments and be a binding exogenous restriction. Another example are political constraints. As a non-renewable resource, coal reserves that can be extracted are available in limited supply. A possible tension between political and commercial interest could therefore be the scale of operations. If there is economies of scale, management would want to take advantage of this and not restrict operations to a sub optimal level. On the other hand, this could endanger the continued presence of economic activities as reserves would run out at a faster pace, possibly in conflict with political interests and the company could be instructed to reduce production.

The employment decision is in principle also a choice variable for the company, but again there might be considerations that restrict that choice. It may be the case, e.g., that the manning during the Cold War was influenced by the manning on the Soviet side in order to keep some balance in populations.

Due to the fact that the Norwegian State owns close to all shares in SNSK, there are no doubt factors other than economic factors that play an important role in understanding the development of the company. Long-term strategic interests have been and still are important in order to understand the direct and indirect regulations of industrial activities in the Arctic[1]. According to official declarations regarding the goals and means of Norwegian policy, the overriding ambition has always been to keep Svalbard out of conflicts between the (former) Superpowers and to ensure credible Norwegian governance over the islands. It is also stated that the main tools for policy achievement are a consequent upholding of the Svalbard treaty from 1920, and maintaining Norwegian activities on the islands, of which coal production has been decisive[2].

There may be considerable acceptance for incurring costs in order to accomplish national political objectives in Svalbard, but it should still be done as cost efficient as possible from a societal point of view and inefficient solutions should be ruled out. After all, there are several alternatives that could potentially serve to ensure substantial Norwegian presence. Alternatives already present include tourism, research and university education. Our analysis based on the company's annual reports may shed some light on the efficiency of coal production as the preferred policy instrument.

We recognize that the political interests constitute exogenous factors which are very difficult to find meaningful empirical representation for. It is therefore reasonable to let the data we have available on firm performance, talk for themselves in order to distinguish dates where the footprints of data are large enough to detect changes in a statistical sense, and then turn to historical information that could be relevant in explaining the changes. The historical information could be related to changes in technology, market constraints or political constraints.

In the next section we give a presentation of the data followed by a univariate analysis of time series properties (the complete dataset is found in the Appendix). We proceed by looking for structural breaks with unknown timing in the time series data to identify possible break dates for turnover, productivity and decompositions. Then we present descriptive statistics for the distinct periods. This is followed by offering some possible explanations for the changes based on the information on break dates. We round off with a discussion summarizing results.

1. Data

Annual reports from the company are publicly available back to 1916 and are our main source of information. The first year of regular operations is 1922-1923 (accounting year from July 1st to June 30th)[3]. Operations were interrupted during WWII – people were evacuated to Britain and the mines were destroyed by the Germans. The period from 1922-1923 to 1940-1941 represents 19 years of operation. After rebuilding, by 1947-1948 the production level exceeded the level before the war. We take 1947-1948 to be the first year of regular operation in the post-war period. At present, the

[1] Military motives are still important in the geopolitics of the Arctic. See, Aalto (2002), Smith and Giles (2007).

[2] Ministry of Justice and the Police, St. meld. nr. 9, 1999. The Svalbard treaty from 1920 "recognises the sovereignty of Norway over the Archipelago of Spitsbergen, including Bear Island, of seeing these territories provided with and equitable régime, in order to assure their development and peaceful utilisation". It was signed by the head of states for the United States, Great Britain and Ireland, India, Denmark, France, Italy, Japan, Norway, the Netherlands, and Sweden. The treaty also states that parties signing the treaty "shall be admitted under same conditions of equality to the exercise and practice of all maritime, industrial, mining or commercial enterprises both on land and in the territorial waters …". Clearly, there is a potential for other parties to establish activities in the area and a substantial Norwegian presence seems as rational choice of policy strategy.

[3] Due to a fire in 1920, operations were severely set back as they hardly had been started after some initial investments following the takeover in 1916 and obstacles in the aftermath of the First World War.

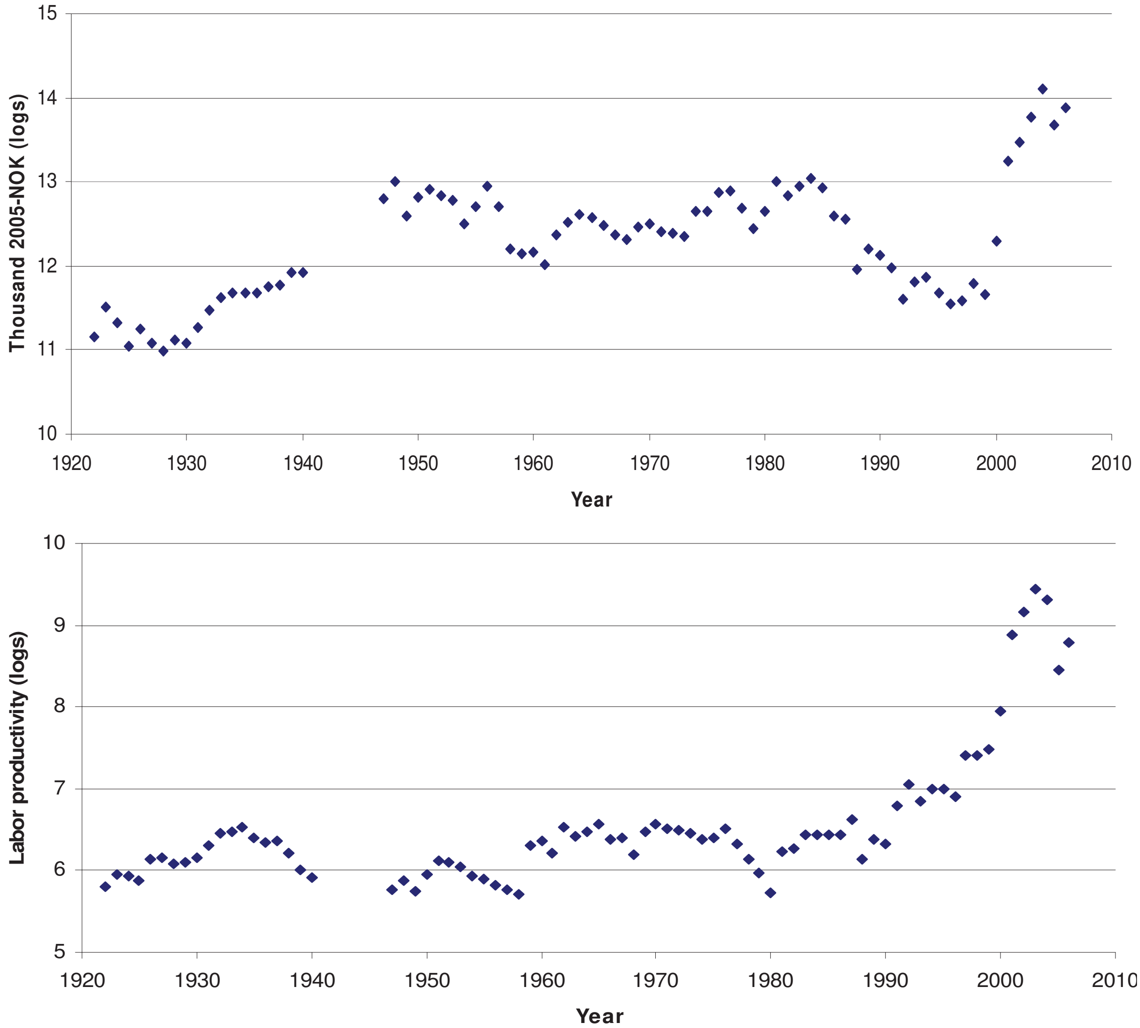
most recent figures are from 2006. Together with the pre-war period this gives a sample of 79 operation years.

Annual reports for more recent years contain much more detailed information than the first years. To construct data series relevant for all years, the limitations imposed by early information is therefore restricting the set of variables to choose from. Two variables we do have information for is the turnover from coal sales measured in prices including freight costs and labor productivity measured by tonnes produced per number of employees. Indeed, these variables are emphasized by the company itself in recent annual reports under "key figures": "Increase in turnover, 1999-2006, 912%; Increase in productivity, 1999-2006, 493%" (Annual Report and Accounts 2006, p. 3).

2. Econometric analysis

We will start our investigation by looking at turnover and labor productivity as performance indicators. However, we also have information on volume shipped so we may decompose turnover in volume and implicit price (c.i.f.), and we have information on volume produced and number of employees by end of year so we may decompose productivity in production quantity and labor input[1].

Our approach will be to let the data talk by looking for structural breaks or shifts in the time series. A preliminary impression of how turnover and productivity have evolved is given in Figure 1. The nominal figures have been deflated by the consumer price index for Norway (base year 2005) and are given in natural logs.



Notes: Data and sources are given in the Appendix. Turnover (c.i.f) is measured in thousands of 2005 NOK using the consumer price index for Norway as deflator. Labor productivity is given as production of coal in tonnes per employee. Both series are given in natural logs. Last production year included before the war is 1940/1941 and first year after the war 1947/1948.

Fig. 1. Performance indicators (1922-2006) real turnover and labor productivity

[1] Please note that all volume figures in Annual reports prior to 1976-1977 were given in imperial tons (short tons). The older figures are transformed to ordinary metric tons (tonnes). C.i.f. is shorthand for cost, insurance, freight and means the price covers the expenses of getting the product to the destination.

As apparent from the graphs, turnover, as well as labor productivity has increased in recent years. We want to see if this change may be detected as a statistically significant break in the time series (in a sense that will be made more precise below). Moreover, we will search for and date other breaks. Once the breaks or shifts are identified and dated we may look for incidences that year that may explain why the shift occurred at that particular point of time.

The methodology for detecting a single unknown break is developed both for data containing a unit root and stationary non-trending data. However, if the data contain a unit root the power of the tests can be improved by using differenced data[1]. It is therefore of interest to test for a unit root and transform data from levels to first differences if the null hypothesis of a unit root cannot be rejected. Moreover, tests for multiple structural breaks are developed for stationary non-trending data, so the questions we posed cannot be fully answered if we do not transform data containing a unit root anyway. Let us therefore start by testing the real turnover and labor productivity series (measured in logarithms) for a unit root.

Since non-rejection of a unit root can be sensitive to specification, we have performed several unit-root tests based on various assumptions about the presence of a structural shift (ordinary augmented Dickey-Fuller, Dickey-Fuller Generalized Least Squares, Zivot-Andrews). The 79 observations are treated as if positioned equidistant along a time line. All tests suggest a unit root. Results are reported in Table 1.

Table 1. Unit root tests for turnover and productivity

Dickey-Fuller unit root tests			
	Constant term and no trend		Constant term and trend
Dickey-Fuller test statistic	-1.74 / .02		-2.20 / -1.09
DF-GLS test statistic	-.83 / .42		-2.53 / -1.40
Unit root tests under structural change:			
	Change intercept	Change trend	Change both
Test statistic	-2.86 / -2.79	-3.04 / -4.04	-3.10 / -4.06

Notes: Data and sources are given in the Appendix. First entry before the slash is for turnover and second entry after the slash for labor productivity. All tests suggest a unit root. For the ordinary augmented Dickey-Fuller test (Dickey and Fuller, 1979), the p-value for the regression without a trend is .41 (turnover) / .96 (productivity) − with a trend .49 / .93. For the DF-GLS tests (Elliot and Stock, 1996) the critical values at the 5 % level are 2.18 (no trend) and 3.10 (trend). The number of lags is 1 for all tests. For the DF-GLS test the number of lags is determined by the modified Akaike information criterion (Ng and Perron, 2002) and the highest lag order is set according to the Schwert method (Schwert, 1989) equal to 11. For the unit root test under structural change (Zivot and Andrews, 1992) the Akaike information criterion is also used. The critical values at the 5 % level are -4.80 (change intercept), -4.42 (change trend) and -5.08 (change both).

[1] See Vogelsang (1997).

On basis of this we leave the data in levels and use differenced data to detect possible structural shifts. We drop the observation for 1940-1941 for reasons that will be made clear when turnover later on is decomposed into price and quantity. Differencing means we loose another observation, leaving us with 77 observations in total.

3. Structural breaks in performance

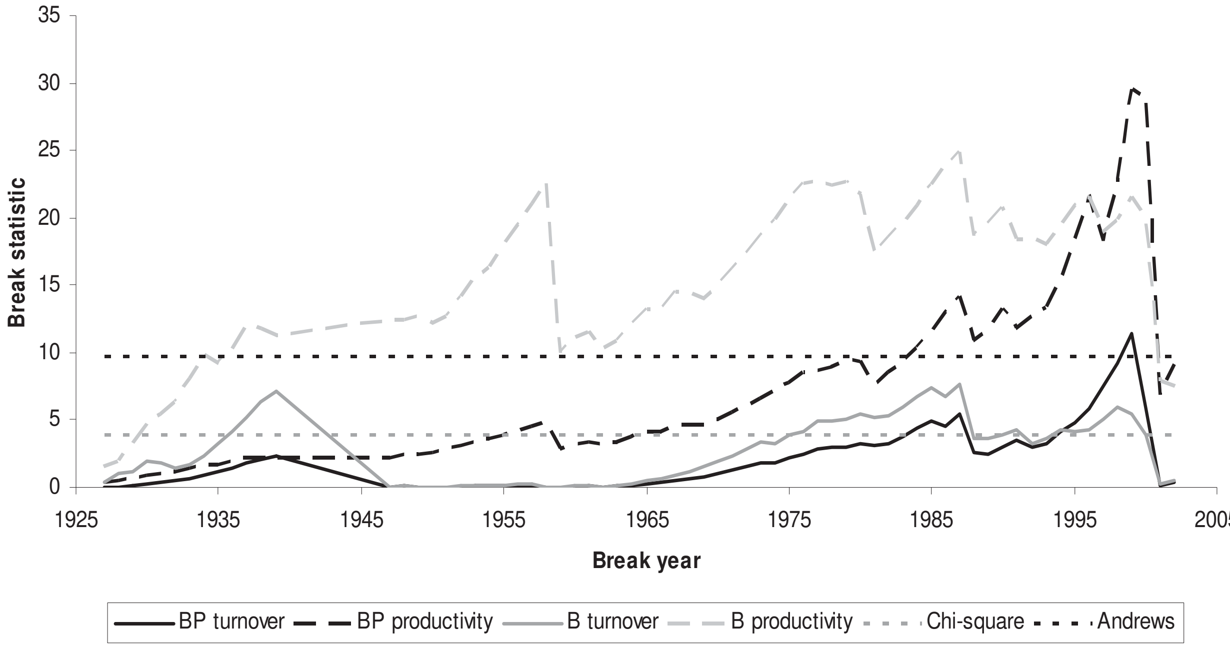
Consider a simple autoregressive model representing the process generating the series:

$$y_t = \alpha + \rho y_{t-1} + e_t,$$
$$Ee_t^2 = \sigma^2,$$

where y is the differenced turnover or productivity that may be interpreted as the growth rate and e is a time series of serially uncorrelated shocks. Greek letters are parameters and E is the mathematical expectation operator. We may now make the idea of a structural break or shift precise: we have a structural break if at least one of the parameters has changed in a statistically significant way at some date in the sample period. Hence, we may distinguish between breaks due to changes in the mean (controlled by the parameters α and ρ) and changes in the variance (σ).

We start by looking at the variance. If the break date were known a priori, we could have performed a simple Breusch-Pagan test for equal variance before and after this date conditional on equality of other parameters or a Bartlett's test allowing other parameters to be different before and after the date as well (or possibly some other test for heteroscedasticity). With unknown break date, we may compute the test statistics for all possible break dates within a range in the sample period. The range is conventionally set to include all sample points except the 5, 10 or 15 percent on each end. Here, we use 5 percent (excluding 4 observations on each end) so the earliest break year considered corresponds to calendar year 1927 and the latest to 2002. If the test statistic exceeds the critical value for any break date, we reject the null hypothesis of equal variance[2]. The test statistic sequences as functions of break date for turnover and productivity are graphed in Figure 2. If we were testing for a known potential shift date the relevant critical value would be the ordinary chi-square critical value with one degree of freedom (equal to 3.8 at the 5% level), but without a priori information the (asymptotic) critical value is much higher (equal to 9.7).

[2] The asymptotic critical values for this kind of test where a parameter (the break date) is present under the alternative, but not the null, are given by Andrews (2003).



Notes: Data and sources are given in the Appendix. Sample for 1923-2006 (except 1940-1946). The break statistics are the Breusch-Pagan statistic (BP) and the Bartlett's statistic (B). For the BP residuals are obtained from running OLS imposing constant parameters across the break year and then regressing the squared residuals on a dummy allowing the constant to be different across the break year. If the dummy enters significantly, this is indication of a break. For the Bartlett's test separate regressions (allowing intercept and slope to be different) are run on the two sub-samples divided by the break year. We have used 5 percent trimming (the potential break year within 4 observations on each end).

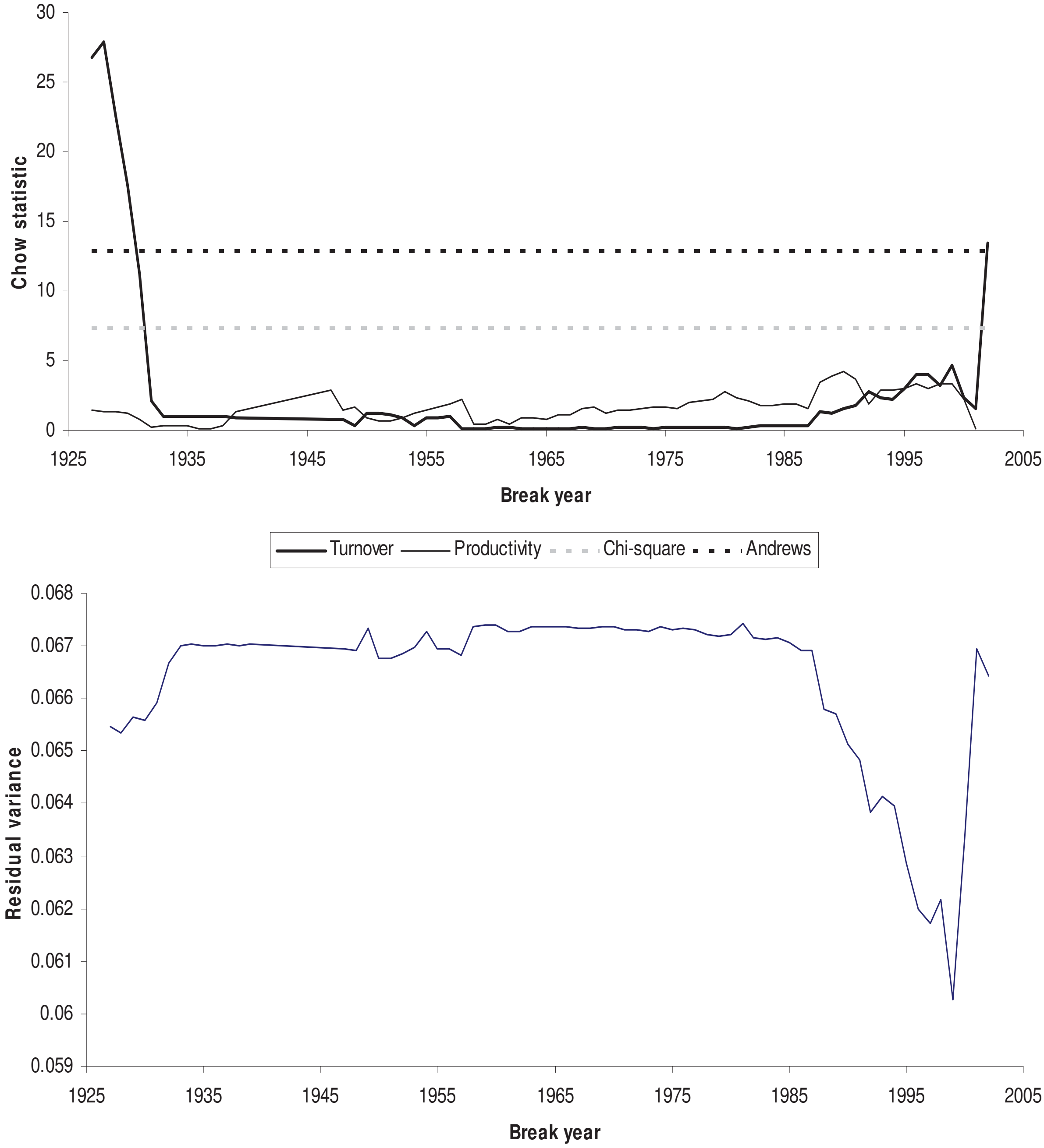
Fig. 2. Break statistics for variance as functions of break year

From Figure 2, we notice that the Breusch-Pagan test points to the same break year for both turnover and productivity, 1999 (the year the curves peak). The Bartlett's test also points to the same year for both series, but 1987. It is clear that there is strong indication of one or more shifts for productivity. The Breusch-Pagan statistic peaks in 1999, suggesting this as the best identified break year. The Bartlett's test however, peaks in 1987. Hence, there is a difference between the tests. Performing second round Bartlett's tests for the two sub-periods, split by the first round break of 1987, reveals no new shifts. Likewise, Breusch-Pagan tests on the period prior to the first round break of 1999, does not reveal any new breaks either. Hence, we may infer that: (1) there appears to be heteroscedasticity for both turnover and productivity; (2) shifts appear to have happened in 1999 and possibly in 1987 for productivity and 1999 for turnover; (3) the test statitics for both series follow the same time pattern, possibly reflecting a high degree of correlation between produced quantity (entering the productivity measure) and shipped quantity (entering the turnover measure).

The next question to be answered is whether there is also evidence for breaks in the parameters controlling the mean. Since homoscedasticity was rejected, we use the Wald version of the Chow test statistic (robust to heteroscedasticity) for all possible break years and compare the maximum to the Andrews critical value as we did for the break statistics for variance[1]. We first compare the robust test statistic to the critical value in order to detect significant breaks. Then, we compute the residual variance to identify the year for this.

The Chow test sequences as a function of break date for changes in both parameters controlling the mean for turnover and productivity are graphed in the upper panel of Figure 3. With known potential break date the relevant critical value would be the ordinary chi-square critical value (for break in both mean parameters equal to 6.3 or two times the critical F-value, at the 5% level), but with unknown break date we should use the (asymptotic) Andrews critical value that is twice as high (12.8). We observe that the test statistic clearly exceeds the Andrews critical value for turnover, but not for productivity. The residual variance for turnover graphed in the lower panel of Figure 3, takes a minimum in 1999, pointing to 1999 as the break year for the mean parameters as well.

[1] Since there appears to be heteroscedatsticity in both series, we take this into account using the Wald version of the Chow statistic with a covariance matrix robust to heteroscedasticity, see Ohtani and Kobiyashi (1986).

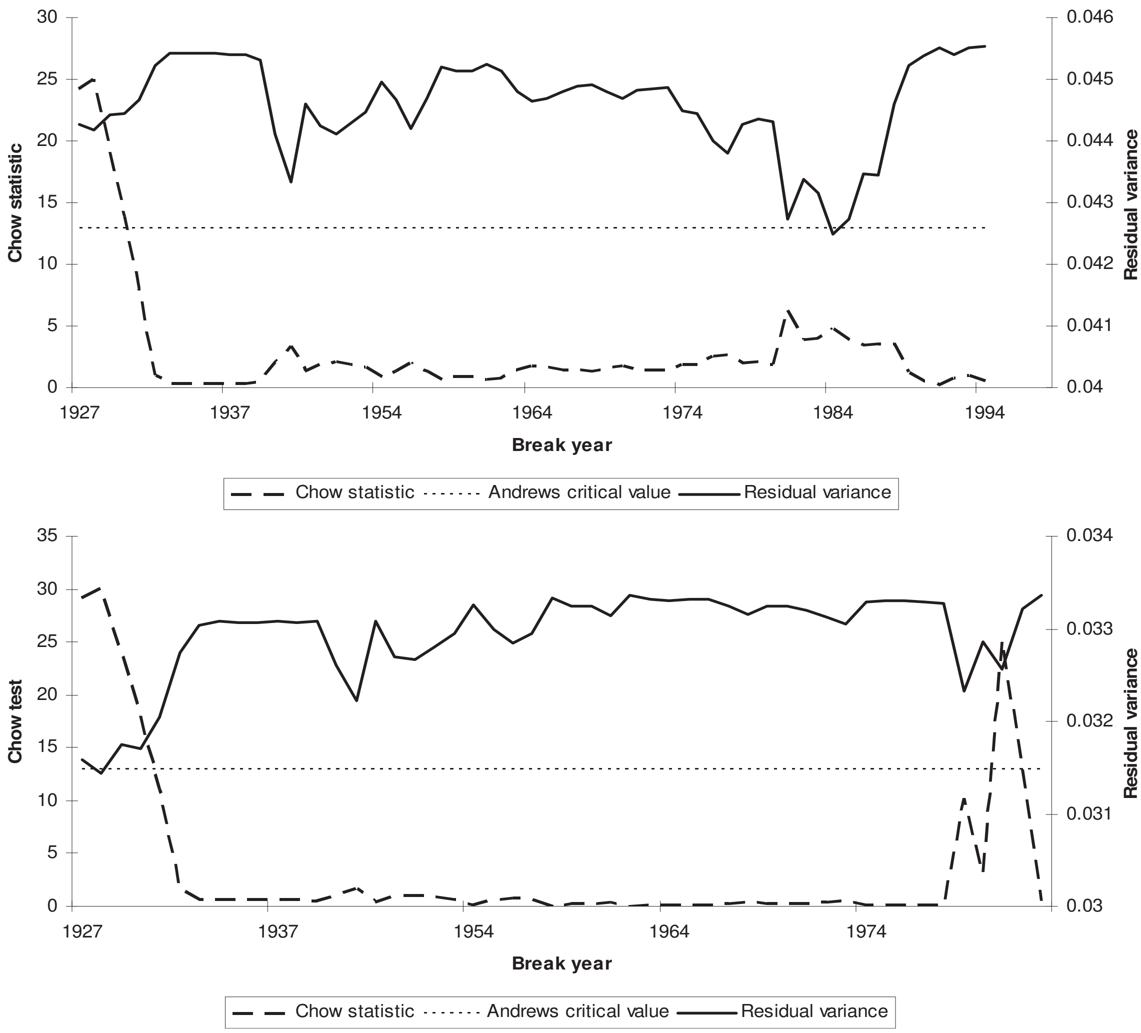


Notes: Data and sources are given in the Appendix. Sample for 1923-2006 (except 1940-1946). The upper panel contains break statistic for turnover and productivity. The statistic is the heteroscedasticity robust version of the Chow statistic for a break in both parameters controlling the mean. We have used 5 percent trimming (the potential break year within 4 observations on each end). The lower panel presents the residual variance for turnover as a function of break year.

Fig. 3. Break statistic for mean as function of break year

In order to identify additional structural shifts, we split the sample at the break date and consider the first period sample only. Repeating the procedure we used for the whole sample, it is clear that there is a statistically significant break. The Chow statistic exceeds the 95 percent level Andrew critical value by far (the broken curve in upper panel, Figure 4) and the estimated break year is 1984 (the minimum point on the solid curve).

Continuing the search for more shifts, the lower panel of Figure 4 reveals that we have another shift in 1928.



Notes: Data and sources are given in the Appendix. Upper panel: sample for 1923-1998 (except 1940-1946). Lower panel: sample for 1923-1983 (except 1940-1946). The original trimming corresponding to 5 percent of the full sample (4 observations on each end) is maintained throughout the search. The Chow statistic based on estimation robust to heteroscedasticity is used to test for significant breaks in both parameters controlling the mean. The residual variance is used to identify the point estimate of the break year.

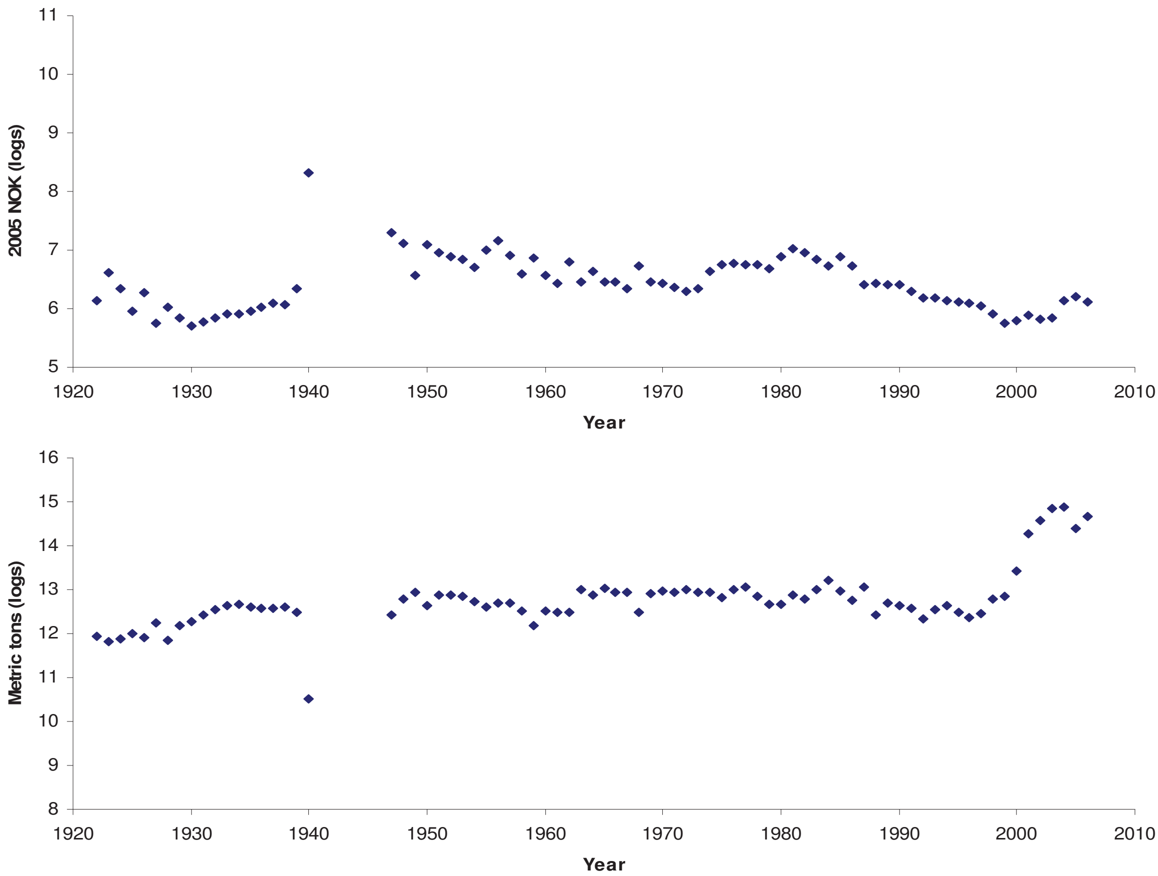
Fig. 4. Sequential search for structural breaks in turnover

Is there any break between 1928 and 1984? 1948 would have been identified as yet another one if we had suspected 1948 to be a break year and tested this a priori presumption, but testing for this with unknown timing means the Chow statistic is too small to be significant. In total, there is therefore indication of at least three structural breaks for turnover: 1928, 1984 and 1999.

We now decompose turnover and productivity and undertake a similar analysis of the components in order to see whether the breaks can be assigned to one or the other. For turnover the components are real price (c.i.f.) and quantity shipped, for productivity quantity produced and labor input measured in the number of employees. The components may in varying degree over time be more or less within or outside the control of the firm. If outside, hence exogenous to the firm, shifts should be interpreted in terms of good fortune or bad luck and not to good or bad management. If within control, breaks may be interpreted in terms of shifts in performance. Hence, the decomposition may make more sense when assessing management performance than looking at more aggregate measures like turnover and productivity.

3.1. Decomposition of turnover. We have information on how much coal is shipped and can therefore compute the implicit annual average real price (c.i.f.). The series for the price and quantity are plotted against time in Figure 5. The 1940-1941 observation is an outlier that does not qualify as an ordinary year of operation and is left out of the sample (as we did for turnover as well although the high price is offset by the low quantity). The low quantity and extreme price that year may be explained by the war.

As for turnover, we test for a unit root using different tests in order to obtain more robust results. The results are reported in Table 2 below, where the first entry (before the slash) is for the price series and the second (after the slash) is for volumes.



Notes: Data and sources are given in the Appendix. Real price (c.i.f) is measured in 2005 NOK using the consumer price index for Norway as deflator. Quantity is quantity shipped in tonnes (data prior to labor productivity is given as production of coal in tonnes per employee. Both series are given in natural logs. Last production year included before the war is 1940/1941 and first year after the war is 1947/1948.

Fig. 5. Price and quantity (1922-2006)

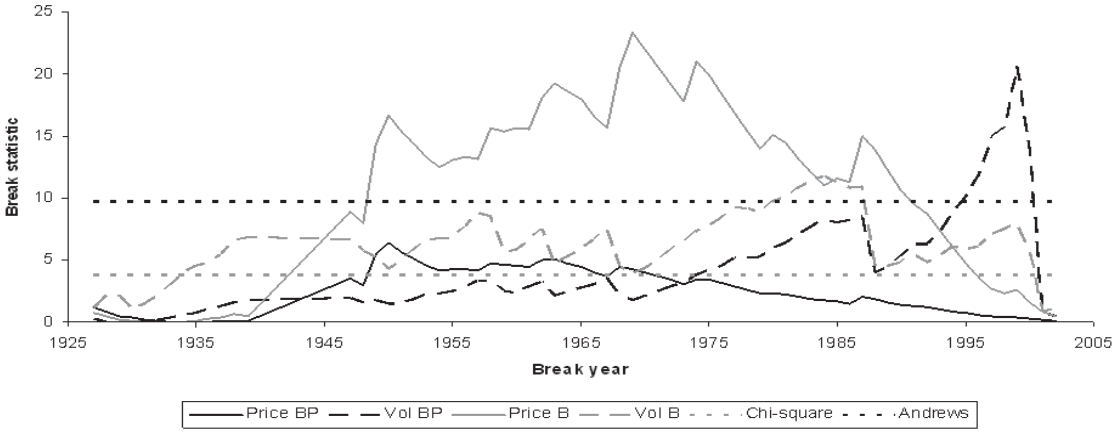
Table 2. Unit root tests

Dickey-Fuller unit root tests			
	Constant term and no trend	Constant term and trend	
Dickey-Fuller test statistic	-2.43 / -0.66	-2.43 / -1.48	
DF-GLS test statistic	-1.62, -1.41 / 0.40	-1.74, -1.51 / -1.58	
Unit root tests under structural change			
	Change intercept	Change trend	Change both
Test statistic	-4.20 / -1.93	-3.79 / -3.62	-4.04 / -4.28

Notes: For references and sources, see note to Table 1. First entry before the slash is for price. Second entry after the slash is for volume. All tests suggest a unit root. For the ordinary augmented Dickey-Fuller test with one lag, the p-value for the regression without a trend is .13 (price) and .86 (volume); with a trend .37 (price) and .84 (volume). For the DF-GLS test the critical values at the 5 % level are for no trend -2.18 and -2.17 (first and second lag, price), and -2.18 (first lag volume). With a trend the critical values are -3.10 and -3.07 (first and second lag, price), and -3.10 (first lag volume). The number of lags is determined by the modified Akaike information criterion and the highest lag order is set according to the Schwert method, equal to 11. For the unit root test under structural change the Akaike information criterion is also used giving one lag for price and zero lags for volume. The critical values at the 5% level for the test is -4.80 (change intercept), -4.42 (change trend) and -5.08 (both).

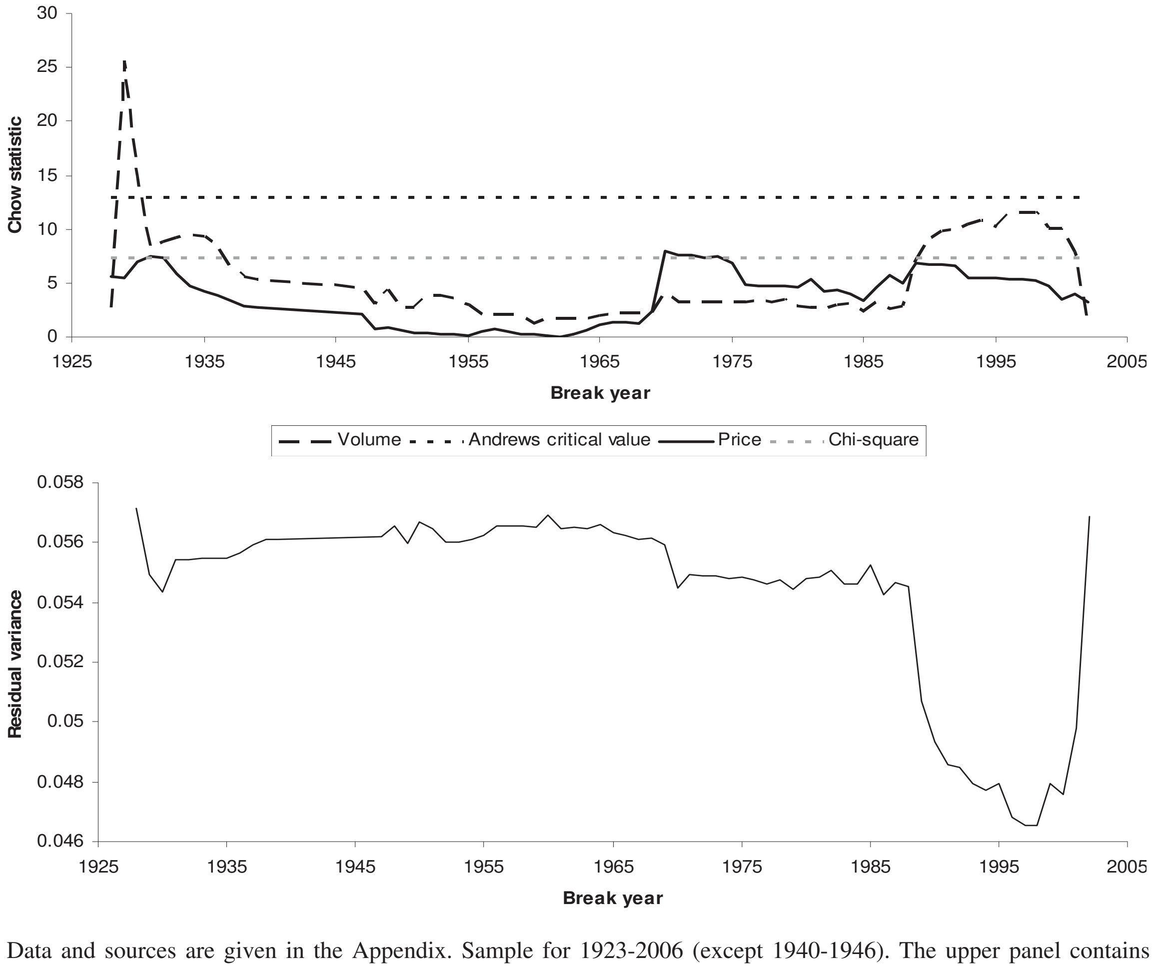
Since the series appear to contain a unit root we difference the data and proceed with the analysis as we did for turnover. We first test for shifts in the variance. From Figure 6, we observe that both the Breusch-Pagan test and the Bartlett's test indicate a shift for volume, although the identified timing differs: 1999 for the first test and 1984 for the second. For price, only the Bartlett's test suggests a shift (1969). Repeated search within subsamples delineated by first round breaks does not reveal additional structural changes.

We proceed by looking for breaks in the mean, using the Wald version of the Chow statistic as we did for turnover and productivity. The upper panel of Figure 7 indicates that there is a shift for volume shipped and the lower panel suggests 1997 as the year. For price there appears to be no significant shift, but we do observe that the test statistic exceeds the critical chi-square value around 1970. The Bartlett's test suggested a break in variance for price around 1969. Hence, we could argue that a reasonable procedure would be to test for a change in variance with unknown date and then proceed to test for a shift in mean for the year identified or an interval around the point estimate. In this case, we might conclude that there is some suggestion that there may be a shift in both variance and mean around 1969-1970 for price.



Notes: Data and sources are given in the Appendix. Sample for 1923-2006 (except 1940-1946). The break statistics are the Breusch-Pagan statistic (BP) and the Bartlett's statistic (B). For the BP residuals are obtained from running OLS imposing constant parameters across the break year and then regressing the squared residuals on a dummy allowing the constant to be different across the break year. If the dummy enters significantly, this is indication of a break. For the Bartlett's test separate regressions (allowing intercept and slope to be different) are run on the two sub-samples divided by the break year. We have used 5 percent trimming (the potential break year within 4 observations on each end).

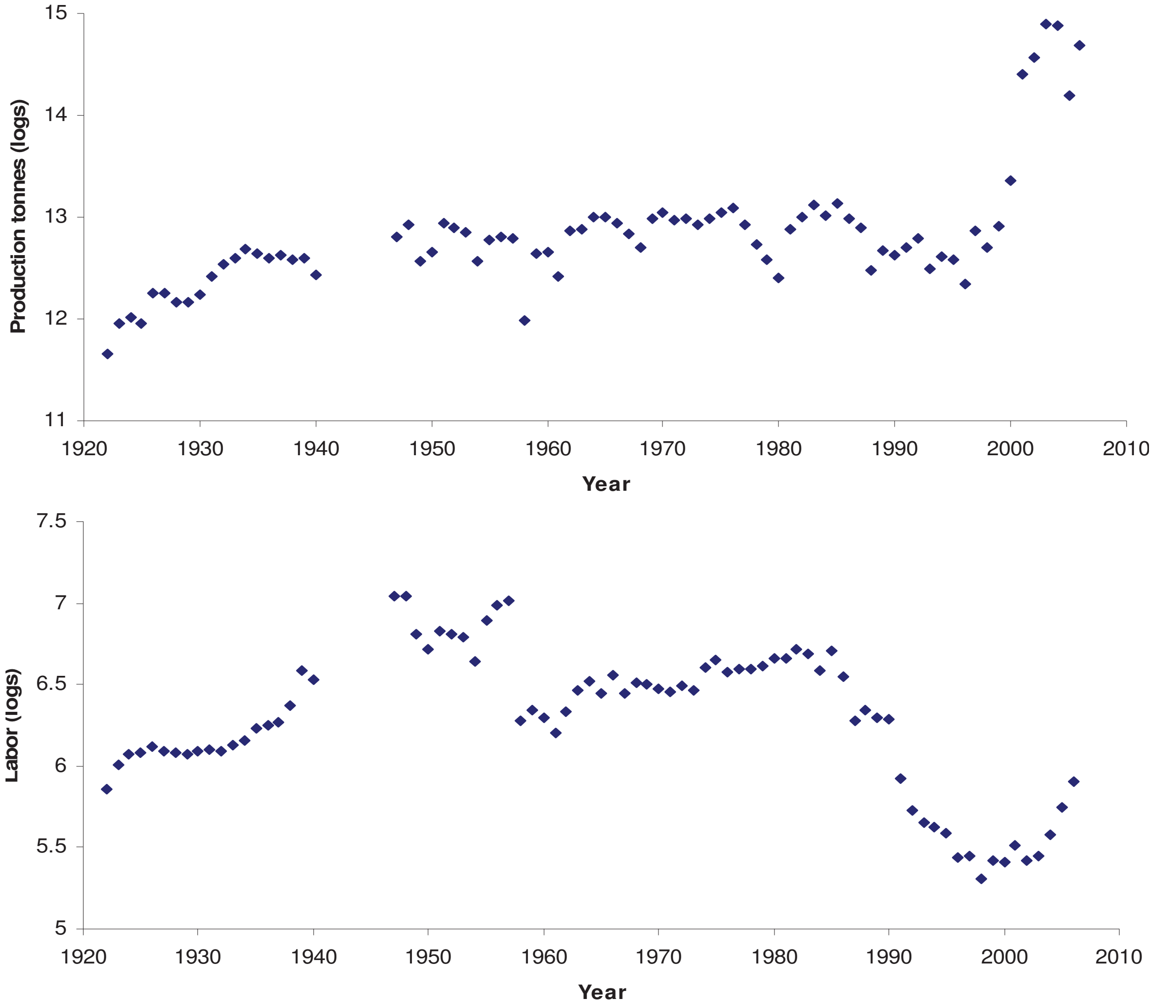
Fig. 6. Break statistics for variance as functions of break year



Notes: Data and sources are given in the Appendix. Sample for 1923-2006 (except 1940-1946). The upper panel contains break statistic for turnover and productivity. The statistic is the heteroscedasticity robust version of the Chow statistic for a break in both parameters controlling the mean. We have used 5 percent trimming (the potential break year within 4 observations on each end). The lower panel presents the residual variance for volume shipped as a function of break year.

Fig. 7. Break statistic for mean as function of break year

3.2. Decomposition of labor productivity. Labor productivity may be decomposed into quantity of coal produced during an accounting year and labor input as measured by the number of employees at the end of the calendar year. Both series are plotted against calendar years in Figure 8 below.



Notes: Data and sources are given in the Appendix. Quantity is quantity produced in tonnes (data prior to 1976 were given in imperial tons, but are transformed to metric tons (tonnes)). Labor input is given as the number of emplyees at end of calendar year within the accounting year. Both series are given in natural logs. Last production year included before the war is 1940/1941 and first year after the war is 1947/1948.

Fig. 8. Quantity produced and labor input (1922-2006)

Both series have been tested for a unit root the same way we have done for the previous series.

Table 3. Unit root tests

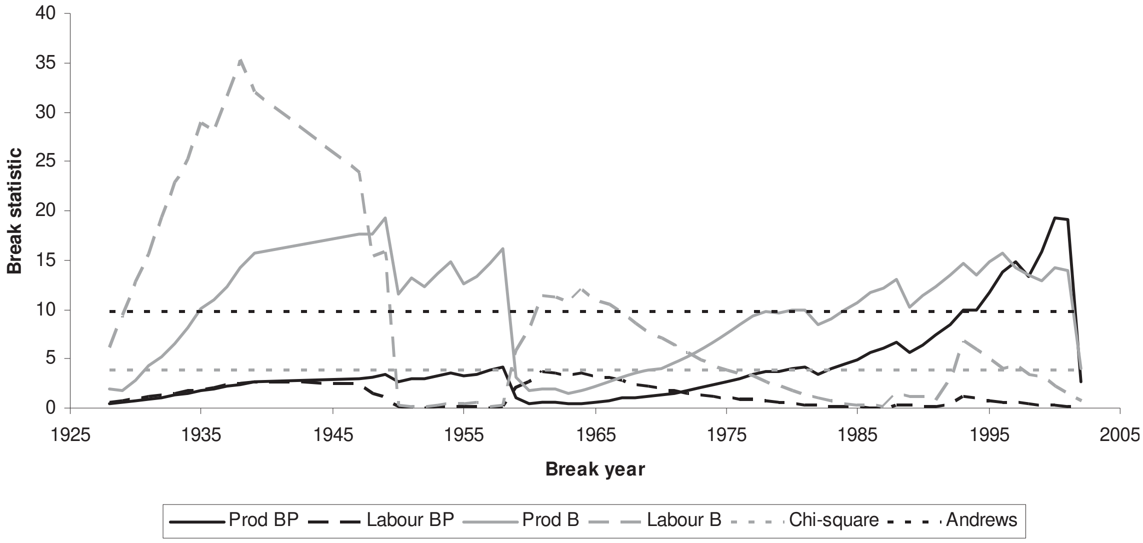
Dickey-Fuller unit root tests			
	Constant term and no trend		Constant term and trend
Dickey-Fuller test statistic	-1.26 / -1.50		-2.06 / -2.10
DF-GLS test statistic	.39 /-1.16		-1.82 / -1.27
Unit root tests under structural change			
	Change intercept	Change trend	Change both
Test statistic	-2.56 / -3.67	-4.39 / -2.70	-5.11 / -2.94

Notes: For references and sources, see note to Table 1. First entry before the slash is for quantity. Second entry after the slash is for labor. For labor, all tests suggest a unit root. For quantity the results are mixed. The number of lags is 1 for all Dickey-Fuller tests. For the ordinary augmented Dickey-Fuller test the p-value for the regression without a trend is .65 (quantity) and .53 (labor) with a trend .57 (quantity) and .54 (labor). For the DF-GLS test the critical values at the 5 % level are for no trend -2.18 and -3.09 with a trend.

The number of lags (one) in the DF-GLS test is determined by the modified Akaike information criterion and the highest lag order is set according to the Schwert method, equal to 11. For the unit root test under structural change (Zivot-Andrews test) the Akaike information criterion is also used giving no lags for both series. The critical values at the 5 % level is -4.80 (change intercept), -4.42 (change trend) and -5.08 (both).

All the tests suggest a unit root for labor. For quantity produced, the results are mixed. If we had only done a Zivot-Andrews test allowing a break in intercept and trend or trend only, we would have rejected the null of a unit root for the quantity series at the 5 percent level. However, the other tests suggest a unit root and we prefer to err on the right side and use first differences for quantity as we have done for the other series.

Transforming data, the break statistics for variance as functions of break year have been computed and plotted in Figure 9.

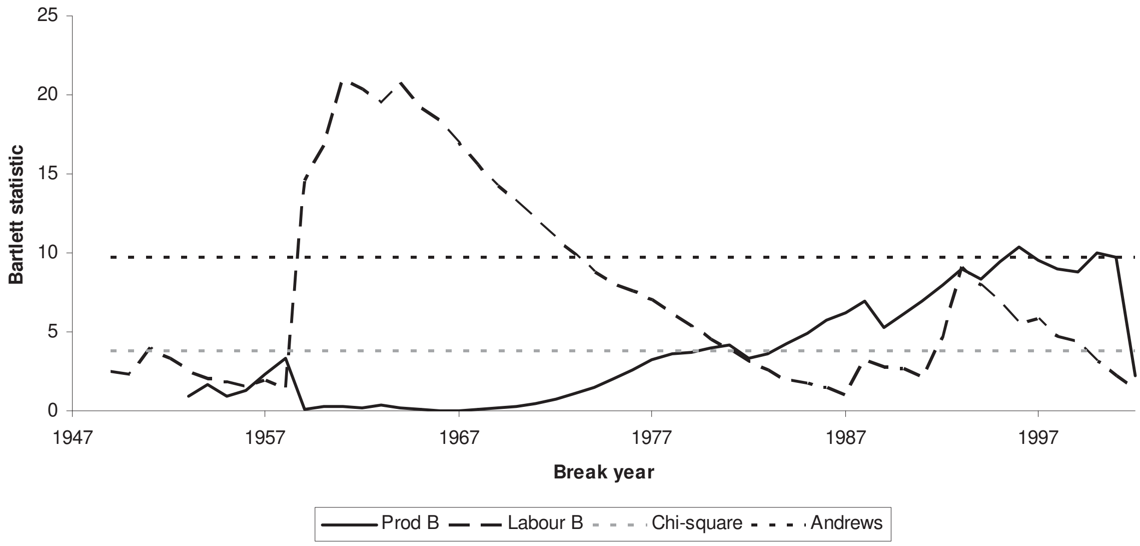


Notes: Data and sources are given in the Appendix. Sample for 1923-2006 (except 1940-1946). The break statistics are the Breusch-Pagan statistic (BP) and the Bartlett's statistic (B). For the BP residuals are obtained from running OLS imposing constant parameters across the break year and then regressing the squared residuals on a dummy allowing the constant to be different across the break year. If the dummy enters significantly, this is indication of a break. For the Bartlett's test separate regressions (allowing intercept and slope to be different) are run on the two sub-samples divided by the break year. We have used 5 percent trimming (the potential break year within 4 observations on each end).

Fig. 9. Break statistics for variance as functions of break year

Both the Breusch-Pagan and the Bartlett's test suggest a structural change in variance for produced quantity, but they point to different break years: 2000 and 1949. The shift in 2000 corresponds well with the break for volume shipped (year 1999), reflecting high degree of correlation between the two series. The Bartlett's test pointed to 1984 for volume shipped whereas here the break year is 1949. It would be more reasonable that approximately the same year had been identified, and this makes us sceptical about the test's ability to pick up what we are aiming for. For employment, only the Bartlett's test suggests a break (year 1938).

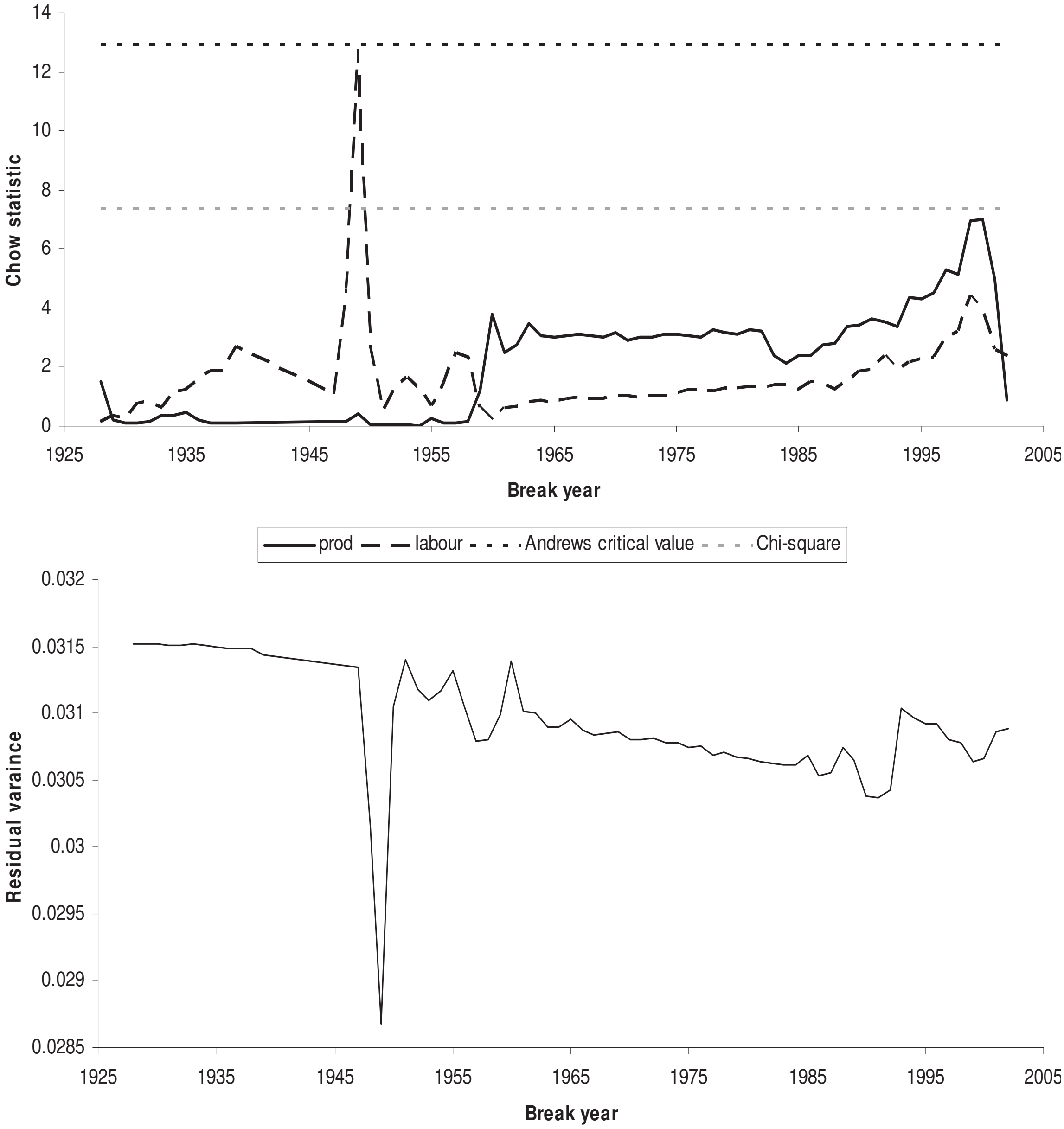
Repeating the procedure for subsamples, reveal no new breaks using the Breusch-Pagan test. The Bartlett's test, however, suggests a structural shift in 1996 for produced quantity (not so far from the first round break year identified by the BP test) and a break in 1961 for employment (Figure 10).



Notes: Data and sources are given in the Appendix. Sample for produced quantity: 1949-2006, sample for labor input: 1938-2006. The break statistic is the Bartlett's statistic. Separate regressions (allowing intercept and slope to be different) are run on the two sub-samples divided by the break year. We have used 5 percent trimming of the first round full sample (the potential break year within 4 observations on each end).

Fig. 10. Break statistics for variance as functions of break year (second round)

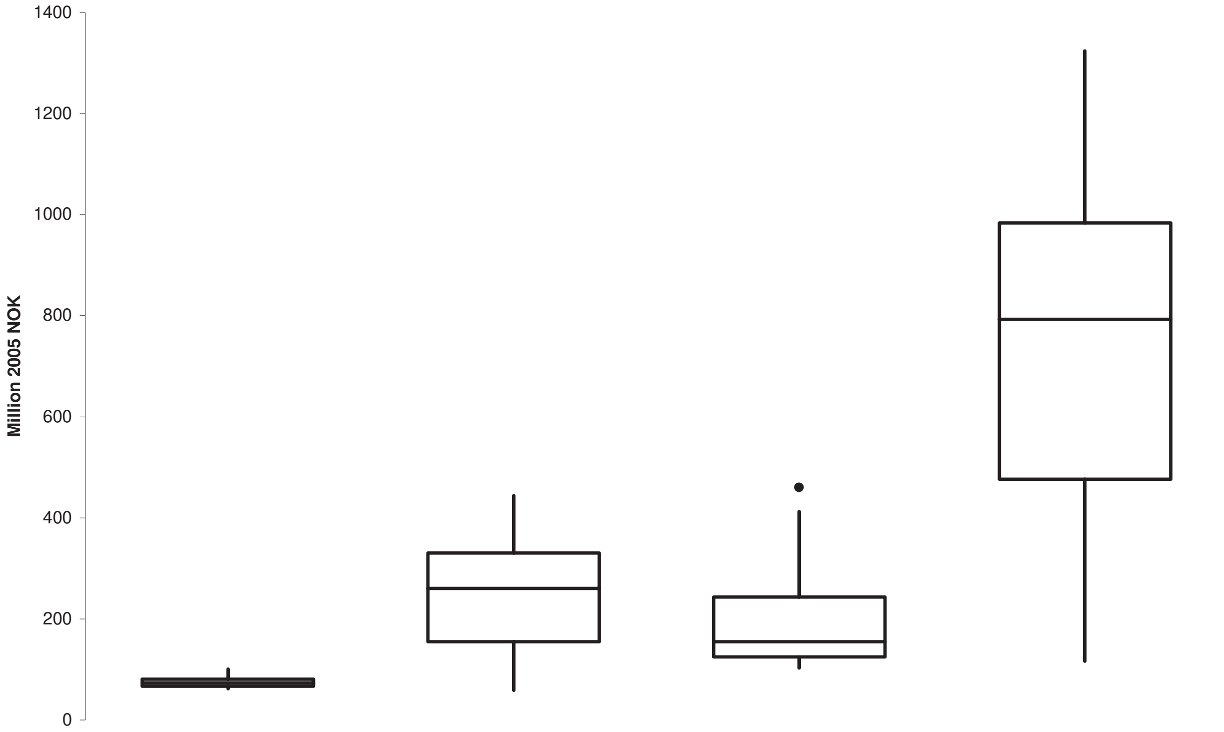
We proceed by looking for breaks in the mean, using the Wald version of the Chow statistic. The upper panel of Figure 11 indicates that there is a shift for labor input that are almost significant at the 5 percent level and the lower panel suggests 1959 as the break year. For volume produced there appears to be no structural shift at any conventional significance level.



Notes: Data and sources are given in the Appendix. Sample for 1923-2006 (except 1940-1946). The upper panel contains break statistic for employment and produced quantity. The statistic is the heteroscedasticity robust version of the Chow statistic for a break in both parameters controlling the mean. We have used 5 percent trimming (the potential break year within 4 observations on each end). The lower panel presents the residual variance for employment as a function of break year.

Fig. 11. Break statistic for mean as function of break year

3.3. Distinct periods. On basis of the analysis of possible years for structural shifts, we are rather confident of a break in all parameters for turnover in 1999, possibly also in the mid 1980's. We have also found evidence for a break in the mean in the late 1920's. The break in the late 1990's is reflected in a shift in volume shipped about the same time. The same apply to the variance break in the mid 1980's. The other structural changes in turnover cannot be attributed to either price or quantity alone, but is a result of the two interacting. The break years identified for turnover are estimates and not exact. We choose to use the point estimates for break in the mean to suggest four different distinct periods: 1922-1927, 1928-1983, 1984-1998, and 1999-2006. Recall that what we are analyzing are breaks in first differences or growth rates, not levels. However, growth rates ultimately determine the levels so let us start by looking at the distribution of the level of turnover for the four distinct periods.



Notes: Data and sources are given in the Appendix. From left to right, the distributions for period T1: 1922-1927, T2: 1928-1983, T3: 1984-1998, and T4: 1999-2006. The box spans the range between the 1st and 3rd quartile of the distribution (the interquartile range, IQR), hence a measure of the variability, whereas the line inside the box denotes the median, hence a measure of the center in the distribution. The vertical lines, "the whiskers", span the range between the 1st quartile minus 3/2 times the IQR and the 3rd quartile plus 3/2 times the IQR, hence yet another measure of variability.

Fig. 12. Box plots: turnover for distinct periods

Figure 12 contains box-plots for the four periods. The center of the distribution is represented by the median and not the mean (the solid line inside the box). We observe that the median appears to be distinctly different for the four periods and in particular for the last period. The variability is represented by both the height of the box (the interquartile range) and the vertical line penetrating the box. The box plot for the last period is distinctly different from the others. The Bartlett's test also suggested that the variance for the third period was different whereas there was no indication of difference between the two first periods.

Let us now look at mean and variance for the growth rate (first differences) and decompose it into components representing price and quantity. The mean in turnover growth is simply the sum of mean price and quantity growth, and the variance is equal to the sum of variances (the direct effects) plus two times the covariance (the interaction effect)[1]. Results are presented in Table 4. We observe that the mean annual growth rate in real turnover is 3.5 percent and that all is due to growth in quantity shipped, the real price (c.i.f.) is on average stable. As for volatility, price and quantity account for roughly equal shares and the interaction effect is negative so on average volatility in quantity growth and volatility in price growth is negatively correlated. An interesting implication of this decomposition is that we can get an idea of to what extent the basic profit maximizing model fits the data or not. If the model offers a poor description, we may suspect that constraints (political or otherwise) have been effective. A very general property of profit maximizing behavior under price taking is that a price increase should be associated with a quantity increase and the other way around (the Weak Axiom of Profit Maximization or WAPM)[2]. If this were to hold, we should have that a negative (positive) mean growth rate in price went along with a negative (positive) mean growth rate in quantity. From Table 4, we observe that this is overall not true although it is fulfilled in the 3 last periods. However, this is a weak test for the WAPM and we can say more by looking at the whole data series. Comparing the price and quantity data for each year, the WAPM only holds in 29 out of 77 years of operation. In the first period, it is in fact violated for all years, whereas in the last

[1] This decomposition of variance has a long history in agricultural economics to identify sources of volatility in income, see Burt and Finley (1968). The point is to identify how much is due to prices (exoegenous) and how much to produced crop.

[2] See Varian (1984).

period the WAPM holds in half of the years. Hence, profit maximizing behavior appears to be a poor description of realities, although there is some indication that it is more appropriate today than 80 years ago. Now, we should be careful here since a positive quantity growth associated with a negative price growth could be consistent with profit maximizing behavior provided the company for some reason failed to be on its supply curve to start with. In that case, the wrong sign indicates that the company is poorly adjusted at the outset but not necessarily that the move is not right. Poorly adjusted could be, e.g., that increasing returns are not exhausted and that increased volume could lead to higher profit even if the coal price goes down. There may also be situations where the failure of WAPM is due to factors that prevent the company from reacting to price changes. An example is the big fire that took place in Svea Nord in 2005 that effectively reduced shipped quantity by 38 percent at a time when the price increased by 23 percent. We should also be aware of long-term contracts that constrain the company from continuously adjusting volume. Besides chance events and constraints through long-term commercial commitments, political constraints imposed by Government in response to geopolitical concerns may be an important reason that the WAPM fails. With these caveats, we now leave the WAPM and turn to the descriptive statistics for the different periods.

Table 4. Mean and variance of annual growth for turnover, price and quantity

Period	Turnover		Quantity		Price	
	Mean	Variance	Mean	Variance	Mean	Variance
1922-2006	.035	.069	.036	.059	-.000	.056
1922-1927 (N = 5)	-.013	.081	.065	.037	-.078	.201
1928-1983 (N = 49)	.038	.048	.016	.038	.022	.063
1984-1998 (N = 15)	-.078	.057	-.015	.070	-.063	.012
1999-2006 (N = 8)	.263	.172	.236	.157	.027	.020
	Variance decomposition					
Period	Direct price effect		Direct quantity effect		Covariance	
1922-2006	49 %		51 %		Negative	
1922-1927	85 %		15 %		Negative	
1928-1983	62 %		38 %		Negative	
1984-1998	15 %		85 %		Negative	
1999-2006	11 %		89 %		Negative	

Notes: Data and sources are given in the Appendix. The direct effects are calculated as shares of price and quantity variance added (following Burt and Finley, 1968). The interaction effect is 2 times the covariance between price and quantity growth (only the signs are reported).

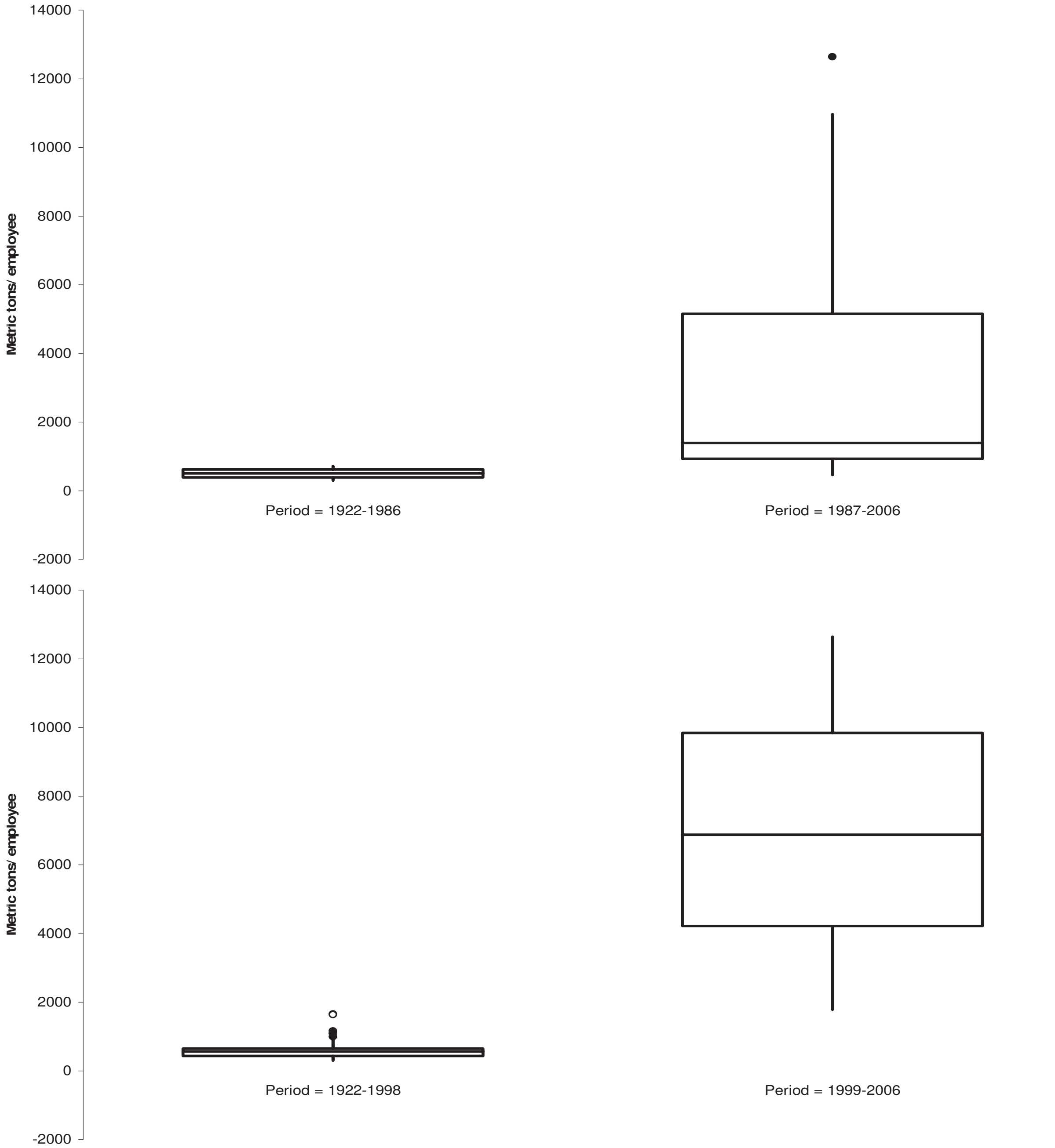
Although quantity mean annual growth in the 20's is as high as 6.5 percent, the price falls even more (7.8 percent) so the net effect on turnover is negative. Most of the volatility in turnover growth can be attributed to price movements in this period.

From the late 20's until the mid 80's we have the longest period with stability in the parameters, mean growth in turnover is a bit higher than for the whole sample, but price accounts for more than quantity. Price also continues to be the most important source for volatility although less so than in the first period.

From the mid 80's until the late 90's, there is again a negative mean growth rate for turnover as in the 20's, but much stronger (-7.8 percent). Price reductions are almost as large as in the 20's but this time quantity is also falling. Another interesting difference is the reversed role of price and quantity in turnover volatility. Now, most volatility is accounted for by movements in quantity.

From the late 90's there is a dramatic shift. Mean growth in turnover is jumping to more than 26 percent per year. Most of it is due to quantity but also the price is contributing with 2.7 percentage points which is not much compared to quantity, but still the highest growth rate for price in any of the periods. Quantity is also accounting for most of the volatility in turnover. Hence, price and quantity gradually change importance as sources for turnover volatility: in the 20's price is by far the most important whereas in the last period this position is taken over by quantity.

For productivity we could only detect a shift in the variance and the suggested break year was 1999 as judged by the Breusch-Pagan test and 1987 by the Bartlett's test. A visual impression of differences in distribution before and after the two suggested break years is given in Figure 13.



Notes: Data and sources are given in the Appendix. The upper panel is based on 1987 being the break year (suggested by the Bartlett's test), the lower panel 1999 (suggested by the Breusch-Pagan test). The box spans the range between the 1st and 3rd quartile of the distribution (the interquartile range, IQR), hence a measure of the variability, whereas the line inside the box denotes the median, hence a measure of the center in the distribution. The vertical lines, "the whiskers", span the range between the 1st quartile minus 3/2 times the IQR and the 3rd quartile plus 3/2 times the IQR, hence yet another measure of variability.

Fig. 13. Box plots: productivity for distinct periods

As for turnover, we have also computed mean and variance for productivity growth and the components: produced quantity and labor input. The decomposition of variance in productivity in the lower panel of Table 5, now shows that the covariance between labor and quantity in all but the last period is positive. This means that the interaction effect is negative, since productivity is the ratio of quantity to labor. Hence, the total variance is the sum of variance for the components minus two times the covariance.

Table 5. Mean and variance of annual growth for productivity, production and labor

Sample	Productivity		Production		Labor	
	Mean	Variance	Mean	Variance	Mean	Variance
1922-2006	.039	.059	.039	.070	.000	.021
1922-1986	.011	.027	.023	.046	.012	.022
1987-2006	.117	.146	.085	.142	-.032	.020
1922-1998	.023	.036	.015	.048	-.008	.022
1999-2006	.173	.266	.248	.488	.075	.008

Table 5 (cont.). Mean and variance of annual growth for productivity, production and labor

Sample	Labor effect	Production effect	Covariance
1922-2006	23 %	77 %	Positive
1922-1986	32 %	68 %	Positive
1987-2006	12 %	88 %	Positive
1922-1998	31 %	69 %	Positive
1999-2006	3 %	97 %	Negative

Notes: Data and sources are given in the Appendix. The direct effects are calculated as shares of price and quantity variance added (following Burt and Finley, 1968). The interaction effect is minus 2 times the covariance between price and quantity growth (only the signs are reported).

Annual mean growth in labor productivity is 3.9 percent and as for turnover, on average it is the quantity component that accounts for all. Labor input has on average not changed. We were not able to detect breaks in the mean. Still, the mean growth rates before and after the break year for variance look very different, increasing ten-fold. Volatility in productivity is clearly increasing over the break year and so is the importance of quantity as a source of volatility. An interesting point here is that the covariance between labor and quantity turns negative in the last period if we base the break year on the Breusch-Pagan test. This means that the interaction effect is positive, both labor growth and quantity growth contributes to higher volatility for productivity.

Discussion

There appears to be heterogeneity among subsamples representing different periods of operation. The mean turnover growth rate is substantially and significantly higher in recent years compared to the early years. Variation in price (primarily exogenous and external to the firm) and variation in quantity (endogenous and internal to the firm) appear to play different roles in the determination of the variance for the turnover growth in different periods. In the last period from 1999 to 2006, the variance is almost entirely determined by variance in quantity. Hence, variation in turnover growth appears to be related to the firm's own actions. In the first period from 1922 to 1927, it is the other way around: most variation is due to variation in the price that is primarily exogenous to the firm in the economic sense. When we look at the overall average mean growth in turnover, all is accounted for by the mean growth in quantity. In other words, the real price (c.i.f.) has hardly changed over close to a century, although the volatility for price is almost as large as for quantity.

High turnover growth is not necessarily a good indicator of high performance. Provided supply is adjusted optimally at the outset, a turnover increase when prices fall because quantity is increased sufficiently is not a sign of profit maximizing management. If the company were maximizing profits supply should be reduced and turnover fall. There may be many reasons why the company fails to adjust supply in an optimal way. However, it is interesting to observe that the company has failed to raise (lower) supply when prices have increased (decreased) in 48 out of the 77 years of operation that we have analyzed. People arguing that an economic analysis of the company is irrelevant because the company has been run for other purposes may have a point. However, without this analysis we would have missed the fact that the data clearly suggest that the relevance of the economic model has changed over the years. In the first period from 1922 to 1927, the behavior of the company did not correspond to what we would expect from the simple profit maximizing model in any year. In the last period from 1999 to 2006 the score is 50 percent. This may be interpreted as indication that the constraints that restrict the feasible management options have changed over time.

As an example of how exogenous events may drastically affect operation, a fire that started in July 2005 stopped production for 8 months. If we look at 2005 and 2006, prices increased from 2004 to 2005, but the company failed to take advantage of this, probably because of the incidence. From 2005 to 2006 prices fell, but the company increased supply. However, this could well be consistent with the profit maximizing model since supply in 2005 probably was far below the desired level. This example suggest that it might be fruitful to go back and look for particular circumstances that may have restricted the set of feasible decisions open to the management before making any strong statements about management.

We have also looked at another key indicator highlighted in the company annual reports in recent years, labor productivity as measured by production per person employed. We have not been able to detect any clear shifts related to the mean growth rate as we could for turnover. However, there is a shift in volatility in recent years. Depending on the test, the suggested break year is 1987 or 1999. The variance in productivity in the period after the break year is much larger than before. The main contribution to the variance is from produced quantity and not from the variance in labor input, and the role played by produced quantity has increased considerably after the break. The overall mean productivity growth is 3.9 percent, rising from a modest 2.3 percent per year in the period prior to 1999, to 17.3 percent after. This shift clearly reflects the change in technology from conventional mining to continuous mining. The shift in 1987 could be related to several events taking place far outside Svalbard that led to a collapse in the coal market in the late 1980s (Gjelsvold and Storhaug, 1991). Firstly, the drastic price fall on crude oil in 1986. Secondly, the hoarding of coal in Antwerpe/Rotterdam/Amsterdam (ARA) by German interests that anticipated the international boycott of the apartheid regime in South Africa.

It is important to notice that the break analysis is based on *growth rates*. Hence, an estimated break year of 1999 means that the break translates into a break in *level* the subsequent year in 2000. The level and variability in level for turnover is therefore found to be substantially larger in the year 2000 and later than previously. Our analysis also suggests substantially higher variability in the productivity level in year 2000 and later than before. The obvious explanation for this is the removal of the production cap by the Government this year. Presumably, the removal of the cap would not have been done if continued coal production were considered essential to ensure credible Norwegian governance.

We have also detected a break year in 1984 that translates into a break in levels in 1985. This may also be linked to Government policy. A production cap was introduced in 1984. Again, this may be seen in connection with the importance the Government attached to continued coal production as a policy instrument in order to balance the still considerable presence of the Soviet Union at that time. Presumably, the cap would not have been introduced if continued coal production were not considered essential to ensure credible Norwegian governance. There were also events taking place internationally that we have already argued may be related to the collapse in the coal market in the late 1980s. Hence, both domestic and global factors appear to possibly have been interacting.

The third break year identified is 1928 corresponding to a break in levels in 1929. It is reasonable to attribute this to the difficulties experienced in the global economy and repercussions in the coal market. Although the dominant market for the company in the early years geographically was the northern part of Norway, competition intensity is reported to have increased from the mid 1920s through import of British coal in the south and Dutch coal in the north (Gjelvold and Storhaug, 1991, p. 196).

This concludes our illustration of how the structural break methodology may serve as a screening device and point to periods of time where richer descriptions and analysis are particularly important. Researchers in business administration and economic historians would probably be able to add a lot more to this, giving details about internal processes of the firm, important events on international coal markets and national protectionist policies, that may expand on the suggested explanations that we have put forward in this discussion. It would also be interesting not only to learn more about why 'the dog did bark', but also to know why 'the dog did not bark', to paraphrase Sherlock Holmes[1]. Why is it, e.g., that the turmoil triggered by the Suez crisis in 1956 does not show up in our data whereas the price fall on oil in 1986 apparently does? We leave this kind of questions open for future research.

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[1] A famed expression from the short story *Silver Blaze* (Conan Doyle, 1894).

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Appendix

Table 1. Data file

Year	Turnover	CPI	Productivity	Production	Quantity shipped	Employment	Price
1922	3642	5.2	330	115443	151471	350	461
1923	4883	4.9	383	154950	135670	405	740
1924	4425	5.4	378	164601	143428	435	573
1925	3411	5.5	356	155985	162494	438	384
1926	3641	4.7	463	211077	146532	456	530
1927	2726	4.2	476	210735	209488	443	312
1928	2302	3.9	438	192481	141175	439	417
1929	2511	3.7	447	192910	195539	432	344
1930	2351	3.6	472	208120	216113	441	298
1931	2734	3.5	550	245714	246972	447	319
1932	3242	3.4	633	279822	280097	442	342
1933	3697	3.3	649	296539	304855	457	367
1934	3968	3.4	692	325082	315965	470	371
1935	3982	3.4	604	307626	301976	509	389
1936	4137	3.5	572	296980	291191	519	409
1937	4769	3.7	576	304198	287439	528	444
1938	5063	3.9	499	293138	298355	587	434
1939	5873	3.9	407	295947	267801	728	561
1940	6848	4.5	367	251028	37086	684	4087
1947	22335	6.2	317	364019	246069	1149	1471
1948	26764	6.1	360	413614	410274	1149	1238
1949	18058	6.2	315	285857	410274	907	714
1950	23817	6.4	381	314388	307979	825	1203
1951	30079	7.5	452	416740	386621	922	1041
1952	30929	8.2	443	400503	389580	905	972
1953	29556	8.3	426	379434	381777	891	928
1954	23418	8.7	377	288482	333430	766	808
1955	28692	8.8	361	355616	299734	986	1091
1956	38033	9.1	337	365777	325135	1085	1282
1957	31061	9.4	322	359681	330215	1118	1002

Table 1 (cont.). Data file

1958	19601	9.8	302	160535	272301	531	733
1959	18844	10.1	545	310910	195081	570	958
1960	19241	10.1	578	312942	269252	541	709
1961	16929	10.3	499	245883	264172	493	620
1962	25781	10.9	685	385082	264172	562	899
1963	30583	11.1	615	394226	436900	641	629
1964	34959	11.7	653	442396	394610	677	755
1965	35350	12.3	706	443304	454173	628	635
1966	33451	12.7	586	415152	418383	708	630
1967	31088	13.2	599	378053	416901	631	565
1968	30629	13.7	491	330684	265188	673	841
1969	36142	14.1	647	432899	406419	669	632
1970	42010	15.6	714	462738	431820	648	626
1971	40638	16.6	677	430451	421659	636	581
1972	42582	17.7	661	438125	441980	663	544
1973	44438	19.1	639	411522	413531	644	562
1974	65090	20.9	593	435910	411499	735	759
1975	73029	23.3	602	465036	367801	772	853
1976	98531	25.5	672	483112	490667	719	866
1977	111093	27.8	560	409000	471000	731	848
1978	96982	30.1	460	336842	381000	732	847
1979	79742	31.5	394	292789	315000	744	805
1980	108258	34.9	309	242000	314000	783	987
1981	175906	39.6	506	395000	397652	780	1117
1982	165709	44.1	533	440000	359000	826	1046
1983	201627	47.9	626	502000	448000	802	940
1984	234426	50.9	625	451300	554000	722	831
1985	221657	53.8	621	507000	423000	816	974
1986	168678	57.6	624	436000	349000	699	839
1987	179014	62.6	750	399000	472685	532	605
1988	103685	66.8	466	264000	251414	567	617
1989	139847	69.9	587	318000	326000	542	614
1990	133426	72.7	562	303000	304313	539	603
1991	119159	75.2	885	330000	290497	373	545
1992	83731	77.0	1162	358000	227200	308	479
1993	105870	78.7	937	268000	278000	286	484
1994	112924	79.8	1087	301200	305500	277	463
1995	96810	81.8	1098	292094	261000	266	453
1996	85062	82.8	994	229636	232500	231	442
1997	91399	85.0	1659	386440	255200	233	421
1998	113799	86.9	1633	328170	356163	201	368
1999	103713	88.9	1787	403939	375439	226	311
2000	201937	91.7	2834	631926	666724	223	330
2001	530442	94.4	7209	1787784	1565502	248	359
2002	683263	95.7	9474	2131691	2133383	225	335
2003	935772	98.0	12635	2944000	2806356	233	340
2004	1303502	98.4	10958	2904000	2861421	265	463
2005	871156	100.0	4684	1470818	1770448	314	492
2006	1096672	102.3	6544	2394940	2358690	366	455

Notes: 'Year' is referring to accounting year (July 1-June 30, 1922 to 1980, April 1-December 31, 1980, and calendar years thereafter). 'Turnover' is nominal revenues in thousands of NOK gross of transport costs (value c.i.f.), CPI is the Norwegian consumer price index, 'Production' is production of coal in metric tons (converted from long tons that were used until 1976; 1 ton = .984 long ton), 'Quantity shipped' is the quantity shipped defined as for production, 'Employment' is a number of persons employed (usually measured by the number late in the calendar year), 'Productivity' is defined as production divided by employment, "Price" is the average coal price c.i.f. per metric ton defined by turnover (times thousand) divided by quantity shipped.

Source: The CPI is downloaded from Statistics Norway (http://www.ssb.no). All other variables are constructed from raw data obtained from the company's annual reports (available at the Regional State Archives in Tromsø).